The Residential Collateral Channel

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Preliminary – Comments Welcome

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 directors' residential collateral estimated to increase investment by £0.07 and total wage costs by £0.10. 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 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. A simple 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 related to 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.

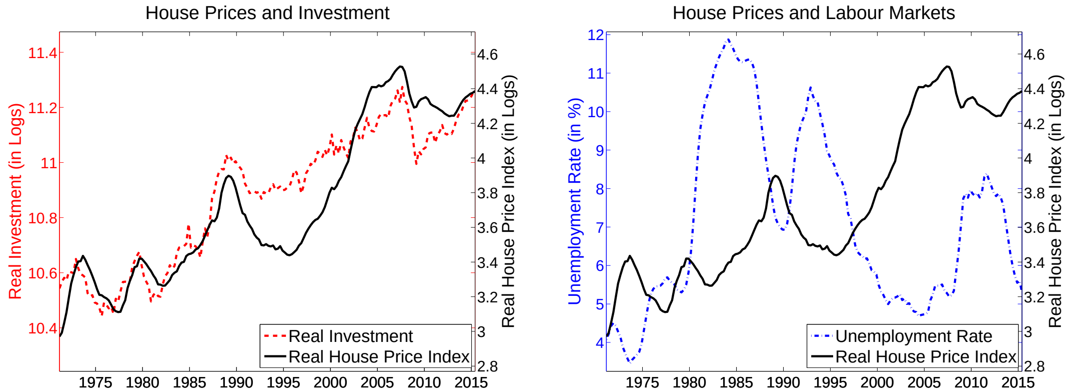
There are several possible channels through which real estate collateral may affect the economy, with a stylised representation presented in Figure 2. First, as shown in the bottom panel, an increase in the value of houses can enable the owners to extract equity to fuel consumption (e.g. Mian and Sufi (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 2000-2012 period. The first set of results is related to the corporate collateral channel: a £1 increase in corporate collateral values leads the representative firm to increase investment by around £0.04 and total wage costs by around £0.06. 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 related to the residential collateral channel: a £1 increase in the value of the homes of the average company director causes the representative UK firm to increase investment by around £0.07 and total wages by around £0.10. 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 no corporate collateral. However, the directors of the median firm own their residential property, which between them is worth around 20% of annual turnover. In our sample the median firm has less than 50 employees. However, in the UK, such small firms along with start-ups were responsible for 66% of jobs created from 1998 to 2010 (Anyadike-Danes, Bonner, and Hart (2011)). Moreover, we estimate that the value of residential real estate held by company directors (£1,100 Billion) is around 75% larger than the value of commercial property (£650 Billion), suggesting that the residential collateral channel may have a greater aggregate impact than the corporate collateral channel.[1]

[1]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 1: Real House Prices and the UK Business Cycle



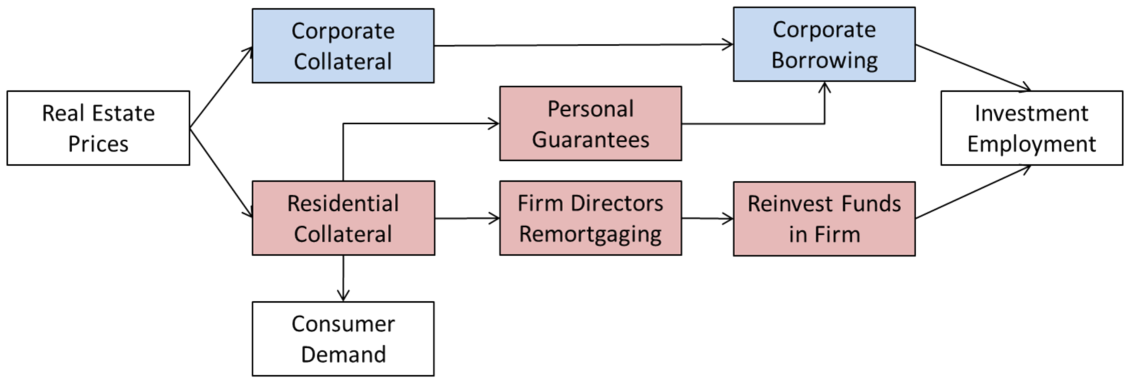
Notes: House price index is from Nationwide, investment and unemployment data are from the ONS.

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 data which provides unrivaled data coverage compared to the existing literature.

To arrive at the first set of estimates related to 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. First, we compare within a local authority the sensitivity of corporate activity to property prices across firms that do and do not own real estate. Second, we compare the corporate activity of land-holding firms across local authorities with different variation in 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 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

Figure 2: Real Estate Collateral Channels



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 (2015) 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 related to 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 director remortgaging. 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 director's residential collateral as it provides a more liquid source of collateral than commercial real estate and also aligns incentives through piercing the corporate veil. For this latter reason, the two types of collateral may thus 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 80% of lending to businesses (by volume) is secured on property with 30%[2] of lending secured with a personal guarantee, typically with an explicit or implicit claim against their residential property.[3]

A back-of-the-envelope calculation based on our microeconometric results suggests that a 1% rise in land prices leads to a 0.34% rise in investment and 0.13% rise in total wage costs through the residential collateral channel, and a respective 0.11% and 0.04% 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 1.4% 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 and land prices. 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 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 frame-

[2] Note that loans can be secured by more than one type of collateral so can add to more than 100%.

[3] 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.

work 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 2000-2012, 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.

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 exclude companies of the following types: "Economic European Interest Grouping", "Guarantee", "Industrial/Provident", "Limited Liability Partnership", "Not companies Act", "Other", "Royal Charter", "Unlimited", "Public Investment Trust", thereby ensuring that our sample contains only limited liability companies to which the Companies Act applies. In addition, we exclude from the sample firms operating in 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.

Moreover, we exclude companies that have a parent with an ownership stake greater than 50%. This is to ensure that the accounts used have the highest degree of consolidation possible, to prevent the double counting of subsidiaries and to ensure that the financial position of the company regarding the collateral it has available is correctly accounted for. This leaves us with a sample of around 15 million firm-year observations for an average of 1.3 million firm observations per year. For the purpose of empirical analysis, we drop observations which are missing data on the key variables. The exact sample size is reported in the regression tables. We next discuss a few key variables in more detail.

Land Holdings To measure corporate land holdings, we use the balance sheet item "Land and Buildings" from BVD. The main challenge is to impute market values from the book values that firms report to the company registrar. To address this challenge, 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, $L^B_{i,j,t}$ 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.

A recurring problem with this method is the assumption regarding the market value of land in the base year, $L^Y_{i,j,0}$. To address this problem, 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.[4] Additionally, whenever the book value of land and buildings is zero, we infer that the market value is also zero. Then we can apply algorithm 2.1 to get a more precise estimate of the market value of commercial land holdings.

