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Alessia De Stefani
ads@nationalbanken.dk
DANMARKS NATIONALBANK

Simon Juul Hviid
sjh@nationalbanken.dk
DANMARKS NATIONALBANK

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Abstract
We study the effect of house price developments on home-equity extraction and household expenditure, exploiting detailed administrative data covering the entire population of Danish homeowners between 2009 and 2016. We establish causality between house price developments and household decisions through an instrumental variable strategy, exploiting the origin-push migration measure proposed by Saiz (2007) as an instrument for local house price developments. Our findings indicate that a 1 percent increase in house prices increases home-equity extraction by 0.21 percentage points, conditional on a positive extraction decision. This average effect, however, conceals a large heterogeneity across borrowers: those with high ex-ante leverage are significantly more responsive to house price developments than borrowers far from their credit limits, particularly when the constraint binds on the LTV dimension. Furthermore, the effect of house prices on expenditure is entirely driven by home equity extraction. For each DKK borrowed, we estimate the expenditure response to be 0.31 DKK. Our results indicate that the co-movement of house prices, leverage and expenditure can largely be attributed to a collateral effect.

Resume
Vi undersøger effekten af husprisændringer på belåning af friværdi og husholdningernes forbrug, hvor der udnyttes detaljerede administrative data for hele populationen af danske boligejere fra 2009 til 2016. Vi etablerer kausalitet mellem boligprisudviklingen og boligejernes beslutninger gennem en IV-strategi, der udnytter origin-push-migration, der er foreslået af Saiz (2007), som et instrument for den lokale boligprisudvikling. Vores resultater indikerer, at en stigning på 1 procent i boligpriserne øger belåningen af friværdien med 0,21 procentpoint, betinget af at friværdien belånes. Denne gennemsnitlige effekt dækker over en stor grad af heterogenitet på tværs af låntagere: Dem med høj ex ante-belåning reagerer betydeligt mere på boligprisudviklingen end låntagere langt fra deres kreditgrænser, især når det er belåningsgraden, der er bindende. Endvidere er effekten af boligpriserne på forbrug helt drevet af udtræk af friværdi. For hver krone lånt finder vi, at forbruget stiger med 0,31 DKK inden for samme år. Resultatet indikerer, at bevægelsen i boligpriser, boliglån og forbrug overordnet kan tilskrives en kollateraleffekt.

Key words
Mortgage decisions, house prices, origin-push migration.

JEL classification
D12; D14; R32.

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Housing as Collateral and Home-Equity Extraction *

Alessia De Stefani† Simon Juul Hviid‡

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We study the effect of house price developments on home-equity extraction and household expenditure, exploiting detailed administrative data covering the entire population of Danish homeowners between 2009 and 2016. We establish causality between house price developments and household decisions through an instrumental variable strategy, exploiting the origin-push migration measure proposed by Saiz (2007) as an instrument for local house price developments. Our findings indicate that a 1 percent increase in house prices increases home-equity extraction by 0.21 percentage points, conditional on a positive extraction decision. This average effect, however, conceals a large heterogeneity across borrowers: those with high ex-ante leverage are significantly more responsive to house price developments than borrowers far from their credit limits, particularly when the constraint binds on the LTV dimension. Furthermore, the effect of house prices on expenditure is entirely driven by home equity extraction. For each DKK borrowed, we estimate the expenditure response to be 0.31 DKK. Our results indicate that the co-movement of house prices, leverage and expenditure can largely be attributed to a collateral effect.

JEL Classification: D12; D14; R32
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†*Danmarks Nationalbank, Research*. E-mail: ads@nationalbanken.dk.
‡*Danmarks Nationalbank, Economics and Monetary Policy*. E-mail: sjh@nationalbanken.dk.

1 Introduction

The co-movement of house prices, leverage and consumption is a well-documented characteristic of the past two decades (Kaplan et al., 2017). A large body of empirical literature indicates that house price fluctuations are directly linked to household expenditure and borrowing decisions (See e.g. Mian and Sufi (2009); Mian and Sufi (2011); Mian et al. (2013); Disney et al. (2010); Bhutta and Keys (2016); Aladangady (2017)). In particular, cash-out refinancing activity depends with different degrees upon fluctuations in house prices and interest rates (Bhutta and Keys (2016); (Cloyne et al., 2017)) and can therefore constitute a crucial mechanism of transmission of monetary policy (Wong, 2016).