Given the imputed market value of land holdings, the market value of collateral relevant to borrowing arrangements is computed as:

$$collateral_{i,j,t} = L^{Y}_{i,j,t-1} \frac{L^{P}_{j,t}}{L^{P}_{j,t-1}}, \tag{2.2}$$

which implies that the collateral available to firm i, operating in region j, at time t is the previous year's market value of land holdings, $L^{Y}_{i,j,t-1}$, (calculated by the recursion 2.1 above) multiplied by the change in market value, $\frac{L^{P}_{j,t}}{L^{P}_{j,t-1}}$, which is proxied by land price inflation in region j. This two-step approach to impute the market value of collateral allows us to control for mechanical changes in collateral values that would occur as a result of equating the market value of land holdings to the market value of collateral. In that case, $L^{Y}_{i,j,t} = collateral_{i,j,t}$, and collateral values may change because of current year changes in capital expenditures, thereby causing changes in book values, $dB_{i,j,t}$. Our two-step approach aims to circumvent this endogeneity problem.

Corporate Activity 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 turnover. Profit margins are measured by the item "Operating Profits" scaled by lagged turnover.

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.[5] In contrast, a

[4] Given that our real estate price series starts in 1995, we are limited to observing firms that were incorporated after 1995.

[5] 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

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 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.

Credit Instruments We consider a number of liability variables from BVD including the items "Bank Deposits", "Bank Overdrafts", "Long Term Debt", "Short Term Loans and Overdrafts", "All Director Loans", "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:

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

These variables will be used to control for potential firm heterogeneity. To prevent outliers distorting the results, all the ratios are winsorized 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.[6][7] 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.

different types of geographical region.

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

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

Given this information, we can match the director's address to our transactions 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, 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.

2.3 Mortgage Data

Data on mortgage originations are taken from the Product Sales Database (PSD) provided by the UK Financial Conduct Authority.[8] The dataset provides a wealth of loan-level information on the universe of regulated residential mortgage originations in the UK since 2005, including 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.[9]

[8] 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.

[9] 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.

Using this data we can directly observe the residential collateral channel by tracking whether the remortgaging decision of a company director subsequently led to the injection of some of the mortgage into the company in the form of director loans or the purchase of issued equity. The identification of this channel can be tightened further by ruling out director remortgages that were for debt consolidation, home improvements or a pure remortgage. This leaves us with remortgages in the 'other' category, which includes remortgages for business reasons. Using this data, in future work we will be able to determine how changes in residential collateral affect the probability of a director remortgaging for such reasons. As companies typically have multiple directors, we can hold company demand for funds constant with a firm-time fixed effect and examine how changes in the collateral value of their residential property affects the probability that a company director remortgages their property.

In future work we shall also 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 amortization 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 don't 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.[10] 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.

[10]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.

2.4 Summary Statistics

Table 1 presents summary statistics on the accounting variables used in the paper. The median values of turnover and number of employees in the whole sample are about £5.3m and 42, respectively, which is much smaller than the corresponding mean values (£104m and 631). This skew in the distribution suggests that our sample is dominated by small and medium-sized enterprises. Figures 5 and 6 of the Appendix presents histograms to show the shape of the distribution for all the variables in Table 1.

A notable feature of the data is that the median firm owns no commercial real estate. However, the average company director's residential home is worth about 7% of the given firm's annual turnover. Given that the average firm in our sample has three directors, the value of potentially collateralisable residential property owned by company directors can amount to around 20% of the given firm's annual turnover.

Table 1: Summary Statistics

Variable	**Mean**	**Median**	**25%tile**	**75%tile**	**N**
Levels					
Turnover (£ 000s)	104214	5286	893	15714	40677
No. Employees	631	42	10	127	40677
Ratios (to Turnover)					
Operating Profit	-0.37	0.03	0.00	0.09	40309
Remuneration	2.00	0.27	0.14	0.44	40677
Investment	0.50	0.01	0	0.05	40677
Total Assets	2.60	0.52	0.34	0.93	40659
Firm Collateral	0.53	0	0	0.06	40677
Avg Director Collateral	1.10	0.07	0.03	0.32	20765
Cash	0.19	0.01	-0.04	0.08	36906
Debt	1.20	0.15	0.06	0.41	35076
Directors Loans	0.12	0	0	0.06	29623

Note: The statistics are calculated using our sample of observations from the BVD used in the activity regressions. 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 & buildings.

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. Moreover, cash ratios, 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 average 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 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 tested using two sources of variation. First, we compare the responsiveness of economic activity of firms that do and do not own commercial real estate within the same region. Second, using regional house prices as a proxy for corporate real estate prices, we compare the responsiveness of real estate owning firms across 172 different regions.

To estimate the effects of real estate shocks on 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:

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

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.

Table 2: Firm Activity and the Corporate Collateral Channel

	Investment	Total Labour Cost	Employment
Firm Collateral	0.0459***	0.0803***	0.0045***
	(0.017)	(0.016)	(0.001)
Cash Ratio	0.1867***	0.1881***	0.0077***
	(0.039)	(0.024)	(0.001)
Leverage Ratio	0.0259	0.0389***	0.0037***
	(0.024)	(0.015)	(0.001)
Profit Margin	-0.0986***	-0.4060***	-0.0175***
	(0.034)	(0.017)	(0.001)
N	35058	35058	35058
Adjusted R^2	0.23	0.71	0.77
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: standard errors in parentheses. The table reports the empirical link between corporate collateral and firm activity. The dependent variables are investment, wages and employment. All models control for firm fixed effects and region-time fixed effects. Cash Ratio, Profit Margins and Leverage Ratio enter with a lag. The number of observations is lower than in Table 1 due to the dropping of singleton observations.

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 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.[11]

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 and total labour costs of the firm by approximately 5p and 8p, respectively. The employment estimate (0.0045) can be interpreted as an increase of £220,000 in corporate collateral values resulting in the hiring of approximately one additional worker.

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 indirectly through backing a personal guarantee, or directly through a remortgaging of the property and injection of the funds into the firm in the form of debt or equity. In this subsection, we explore this latter route, which we can directly observe in our dataset. 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 external financing position, measured as the change in issued equity and the change in director loans (all loans and long term loans). All measures are scaled by turnover to construct ratios.

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

Number of directors remortgaging	0		1		2	
Variable	**Mean**	**N**	**Mean**	**N**	**Mean**	**N**
Change in Issued Equity	0.007	1250467	0.01	45807	0.023	1836
Change in Director Loans	1.039	155018	1.385	7554	2.933	511
Change in Director Loans (long term)	0.498	211874	0.834	9622	1.001	594

Note: The statistics are calculated using all firm observations from BVD and all mortgagor observations from the FCA's Product Sales Data, where we could match up company directors with mortgage contracts, using information on date of birth and postcode of home addresses. We excluded firms that have more than ten directors. The data covers the period 2005-2012.

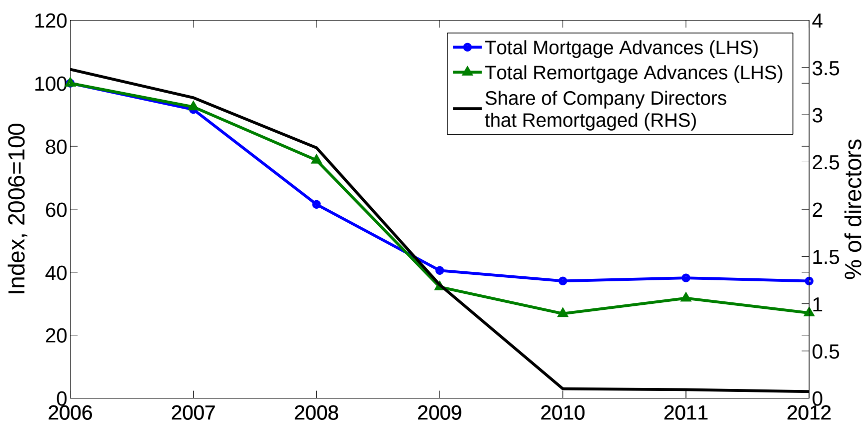
We distinguish between companies according to the number of directors that remortgaged in

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

the given accounting year. Our results show that a company *one* director of which remortgaged in a given year had a considerably higher ratio of director loan to turnover on average (1.39) than a company where none of the directors remortgaged (1.04). This ratio is more than twice as large for companies *two* directors of which remortgaged in a given year (2.9). In fact, all external finance 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 directors loans as a source of funding, and the fact that we are focusing on the funding of *existing* companies – the results may 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 as well as 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 value of the residential real estate holdings of the average company director increases investment by around £0.07 and the total wage bill by around £0.10. The employment estimate (0.0074) can be interpreted as an increase of £140,000 in the residential collateral values of the average company director resulting in the hiring of approximately one additional worker.

Table 4: Firm Activity and the Collateral Channels

	Investment	Total Labour Cost	Employment
Director Collateral	0.0656***	0.0982***	0.0074***
	(0.022)	(0.013)	(0.001)
Firm Collateral	0.0380	0.0563***	0.0022***
	(0.029)	(0.017)	(0.001)
Cash Ratio	0.1354**	0.1549***	0.0060***
	(0.058)	(0.030)	(0.001)
Leverage Ratio	0.0068	0.0259	0.0024**
	(0.036)	(0.022)	(0.001)
Profit Margin	0.0253	-0.2718***	-0.0078***
	(0.047)	(0.028)	(0.001)
N	16694	16694	16694
Adjusted R^2	0.22	0.75	0.83
Region-time FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes

Firm region clustered standard errors in parentheses

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

Notes: standard errors in parentheses. The table reports the empirical link between residential collateral, corporate collateral, and firm activity. The dependent variables are investment, wages and employment. All models control for firm fixed effects and region-time fixed effects. Cash Ratio, Profit Margins and Leverage Ratio enter with a lag.

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 £0.08 to £0.06, and the estimated impact on investment falling from around £0.05, to £0.04, with the estimated coefficient no longer statistically significant. One possible explanation for the diminished estimated role of the corporate collateral channel would be collinearity between the two collateral measures for a firm. However, the within-firm correlation between the two series is just 0.15, in part because many firms do not own corporate real estate.

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, £140,000 of residential collateral will imply that the firm hires one more worker and pays around an additional £14,000 (using the coefficient estimate of 0.0982). For corporate collateral, the analogous calculation estimates that the marginal worker is paid around £24,000, 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.

It is important to emphasise that these coefficient estimates are not the result of local property price changes influencing local economic conditions: this effect is captured by the inclusion of region-time fixed effects, and directors often do not live in the same region as their firm which provides the additional source of variation necessary to identify η in 4.1.

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 a set of financing variables. 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 short-term debt issuance: a £1 increase in corporate collateral increases short-term debt issuance by about £0.09. Our baseline results in Table 4 suggest that one third of these funds are spent on financing new investment, whereas the remaining two thirds are spent on financing increased wage bills.

As for the residential collateral channel, the impact of increased residential collateral of an average company director has a significant effect on both short-term director's loans and short-term debt issuance, with a more material impact on the latter: a £1 increase in the market value of the director's homes increases short-term director's loans and short-term corporate debt issuance by about £0.01 and £0.14, respectively. As with the corporate collateral channel, the

Table 5: Firm Financing and Collateral

	Equity	ST Dir-Loan	LT Dir-Loan	ST Debt	LT Debt
Director Collateral	0.0011	0.0075**	-0.0007	0.1449***	0.0161
	(0.002)	(0.003)	(0.001)	(0.023)	(0.020)
Firm Collateral	0.0016	0.0035	-0.0004	0.0906***	0.0061
	(0.001)	(0.003)	(0.000)	(0.032)	(0.030)
Cash Ratio	-0.0095**	-0.0003	0.0006	-0.0789	-0.0752
	(0.005)	(0.005)	(0.002)	(0.069)	(0.058)
Profit Margin	-0.0130***	-0.0066	-0.0013	-0.1541***	-0.0313
	(0.004)	(0.006)	(0.001)	(0.046)	(0.035)
Leverage Ratio	-	-	-	-	-
N	15633	16028	14487	16124	14771
Adjusted R^2	0.35	0.70	-0.00	0.66	0.06
Region-time FE	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes

Firm region clustered standard errors in parentheses

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

Notes: standard errors in parentheses. The table reports the empirical link between residential collateral, corporate collateral, and firm financing. All models control for firm fixed effects and region-time fixed effects. Cash Ratio and Profit Margins enter with a lag.

regression estimates from Table 4 suggest that around one third of this extra financing is spent on investment, with the remainder spent on an increased wage bill.

The estimate related to increased short-term directors loans is consistent with the residential collateral channel operating through the reinvestment of funds of company directors following remortgaging of 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 3 above. As with that table, the estimates suggest that the marginal source of insider funding from the residential collateral channel is in the form of directors loans and not issued equity. Directors loans have several advantages over issued equity; they carry no implications for the company ownership structure, have no tax implications for repaying the loans, the interest paid on them is tax deductible, and they can be as liquid as a bank account.