This paper exploits detailed administrative data covering the entire population of Danish households between 2009 and 2016 to study how house price fluctuations affect home-equity extraction, mortgage choice and household expenditure. The high granularity of the data provides a good ground to test the two main hypotheses according to which changes in house prices can shift borrowing and non-housing consumption: through collateral effects and through wealth effects. The question of which channel is responsible for the transmission of house price fluctuations to consumption has received wide attention in the literature (Mian and Sufi (2011); Cooper (2012); Mian et al. (2013); Aladangady (2017); (Cloyne et al., 2017)) since it speaks directly to the debate about the roots of the 2008 financial crisis. Practically, if collateral effects are predominant, people who are close to their borrowing limits will increase their borrowing and consumption patterns more than other households in response to rising house prices; on the other hand, if borrowing and consumption choices are driven by pure wealth effects, the entire cross-section of borrowers should respond in a similar way to house price developments.

Our results point in the direction of house prices affecting household borrowing and spending mainly through the collateral channel. This confirms the intuition that increases in house prices can have important effects on the real economy through the reduction of credit constraints faced by households (Mian and Sufi 2009, 2011; (Cloyne et al., 2017)). Due to the comprehensive features of our data, we are able to link house price developments not only to home-equity extraction activity, but also to investigate individual-level expenditure patterns. Our estimations therefore also speak to the vast applied literature dealing with the relationship between house prices and consumption, particularly with the work that exploits a combination of household-level data and regional heterogeneity (Mian and Sufi (2011); Disney et al. (2010); Basten and Koch (2015); Aladangady (2017); Maggio et al. (2017)).

Methodologically, we establish a causal relationship between house price development and home-equity extraction decisions by exploiting the origin-push migration measure proposed by Saiz (2007) and exploited as an instrumental variable for house price developments in a similar context by Basten and Koch (2015).

The instrument builds on the intuition that in the short run the supply of housing is fixed; therefore a sudden increase in housing demand, such as that generated by migratory inflows, will induce an increase in house prices. However, any migratory inflow is clearly not a valid instrument in itself, since relocation decisions are endogenous to local amenities, expectations, and wage growth which can affect both house prices and mortgage borrowing directly. We therefore exploit the fact that migration inflows from foreign countries have been shown to distribute across the territory according to the historical patterns of settlement from the same country of origin (Card (2001); Saiz (2007)). Therefore, the interaction between aggregate migration inflow from a given country in a particular year, and the shares of migrants living in a particular geographical area within the country in the past (origin-push migration) provide a measure of migration inflows which should be exogenous to contemporaneous productivity conditions in a given region, once controlling for aggregate shocks and regional time-invariant characteristics through time and regional fixed effects. This interaction term can therefore be used to study the effects of migration on house prices as in Saiz (2007) or as an instrumental variable to evaluate how house price developments affect other variables of interest, as in Basten and Koch (2015). We use this origin-push migration measure as an instrument for house price appreciation, exploiting variation over time across Danish municipalities, in order to evaluate the effect that house price growth has on mortgage borrowing activity.[1]

Our baseline results indicate a strong effect of house price growth on home-equity extraction. An increase in house prices in any given year increases not only the probability of home-equity extraction, but conditional on a positive extraction decision, a 1 percent increase in house prices leads to a 0.2 percentage points increase in the outstanding mortgage balance, a magnitude similar to that found by Cloyne et al. (2017) in the UK context. We also find that the effect is highly heterogeneous across consumers. Conditional on a positive extraction decision, homeowners with ex-ante high leverage ratios react to changes in house prices by extracting more home equity than other homeowners, consistent with a collateral-based explanation of reaction to housing wealth. Borrowers with high loan-to-value (LTV) ratios seem to respond to changes in house prices by borrowing significantly more than those with high loan-to-income (LTI) ratios, possibly suggesting a role for credit supply regulation: the LTI borrowing limits posed by banks are not endogenously weakened by rising house prices, while LTV limitations are. Homeowners with an ex-ante LTV above unit extract 0.06 percentage points more equity than homeowners with similar demographic characteristics and LTVs below 40 percent, when exposed to an increase in house prices of 1 per cent. Furthermore, homeowners who choose interest-only mortgages are more responsive to changes in the price of housing. Since this mortgage typology in Denmark is often chosen by young and credit constrained homeowners

[1] While Basten and Koch (2015) study purchase mortgage choice, we are able to focus exclusively on home-equity extraction for existing homeowners and are furthermore able to link this home-equity extraction activity to the expenditure patterns of households. Our analysis differs from Basten and Koch (2015) also in scope, since we focus on disentangling the wealth from the collateral channel, while they focus on analysing the credit supply from the credit demand channel, which we do not address explicitly.

(Larsen et al., 2018), who typically leverage more in the first place (Kuchler, 2015), this evidence also points in the direction of house prices affecting household decisions mainly through a reduction in credit constraints.

Finally, we find that households increase expenditure by 0.065 DKK for each DKK increase in the value of their own housing assets, a magnitude that is nearly identical to that estimated by Aladangady (2017) in the US context. However, we also find that including home-equity extraction in the specification absorbs entirely the direct effect of house price changes on expenditure. In other words, our evidence appear to suggest that house prices do not affect expenditure per se: they do so through their effect on home-equity extraction activity. Conditional on a positive home-equity extraction decision, households convert into spending about 0.31 DKK for each additional DKK extracted in home equity. To our knowledge, the combination of individual-level data detailing both home-equity extraction and spending response as well as the identification of the main channel driving both is novel to a non-US context. Our evidence is overall consistent with Andersen and Leth-Petersen (2018), in that they also find that housing wealth shocks affect the real economy largely through the mortgage market. Focusing on home-equity extraction, our results indicate an important role for housing as collateral, which is consistent with recent evidence originating from the UK and the US (Cloyne et al. (2017);Cooper (2012); DeFusco (2018)).

This paper proceeds as follows. Section 2 provides an overview of the available data. Section 3 describes the methodology. Section 4 presents the results, and section 5 concludes.

2 Data

2.1 Household data: the Danish registries

The data set we use follows the definitions of households, expenditure measures, and aggregation of variables at the household level used in previous work by Andersen et al. (2016) and Hviid and Kuchler (2017), which we briefly describe in this section.

Households

Our data covers the entire population of households living in Denmark between 2009 and 2016. The dataset stems from a range of administrative registries, primarily based on third-party reported data to the tax authorities and covers information such as income, assets as well as a variety of demographic and socio-economic indicators both for individuals and for households. One very interesting feature of this data is its panel dimension, which allows to follow both individuals and households over time, during the entire time frame in which they are tax liable

in Denmark.

Since saving and expenditure choices, like mortgage borrowing, are inherently household-level decisions we aggregate individual-level information to the household level. Statistics Denmark provides a household identifier based on some rules: individuals need to live on the same address and be a married or registered couple. Co-habitants of different sexes and less than 15 years age difference are also defined as a single household; this does not apply if they share custody of a child in which case they are defined as a household independent of age and sex. Children living with parents are included as members of the household up to the age of 25, after which they are registered as a separate household.

Our starting point is the population registry (BEF), which includes individual information about e.g. address of residence, age, gender, and family ties. These informations are merged with the income registry (IND) based on detailed information from the tax authorities including income components and the value of debt and assets. In general, these measures are considered to be of a high quality, as the Danish tax system is founded on third-party reporting with only very limited degree of tax evasion (Kleven et al., 2011).

Information about housing is added from a separate registry of home ownership (EJER), which is supplemented by a registry on housing wealth (FORMEJER) in which imputed value of properties can be found. The property values are calculated by Statistics Denmark as the public valuation, which is used for housing taxation purposes, adjusted by the average difference to actual sales prices for housing units that have been sold within the year. The adjustment is made at the postal code and property type level.