The estimate related to increased short-term debt issuance 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. Finally, it may be relatively costly for the director to remortgage their property, owing to possible transaction costs and prepayment penalties, and the increased mortgage rate they may have to pay following an increase in their residential loan-to-value ratio.

5 Robustness

One possible criticism of our estimated results for the corporate collateral channel is due to 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 or major UK cities (as opposed to local authority level), we lose around 60% of the observations compared to the baseline estimates in Table 4. The results, presented in Table 8 of the Appendix, show similar estimates of both the corporate and residential collateral channels, suggesting the use of residential real estate prices is not a bad proxy.

A possible source of endogeneity in the baseline estimation 4.1 is related to the decision by firms of whether or not to own commercial real estate. 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 9 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 10 of the Appendix, which confirms that the results relative to the baseline do not materially change.

A further potential concern with our identification strategy 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.[12] 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 (2015) 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.[13] We thus estimate, for region j, at date t, the following first-stage regression to predict house prices:

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

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 7 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 11 of the Appendix.

For the residential collateral channel, one potential endogeneity concern is related to 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 exclude company directors that purchased homes in the preceding year. Table 12 of the Appendix confirms that the baseline results for the residential collateral channel are preserved.

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 13 of the Ap-

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

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

pendix highlights 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 (albeit the interaction coefficient is not statistically significant), the residential collateral channel has a greater impact on investment in housing busts. The impact of the residential collateral channel on wages is also more pronounced in busts, with a symmetric effect for the corporate collateral channel.

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 14 of the Appendix. As may be expected, the corporate collateral channel has no impact on investment or labour decisions of small firms, with these firms less likely to own real estate. By contrast, 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.

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 (*gatherer*) who is the supplier of funds and an impatient entrepreneur (*farmer*) 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 rest of the economy is described in Section B of the Appendix.

Credit Constraint We assume that the entrepreneur's optimisation problem is subject to an endogenous credit constraint that takes the following form:

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

where B_t is the real value of debt issued by the entrepreneur, θ is the loan-to-value ratio (LTV), $q_{l,t}$ is the market price of land, $L_{c,t}$ is entrepreneurial commercial land, $L_{r,t}$ is entrepreneurial residential land, $q_{k,t}$ is the relative price of investment in consumption units and K_t is physical capital. The parameter ω measures how collateralisable residential land is relative to commercial land.

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 propagation of housing shocks to the macroeconomy. This exercise can be interpreted as a way of assessing the importance of the residential collateral channel.

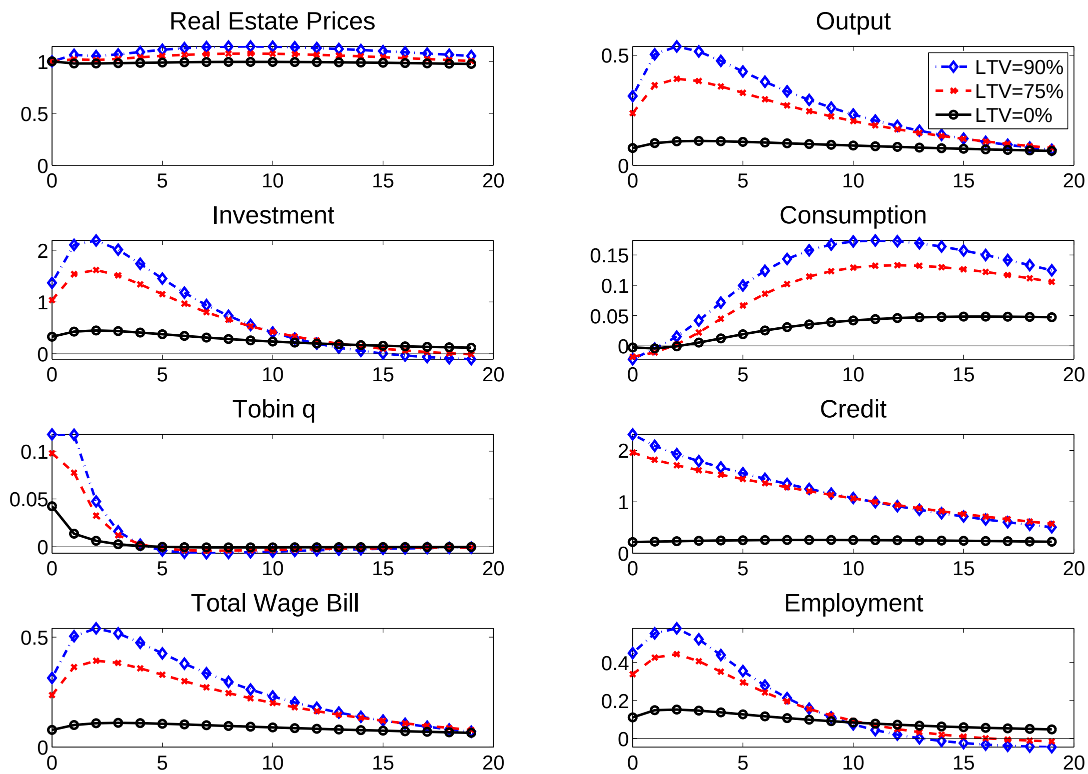
For this exercise, we take all the model parameters from Liu, Wang, and Zha (2013) and make only a few deviations from this model. In their model, residential land is owned entirely by the household. Our main departure is the assumption that 25% of total residential land is now owned by the entrepreneur in steady state.[14] To achieve this allocation we alter steady state preferences for residential land of households and add a new parameter governing the entrepreneur's preference for residential land.[15] This introduces a non-trivial source of residential

[14]To arrive at this number, 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. We estimate $V \approx$ £$1.13 trillion$ which, together with the 2013 estimate for the total value of UK residential properties being $V \approx$ £$4.6 trillion$ (IPF, 2014), suggests that around 25% of the residential housing stock by value is owned by company directors.

[15]Table 15 in the appendix provides an exact description of where our calibration differs from Liu, Wang, and Zha (2013).

collateral for the production sector.

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.

Given the 75% loan-to-value (LTV) ratio on commercial real estate and physical capital in steady-state ($\theta = 0.75$), looping over the parameter values $\omega = [0, 1.0, 1.2]$ allows us to explore the effect of raising the LTV ratio on residential real estate from 0% to 75% and 90%. This gives a sense of how important the residential collateral channel for macroeconomic fluctuations might be. Figure 4 reports the impulse response functions of a housing shock that increases land prices by 1% on impact. The red crossed lines represent the case when residential real estate is as collateralisable as commercial real estate and physical capital. The shock has a 0.4% peak impact on output, the total wage bill and employment, and it has a 1.6% and 2% peak impact on investment and corporate credit, respectively.[16]

[16]These effects are very similar to those found by Liu, Wang, and Zha (2013) who omit the residential collateral channel. However, there is a second important difference between our model and theirs which is that demand for land from the household sector is diminished in steady state due to the need to reallocate some residential land to entrepreneurs. Thus our model generates less endogenous propagation in house prices in response to the shock, which dampens some of the boost to investment from an increase in the value of collateral. This offsets some of the additional propagation that comes from collateralisable residential land.