Our study is focused on home-equity extraction and therefore we exclude households without housing wealth (i.e. renters). We also exclude households which make housing transaction in a given year, the year prior or the forthcoming year, to avoid capturing the extreme borrowing and saving dynamics occurring in the years immediately preceding and following a home purchase. Furthermore, we exclude households in which not every member is fully taxable in Denmark, i.e. we have missing information in the registers on income, and households with self-employed members, as income measures are subject to substantial bunching around the limits of income-tax brackets (le Maire and Schjerning, 2013), indicating that the firm and household economy are inherently difficult to disentangle. Lastly, we exclude households with less than 25,000 DKK (3500 USD) total annual income. All in all, we exclude roughly 15 percent of the sample of homeowners. Stock variables are measured at the end of the year.

Mortgages

For the purpose of this analysis, the central part of the data is composed by detailed loan-level information on mortgages for each household. The Danish mortgage market is relatively similar to the US system, but with a few noteworthy differences (Campbell, 2012). Households can borrow up to 80 percent of the home value and choose between fixed rate mortgages (FRM) and adjustable rate mortgages (ARM) with maturities up to 30 years and for both types there is an interest-only (IO) alternative, which comes at a risk premium to mortgage lenders and an increase in the administration margins. There is no standardised measure of credit worthiness, such as the FICO score known from the US; rather credit assessment is done by the individual banks.[2] A special feature of the FRMs is that they are funded by callable bonds, where households can prepay the loan at face value without incurring penalties, which makes refinancing particularly beneficial for households as interest rates are decreasing, such as they have been over our sample period (Andersen et al., 2015). We show that FRM mortgages are not the main driver of our findings.

The mortgage registry (REAL) is the pivotal registry used in this paper. As of 2009, individual mortgage institutions have reported loan-level information to Danmarks Nationalbank at an annual basis.[3] The registry includes details on e.g. outstanding mortgage amount, principal amount, mortgage typology, date of origination, interest rate, maturity, and administration margins. Lastly, the registry includes a unique identifier of the mortgage borrower, which allows us to merge these data with the other registers.

Home-equity extraction is the key outcome variable of interest. Home-equity extraction by mortgages can either be done by refinancing an existing mortgage or by taking up an additional mortgage. Figure 1 illustrates the amount of households who decide to extract home equity in each year of our sample and additionally the average amount extracted for these households. We define home-equity extraction as a positive change in the principle outstanding mortgage amount over and above 20,000 DKK (3000 USD), irrespectively of how it is achieved (new mortgage or refinancing of existing one) or the ex-ante typology of mortgage debt (FRM or ARM and IO combinations).

Expenditure

Since expenditure data is not readily available in the Danish registers, we follow the approach of Browning and Leth-Petersen (2003), among others, and impute a household-level measure of annual non-housing expenditure from income and wealth information using a framework that can be generalized as income minus the change in net assets:

[2] In some cases the mortgage institutions will make an additional valuation of the underlying collateral.
[3] Initially, the data was reported to the Ministry of Economic and Business Affairs.