Increasing the strength of the residential collateral channel by raising the degree of collateralisability of residential real estate from $\omega = 1$ (75% LTV) to $\omega = 1.2$ (90% LTV) increases the impact of the housing shock substantially. In fact, the blue diamond lines on Figure 4 shows that a housing shock of the same magnitude has about a *35%* larger effect on all macroeconomic variables relative to the baseline. In addition, the black circled show the results when entrepreneurial residential land has no collateral value. In this extreme case, the residential collateral channel is completely absent which leads to a drastic reduction of the propagation. The results show that the housing shock has a four times smaller impact on output and the total wage bill, and a three times smaller impact on investment relative to the baseline ($\omega = 1$).

A key conclusion from this simple exercise is to illustrate that the microeconomic effect related to the residential collateral channel studied in Section 4 may play an important role in understanding macroeconomic fluctuations as well. The model of Liu, Wang, and Zha (2013) focuses on the role of productive (commercial) land as collateral and ignores the role of residential land as a source of collateral for producers. Though unproductive, residential land may be more collateralisable than commercial land. Moreover, 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.

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 £0.04 increase in investment and a £0.06 increase in total wage costs. Similarly, a £1 increase in the value of the average company director's residential real estate leads to around a £0.07 increase in investment and £0.10 increase in 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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Appendix

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)	20219	2203	430	7847	22712
No. Employees	97	18	6	59	22712
Ratios (to Turnover)					
Operating Profit	-.27	.031	-.0032	.085	22522
Remuneration	2.8	.27	.13	.46	22712
Investment	.81	.008	0	.034	22712
Total Assets	2	.44	.3	.72	22700
Firm Collateral	.029	0	0	0	22712
Avg Director Collateral	1.5	.15	.047	.64	10764
Cash	.094	.011	-.039	.088	20199
Debt	1.2	.12	.044	.32	18557
Directors Loans	.13	0	0	.016	15759

Note: The statistics are calculated using our sample of observations from the BVD used in the activity regressions. 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 land & buildings.

Table 7: Descriptive Statistics: Property Holding Firms

Variable	Mean	Median	25%tile	75%tile	N
Levels					
Turnover (£'000s)	215301	11583	4356	32789	17241
No. Employees	1332	103	39	255	17241
Ratios (to Turnover)					
Operating Profit	-.5	.035	.0066	.085	17081
Remuneration	.96	.27	.14	.42	17241
Investment	.11	.02	.0015	.082	17241
Total Assets	3.3	.65	.41	1.2	17236
Firm Collateral	1.2	.085	.014	.31	17241
Avg Director Collateral	.58	.039	.014	.11	9636
Cash	.31	.0056	-.044	.065	16070
Debt	1.1	.19	.077	.54	15916
Directors Loans	.11	0	0	.00081	13401

Note: The statistics are calculated using our sample of observations from the BVD used in the activity regressions. 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 land & buildings.