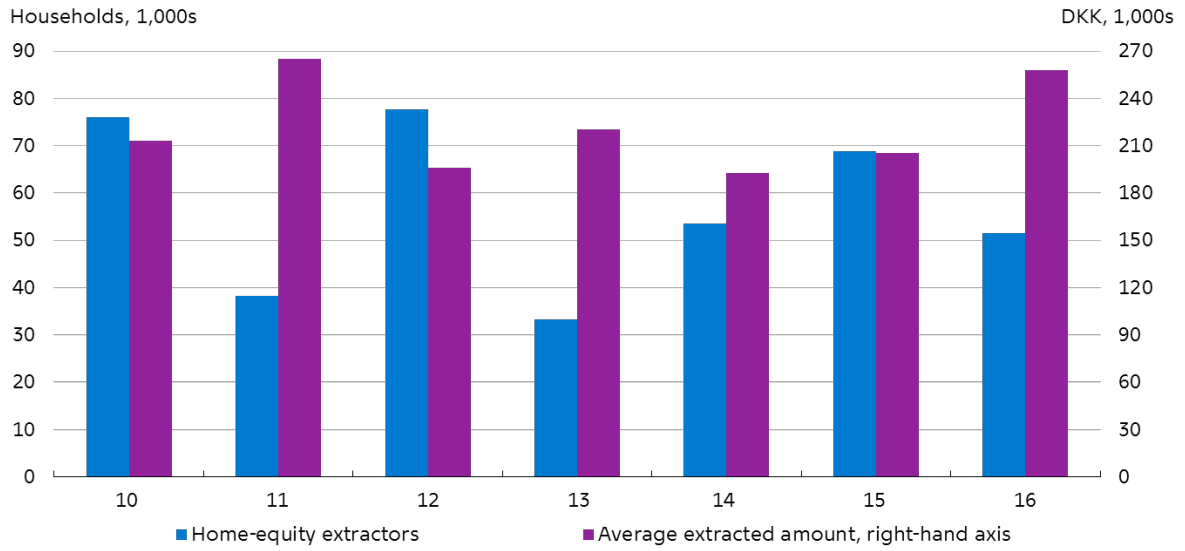

Figure 1: Amount of households that actively increase their outstanding mortgages from 2010-16 and the average mortgage increase. Excludes households involved in housing transactions.

$$Expenditure_{it} = Disposable\ income_{it} - \Delta Net\ worth_{it}.$$

This imputation is generally capable of capturing survey-based consumption measures with a high degree of accuracy(Kreiner et al. (2015) and Abildgren et al. (2018)). Housing appreciation is excluded from the consumption imputation; on the other hand a repayment of mortgages will increase net worth and therefore reduce expenditure. This measure should capture the non-housing expenditure of homeowners fairly well. Pension contributions are measured directly, which allows us to eliminate the measurement error from pensions savings. The consumption imputation is generally less reliable whenever households own significant amounts of stocks and bonds, because in the registries we only observe an overall market value of each asset category, rather than their breakdown and flows within the year. Even if household holdings are adjusted by the development in the leading Danish stock index, OMX C20, this leads to a significant measurement error in the expenditure measure, since it is impossible to disentangle capital gains from active savings in such financial assets. Danish households hold a relatively limited amount of financial assets other than pension accounts and savings accounts, and the effects of this measurement error should be limited to the very top of the income distribution-a section of the population that is unlikely to respond significantly to marginal developments in house prices.

Of course a limitation of this aggregate expenditure measure does not allow us to distinguish between different categories of consumption, in particular whether home-equity extraction is

used to finance durable or non-durable purchases. We proxy for durable expenditure using the only available measure recorded by the tax authorities, car purchases, collected in a household-level registry for tax purposes (BIL). The registry includes an assessed value of car wealth, which can be used to create a measure of car expenditure by observing the change in car wealth from one year to the next.

3 Empirical strategy

From a methodological standpoint, evaluating the causal effects of house prices on household financial decisions is challenging. Mortgage borrowing decisions, spending and house prices are simultaneously affected by omitted and unobservable variables, such as policy changes and expectations. In order to get as close as possible to the estimation of a causal effect of house price developments on home-equity extraction, we employ an instrumental variable strategy based on the origin-push-migration mechanism first proposed by Saiz (2007) to study the effects of migration on house prices and subsequently implemented as an instrument to study the effect of house prices on mortgage choice by Basten and Koch (2015).

Using migration inflows as an instrument for house prices builds on a simple intuition: housing supply is fixed in the short run, since it takes time to obtain building permissions and produce new buildings. Therefore, an upswing in housing demand, like the one caused by an inflow of migrants (both foreign and domestic) might, at least temporarily, increase residential house prices. This intuition applies not only over time, but also cross-sectionally: In a given year, a city with a higher inflow of incomers is likely to experience a higher growth rate in house prices than a city with similar characteristics and a lower inflow, all else being equal.

Of course, relocation decisions are not random. Local economic conditions, job prospects, amenities and wages are all likely to be correlated with both house prices, mortgage choice and migration inflows: therefore, using simple migration inflows in a given municipality and year will run into the same endogeneity concerns that affect house prices in the first place. The origin-push-migration (OPI) methodology can be useful in this context. This methodology, first used by Card (2001) to study the effect of migration on local labor markets, builds on the observation that the geographic distribution of immigrants of a given nationality at any point in time tends to follow closely the pre-existing distribution of residents from the same country of origin. In other words, the ex-ante distribution of residents who hold a particular nationality across Danish municipalities is a strong predictor of the relocation decisions (in terms of municipality of choice) of current immigrants holding the same nationality who decide to immigrate to Denmark in any given year. At the same time, this measure is pre-determined and in itself exogenous to the evolution of local economic conditions at the subsequent time of the inflow. Therefore, the interaction between current aggregate inflows from any given

country and the pre-existing distribution of immigrants of the same origin provides a Bartik (1991)-style instrument for the municipality-level time-varying change in house prices.

Figures 2 and 3 provide a visual representation of the data which forms the basis of our empirical strategy. The Danish territory presents a large degree of heterogeneity in the shares of immigrant population in the year prior to the start of our sample period (Figure 2). Some municipalities, like those in the broader Capital region and the municipalities bordering with Germany, host alone more than 10 percent of the total amount of non-Danish western residents living in Denmark in 2008. We restrict our sample to migratory flows from OECD and EU countries, in order to capture exclusively the migratory inflow that is more likely to drive up housing costs. The years in our sample also witnessed a large inflow across Europe of asylum seekers and migrants originating from conflict areas: however, recent empirical evidence suggests that these migratory inflows are in fact likely to reduce residential house prices, possibly due to a perception of negative externalities that the local population associates with this type of migration (Kürschner and Kvasnicka, 2018). In order to avoid capturing these counteracting effects, we exclude all non-OECD and non-EU countries from our OPI measure. Within our sample, the largest inflow of migrants to Denmark originated from Eastern Europe, particularly Poland and Romania, with Germany and Italy following up.

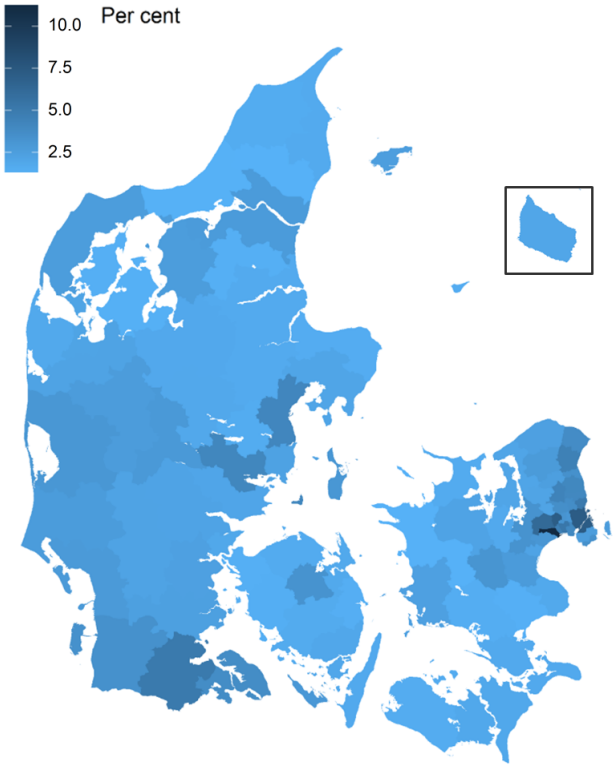

Figure 2: Share of municipal population from EU and OECD countries in 2008. Data from Danish Population Registry.

Our first stage equation exploits the idea that the inflows depicted in Figure 3 can be