Figure 5: Distribution of Some of the Key Variables

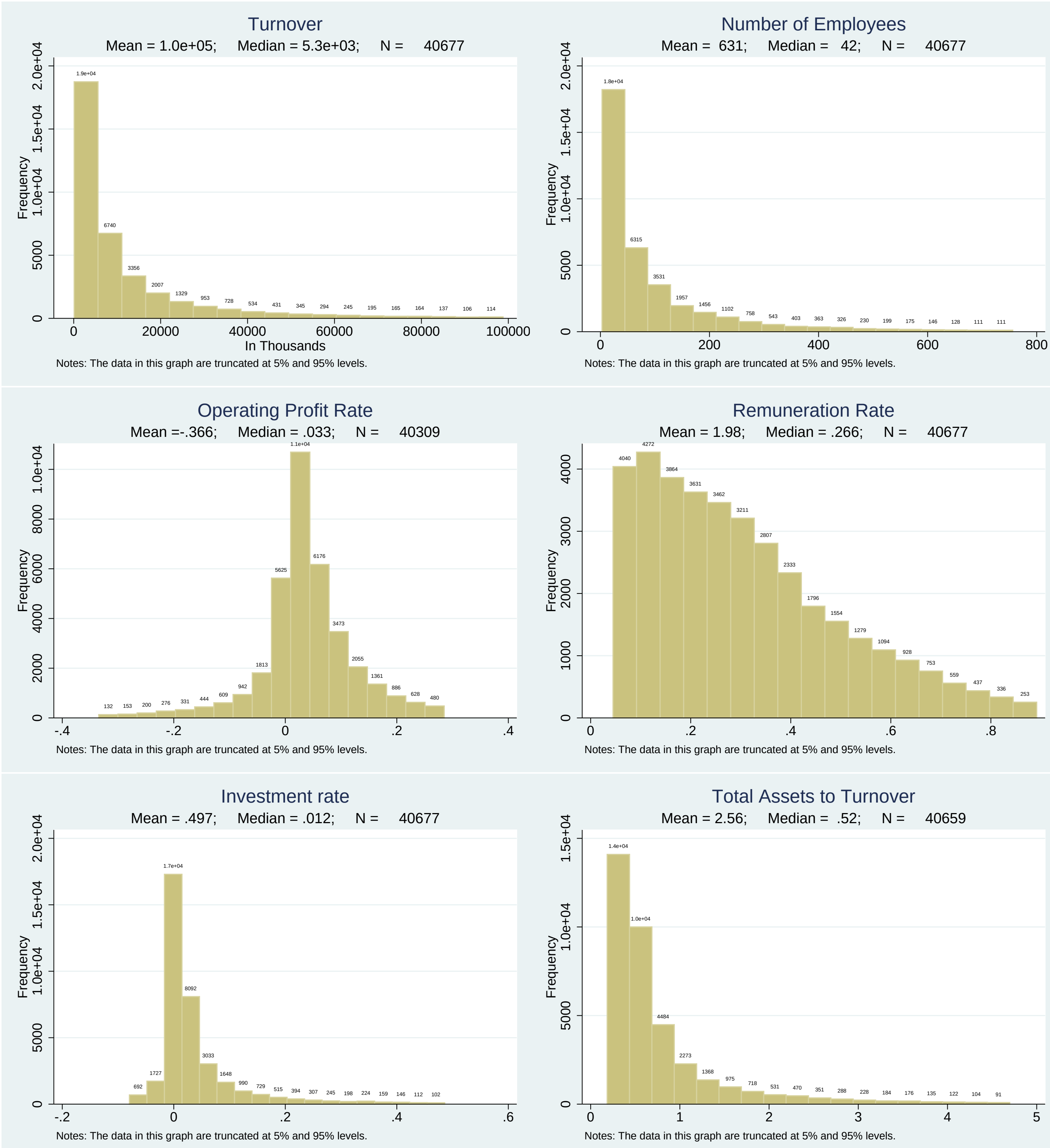
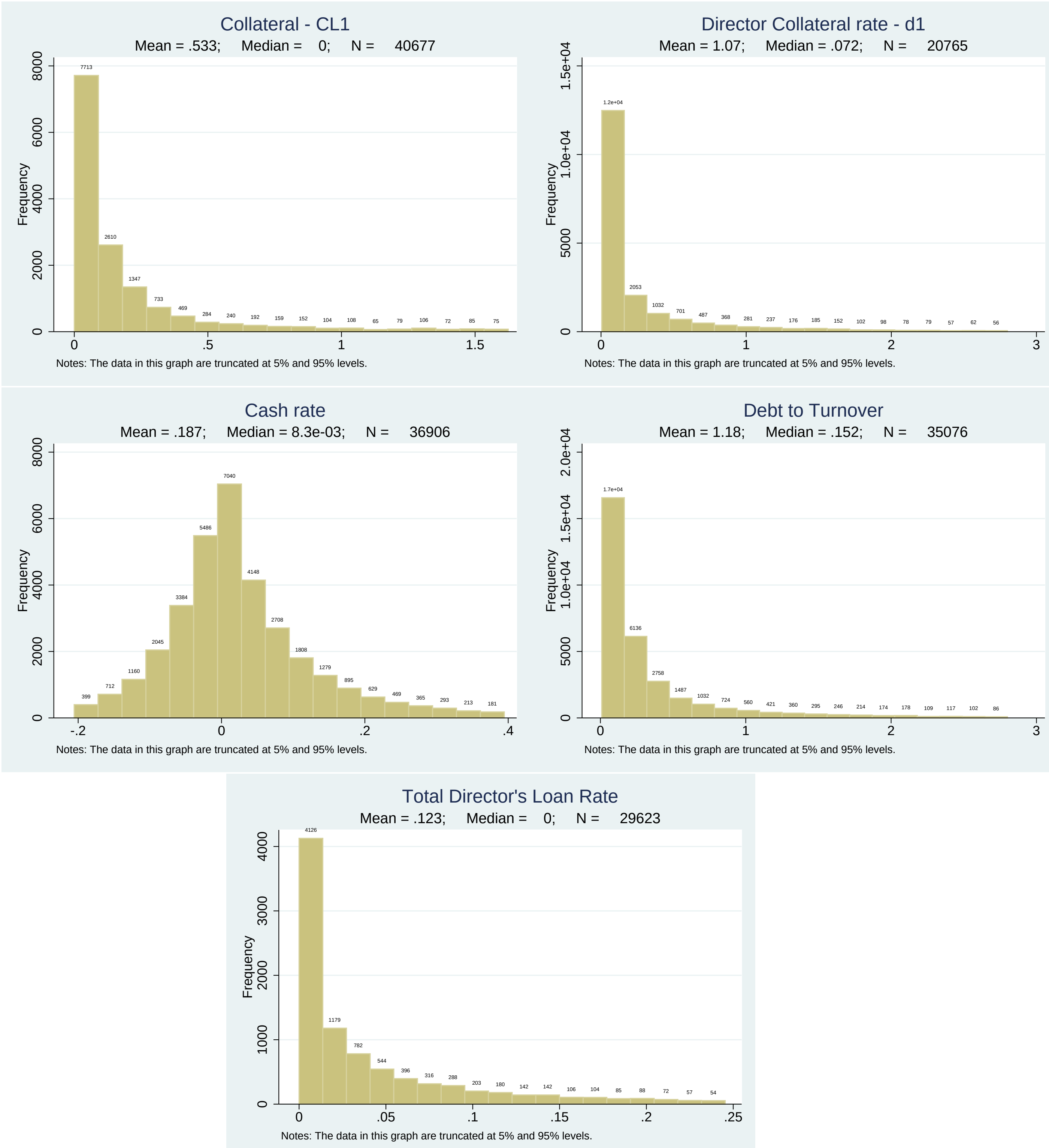


Figure 6: Distribution of Some of the Key Variables



A.2 Additional Regressions

Table 8: Firm Activity and the Collateral Channels: Commercial Real Estate Price Index

	Investment	Total Labour Cost	Employment
Director Collateral	0.0538*	0.0980***	0.0072***
	(0.029)	(0.018)	(0.001)
Firm Collateral	0.0492	0.0707***	0.0031***
	(0.044)	(0.024)	(0.001)
Cash Ratio	0.1187	0.1384***	0.0059***
	(0.075)	(0.044)	(0.002)
Leverage Ratio	0.0222	0.0128	0.0016
	(0.049)	(0.034)	(0.001)
Profit Margin	-0.0208	-0.2965***	-0.0093***
	(0.075)	(0.045)	(0.002)
N	7098	7098	7098
Adjusted R^2	0.21	0.74	0.80
Region-time FE	Yes	Yes	Yes
Industry-time FE	No	No	No
Firm FE	Yes	Yes	Yes

Firm region clustered standard errors in parentheses

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

Table 9: 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

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

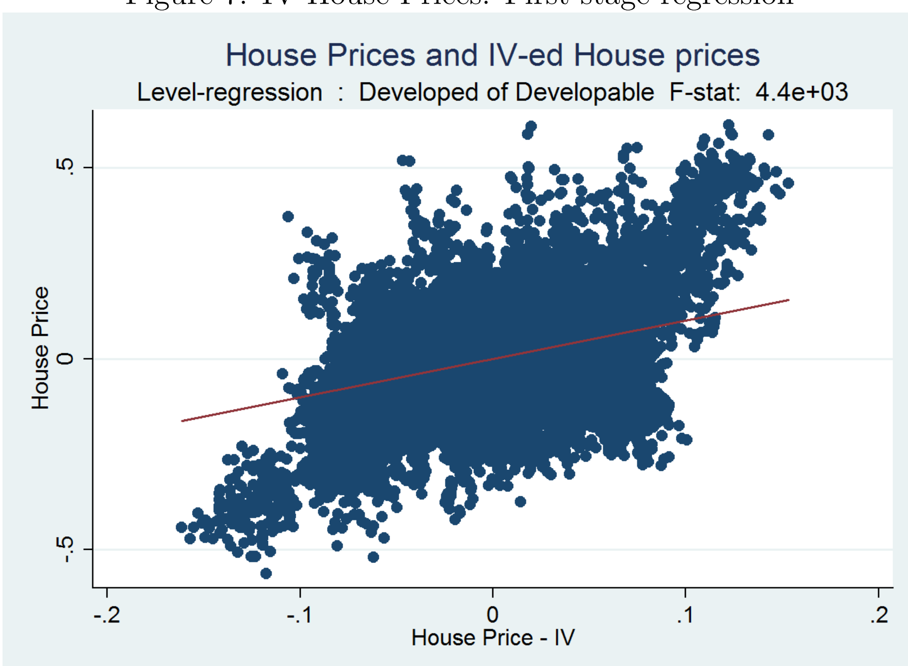
Notes: Regression coefficients of a linear probability model on firm property ownership, including dummy variable for whether the firm belongs to a certain quintile of the total assets, profit margins or age distribution. The regression includes region and industry fixed effects.