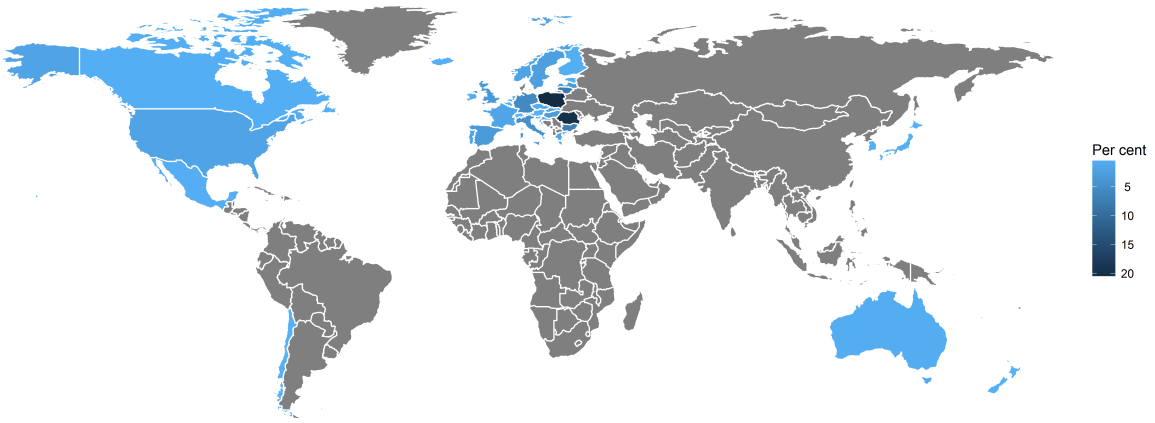

Figure 3: Share of net immigration from 2008-16 from OECD and EU countries. Data from Danish Population Registry.

fictionally distributed across Danish municipalities depending on the pre-existing geographical patterns depicted in Figure 2. Formally, our first stage equation, or the relationship between house prices and migration, is expressed as follows:

$$HP_{imt} = \alpha_0 + \alpha_1 Share^{c}_{m,2008} \cdot Inflow^{c}_{t} + \alpha_2 \Theta_{it} + \phi_m + \lambda_t + \epsilon_{imt} \quad (1)$$

Where HP_{imt} is either the year-on-year change in house value as reported in housing wealth registry or the average square-metre prices of single-family houses experienced by family i living in municipality m at year t, measured by Finance Denmark.[4] Prices are measured on a quarterly basis between 2009 and 2016 and we use observations from the fourth quarter as a measure of end-of-year prices.

Our coefficient of interest is α_1 , which measures the effect of origin-push migration inflows (OPI). OPI is measured by the interaction between $Share^{c}_{m,2008}$, or the share of nationals from country c who were residents of municipality m as a proportion of total number of people from country c living in Denmark in 2008; and the current migration inflow from country c to Denmark as a whole in year t, expressed by $Inflow^{c}_{t}$.

The coefficient α_1 is conditional on a vector of household-level characteristics, Θ_{it}, which control for observable characteristics of the population: annual household income, family size, number of children, age and pre-existing value of the housing stock at the family level. Furthermore, α_1 is conditional on municipality and year fixed effects, ϕ_m and λ_t, which capture both aggregate shocks affecting all municipalities equally at the same point in time and municipality-level time invariant characteristics which are likely to be correlated with house prices (such as geography, and the degree of supply elasticity and overall price level with respect to the average). Municipality and time-fixed effects also capture the direct effect of

[4]Finance Denmark is a Danish association of mortgage, retail, and investment banks.

ex-ante population shares by country of origin, which are constant for each municipality, and the aggregate effects of migration inflows in Denmark in any given year: in other words α_1 measures the effect of the interaction between ex-ante shares and annual migration inflows, while levels in both variables are allowed to influence house prices directly.

Table 1 describes the first-stage results, in which different measures of house price growth are regressed over the shift-share measure of migratory flows by country of origin. The percentage price gain in the value of a given households' primary residence is positively affected by the instrument (column 1) and so is the change in house value expressed in levels (column 2). Reassuringly, these individual-level changes are also reflected in the aggregate measures of within-municipality house price developments, expressed as the average price per square meter (column 3). While there has been a strong heterogeneity in house price developments across Danish municipalities during recent years, with large cities observing the greatest spikes in price development, the result is robust to the exclusion of Copenhagen and Aarhus (column 4).