Table 10: Firm Activity and the Collateral Channels: Ownership Determinants and Industry Fixed Effect Included

	Investment	Total Labour Cost	Employment
Director Collateral	0.0657***	0.0967***	0.0072***
	(0.021)	(0.014)	(0.001)
Firm Collateral	0.0341	0.0560***	0.0021***
	(0.029)	(0.015)	(0.001)
Cash Ratio	0.1295**	0.1551***	0.0060***
	(0.061)	(0.034)	(0.001)
Leverage Ratio	0.0003	0.0236	0.0026**
	(0.034)	(0.023)	(0.001)
Profit Margin	0.0220	-0.2759***	-0.0079***
	(0.048)	(0.028)	(0.001)
N	15514	15514	15514
Adjusted R^2	0.23	0.76	0.83
Region-time FE	Yes	Yes	Yes
Industry-time FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes

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

Figure 7: IV House Prices: First-stage regression



Note: The scatter plots the realised house prices (projected on the region and time fixed effects) against the house prices (projected on the region and time fixed effects) predicted by the instrument $elasticity_j \times i_t$.

Table 11: Firm Activity and the Collateral Channels: IV House Price Series

	Investment	Total Labour Cost	Employment
Director Collateral	0.0615***	0.0979***	0.0073***
	(0.022)	(0.013)	(0.001)
Firm Collateral	0.0448	0.0576***	0.0022***
	(0.030)	(0.017)	(0.001)
Cash Ratio	0.1438**	0.1550***	0.0062***
	(0.059)	(0.031)	(0.001)
Leverage Ratio	0.0124	0.0281	0.0026***
	(0.036)	(0.022)	(0.001)
Profit Margin	0.0235	-0.2729***	-0.0078***
	(0.049)	(0.029)	(0.001)
N	16256	16256	16256
Adjusted R^2	0.22	0.75	0.83
Region-time FE	Yes	Yes	Yes
Industry-time FE	No	No	No
Firm FE	Yes	Yes	Yes

Firm region clustered standard errors in parentheses

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

Table 12: Firm Activity and the Collateral Channels: Excluding Recent Director House Purchases

	Investment	Total Labour Cost	Employment
Director Collateral	0.0738***	0.0962***	0.0072***
	(0.021)	(0.013)	(0.001)
Firm Collateral	0.0360	0.0561***	0.0022***
	(0.031)	(0.018)	(0.001)
Cash Ratio	0.1438**	0.1555***	0.0061***
	(0.061)	(0.031)	(0.001)
Leverage Ratio	0.0090	0.0265	0.0024***
	(0.036)	(0.022)	(0.001)
Profit Margin	0.0190	-0.2786***	-0.0079***
	(0.047)	(0.028)	(0.001)
N	16084	16084	16084
Adjusted R^2	0.22	0.76	0.82
Region-time FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes

Firm region clustered standard errors in parentheses

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

Table 13: Firm Activity and the Collateral Channels: Asymmetry

	Investment	Total Labour Cost	Employment
Director Collateral	0.0968***	0.1142***	0.0075***
	(0.026)	(0.015)	(0.001)
Director Collateral× positive price chg dum	-0.0355**	-0.0182*	-0.0001
	(0.016)	(0.010)	(0.001)
Firm Collateral	0.0119	0.0570***	0.0025***
	(0.030)	(0.021)	(0.001)
Firm Collateral×positive price chg dum	0.0314	-0.0016	-0.0005
	(0.020)	(0.010)	(0.000)
Cash Ratio	0.1389**	0.1574***	0.0061***
	(0.059)	(0.030)	(0.001)
Leverage Ratio	0.0076	0.0267	0.0024**
	(0.036)	(0.022)	(0.001)
Profit Margin	0.0261	-0.2713***	-0.0078***
	(0.047)	(0.027)	(0.001)
N	16694	16694	16694
Adjusted R^2	0.22	0.76	0.83
Region-time FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes

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

Table 14: Firm Activity and the Collateral Channels: Large vs Small Firms (Employment<10)

	Investment	Total Labour Cost	Employment
Director Collateral	0.1171***	0.1734***	0.0115***
	(0.041)	(0.021)	(0.001)
Director Collateral ×Small Firm	-0.0732**	-0.1071***	-0.0057***
	(0.035)	(0.026)	(0.001)
Firm Collateral	0.0497	0.0768***	0.0030***
	(0.044)	(0.023)	(0.001)
Firm Collateral×Small Firm	-0.0439	-0.0725***	-0.0033***
	(0.042)	(0.024)	(0.001)
Cash Ratio	0.1234**	0.1370***	0.0051***
	(0.057)	(0.034)	(0.001)
Leverage Ratio	0.0099	0.0305	0.0026**
	(0.035)	(0.023)	(0.001)
Profit Margin	0.0272	-0.2692***	-0.0076***
	(0.046)	(0.026)	(0.001)
N	16694	16694	16694
Adjusted R^2	0.23	0.77	0.84

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

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 will follow the notation of Liu, Wang, and Zha (2013). We also take most model parameters from them, who obtained their estimates using 6 quarterly US time series and 8 structural shocks including two non-stationary shocks. To simplify the exposition, we omit the description of all structural shocks but the housing shock. We also refer the reader to their paper for further information on the balanced growth path properties of the model.

B.1.1 Household

The representative household maximises the utility function:

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

where $C_{h,t}$ denotes consumption and h_h is the degree of internal habit formation. The parameter β is the subjective discount factor, $\bar{\psi}$ is a scale parameter, $L_{h,t}$ is residential real estate of the household with the corresponding taste shifter φ_t. This is referred to as a land demand shock, and it follows the stationary process:

$$\ln \varphi_t = (1 - \rho_\varphi) \ln \bar{\varphi} + \rho_\varphi \ln \varphi_{t-1} + \sigma_\varphi \varepsilon_{\varphi,t}, \tag{B.2}$$

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 flow-of-funds constraint of the representative household is:

$$C_{h,t} + q_{l,t} \left(L_{h,t} - L_{h,t-1} \right) + \frac{S_t}{R_t} = W_t N_t + S_{t-1}, \tag{B.3}$$

where R_t is the gross risk free 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. Using the flow-of-funds constraint B.3, this yields the familiar Euler-equation:

$$\mathbb{E}_t \Lambda^h_{t,t+1} R_t = 1 \tag{B.4}$$

where $u^h_{c,t} \equiv \frac{1}{C_{h,t} - h_h C_{h,t-1}} - \mathbb{E}_t \frac{h_h \beta}{C_{h,t+1} - h_h C_{h,t}}$ is the marginal utility of consumption, and $\Lambda^h_{t,t+1} \equiv \mathbb{E}_t \beta u^h_{c,t+1} / u^h_{c,t}$ is the household's stochastic discount factor. The optimal labour supply decision is:

$$W_t = \frac{u^h_{c,t}}{u^h_{n,t}}, \tag{B.5}$$

where $u^h_{n,t} = \bar{\psi} N_t$ is the marginal disutility of labour supply.

B.1.2 Entrepreneur

The entrepreneur's utility function is written as:

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

where $\gamma < \beta$ is the subjective discount factor of the entrepreneur, $C_{e,t}$ 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):

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

where $\alpha \in (0,1)$ and $\kappa \in (0,1)$ are the output elasticities of the production factors, and Z is total factor productivity. 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:

$$K_t = (1-\delta) K_{t-1} + \left[1 - \frac{\Omega}{2} \left(\frac{I_t}{I_{t-1}} - \bar{\lambda}_l \right)^2 \right] I_t, \tag{B.8}$$

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:

$$C_{e,t} + q_{l,t} \left[(L_{c,t} - L_{c,t-1}) + (L_{r,t} - L_{r,t-1}) \right] + B_{t-1} = Y_t + \frac{B_t}{R_t} - I_t - W_t N_t, \tag{B.9}$$

where B_{t-1} is the amount of matured entrepreneurial debt and B_t / R_t is the value of new debt. The entrepreneur's ability to obtain credit is subject to the following collateral constraint:

$$B_t \leq \theta \mathbb{E}_t \left[q_{l,t+1} \left(L_{c,t} + \omega L_{r,t} \right) + q_{k,t+1} K_t \right], \tag{B.10}$$

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 corporate collateral value. The credit constraint B.10 limits the amount of borrowing by a fraction of the gross value of the collateralisable assets - land and capital. As in Kiyotaki and Moore (1997), the credit constraint reflects problems of limited contract enforceability. 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. The first-order conditions with respect to residential and commercial real estate and physical capital are written as:

$$\begin{aligned} q_{l,t} =& \mathbb{E}_t \Lambda^e_{t,t+1} q_{l,t+1} + \upsilon \frac{u^e_{r,t}}{u^e_{c,t}} + \frac{\mu_{e,t}}{\lambda_{e,t}} \omega \mathbb{E}_t \theta q_{l,t+1} \\ q_{l,t} =& \mathbb{E}_t \Lambda^e_{t,t+1} \left[\alpha \kappa \frac{Y_t}{L_{c,t}} + q_{l,t+1} \right] + \frac{\mu_{e,t}}{\lambda_{e,t}} \mathbb{E}_t \theta q_{l,t+1} \\ q_{k,t} =& \mathbb{E}_t \Lambda^e_{t,t+1} \left[\alpha \left(1 - \kappa\right) \frac{Y_t}{K_t} + \left(1 - \delta\right) q_{k,t+1} \right] + \frac{\mu_{e,t}}{\lambda_{e,t}} \mathbb{E}_t \theta q_{k,t+1} \end{aligned} \tag{B.11}$$

where we define $u^e_{r,t} \equiv 1/L_{r,t}$ and $u^e_{c,t} \equiv \frac{1}{C_{e,t} - h_e C_{e,t-1}} - \mathbb{E}_t \frac{h_e \gamma}{C_{e,t+1} - h_e C_{e,t}}$ is the marginal utility of consumption, and $\Lambda^e_{t,t+1} \equiv \mathbb{E}_t \gamma u^e_{c,t+1} / u^e_{c,t}$ is the entrepreneur's stochastic discount factor.

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:

$$C_{h,t} + C_{e,t} + I_t = Y_t. \tag{B.12}$$

The land market clearing condition implies:

$$L_{h,t} + L_{r,t} + L_{c,t} = \bar{L} \equiv 1, \tag{B.13}$$

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

$$S_t = B_t. \tag{B.14}$$

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.1.4 Model Parameters

Table 15 summarises the model parameters. With the exception of ω and υ, they are taken from Liu, Wang, and Zha (2013) (LWZ). The preference parameter υ is calibrated to ensure that 25% of residential land is owned by the entrepreneur in steady-state, suggested by the calculation in footnote 14.

Table 15: Benchmark DSGE Model Parameters

Parameter	Description	Value	Source
β	Household's discount rate	0.994	LWZ
γ	Entrepreneur's discount rate	0.986	LWZ
h_h	Household's habit parameter	0.497	LWZ
h_e	Entrepreneur's habit parameter	0.658	LWZ
δ	Depreciation rate	0.037	LWZ
Ω	Investment adjustment cost parameter	0.175	LWZ
α	Capital share	0.300	LWZ
κ	Land share	0.069	LWZ
θ	LTV ratio	0.750	LWZ
$\bar{\psi}$	Labour scale parameter	3.821	LWZ
ρ_{φ}	Persistence of the housing shock	0.999	LWZ
$\bar{\varphi}$	Household's land preference	0.034	chosen to match UK land shares
ν	Entrepreneur's land preference	0.594	chosen to match UK land shares
ω	Collateral weight on residential land	$0 - 1.2$	varied

When looping over the parameter values $\omega = [0, 1.0, 1.2]$, we fix the preference parameters $\bar{\varphi}$ and υ and allow for endogenous reallocation of residential land in steady-state. Table 16 shows that increasing ω reduces (raises) the steady-state level of household and commercial (entrepreneurial residential) land.

Table 16: Steady-state land allocation for different values of ω

	L_h	L_c	L_r
$\omega = 0$	0.54	0.33	0.13
$\omega = 1.0$	0.52	0.31	0.17
$\omega = 1.2$	0.51	0.30	0.19

Note: the sum of land holdings is normalised, $L_{h,t} + L_{r,t} + L_{c,t} \equiv 1$.