Table 1: First Stage

VARIABLES	(1) Change value percent	(2) Change value levels	(3) Avg.Sqm log	(4) Avg.Sqm log, no cities
	OLS	OLS	OLS	OLS
OPI	0.023***	40,535.759***	0.198***	0.758***
	(0.006)	(7,372.403)	(0.031)	(0.161)
Municipality and year FE	Yes	Yes	Yes	Yes
Household controls	Yes	Yes	Yes	Yes
Observations	7,546,007	6,058,799	7,583,991	6,974,114
R-squared	0.316	0.146	0.979	0.976

Source: Elaboration on microdata from Statistics Denmark, registries IND, FAM, BEF, 2009-2016. *Notes*: The dependent variables are the within-household change percentage change in the value of the primary residence in any given year (column 1); the within household change in levels(column 2), and the average square-meter price in a given municipality (column 3). Column 4 is identical to column 3 but excludes Copenhagen and Aarhus. Household controls include lagged housing wealth, age of oldest household member, age squared, annual household income (logs) and income change from previous year, family size, and number of children. Standard errors in parentheses are clustered at the municipality level. *** p<0.01, ** p<0.05, *p<0.1.

These estimates appear sufficiently strong and robust to be used as instruments for the development in local house prices and therefore to study the effects of house price developments on individual-level outcomes.

The second-stage equation is expressed as follows:

$$\Delta Y_{imt} = \beta_0 + \beta_1 \widehat{HP_{imt}} + \beta_2 \Theta_{it} + \varphi_m + \gamma_t + \varepsilon_{imt} \quad (2)$$

Where ΔY_{imt} is the outcome variable for household i living in municipality m at year t. This outcome variable will be expressed alternatively as the binary choice to extract home equity (defined as the decision to increase the mortgage balance by at least 20,000 DKK); or as the increase in the outstanding mortgage amount conditional on a positive home-equity extraction decision; or as annual household expenditure. The other control variables are identical to equation (1) and include a wide set of household-level controls, including income, change in income and past value of the household's home. Municipality and time-fixed effects, φ_m and γ_t, assimilate equation (2) to a staggered difference-in-differences approach, in which we are comparing outcomes for households living in the same municipality and that share the same characteristics Θ_{it}, over time. The exclusion restriction only requires the interaction between ex-ante migrant shares and current flows to be exogenous; the main effects allowed to influence the second stage eoutcomes directly.

4 House prices, home-equity extraction and expenditure

This section describes how house price developments affect home-equity extraction decisions. Our first result is that house price growth significantly increase the probability of home-equity extraction by mortgage borrowing. In table 2 (Panel A) the reduced-form equation shows a strong positive correlation between the OPI instrument and the probability of home-equity extraction (column 1); and both the OLS and IV estimates indicate that the probability of extracting home equity is increasing with house price growth (columns 1 and 2 respectively). Given a positive home-equity extraction decision, a 1 percent increase in local house prices is correlated with an increase in the mortgage balance worth 0.09 percentage points (Panel B, column 2); the coefficient rises to 0.21 percentage points once house prices are instrumented with the OPI measure (column 3). This coefficient has economic significance, representing 10% of a standard deviation in the dependent variable. Given that the average ex-ante outstanding mortgage balance for households who decide to cash-out home equity is roughly 1.3 M. DKK over this time frame, a back-of-the-envelope calculation suggests that a 1 percent increase in municipality-level house prices yields an additional 2,700 DKK (0.002 *1.3 mln) , or 400 USD on average in home-equity extraction per extraction occurrence.

The choice of home-equity extraction is likely to differ substantially among households. If households are credit constrained, the increase in housing wealth relaxes limitations to borrowing and spending activity. In this case ex-ante highly leveraged households are likely to respond more to a positive development in house prices and increase their mortgage balances more than households with similar characteristics and exposed to the same house price development, but subject to a borrowing constraint that is less binding. If wealth effects are instead predominant, the change in house prices should similarly affect households with similar income and demographic characteristics, since the borrowing and spending response to a housing wealth

Table 2: Baseline model of equity extraction

Panel A	(1) Extraction Reduced Form	(2) Extraction Linear	(3) Extraction IV	(4) Avg.Sqm(log) First Stage
OPI	0.151***			0.198***
	(0.016)			(0.031)
Avg.Sqm(log)		0.463***	0.792***	
		(0.051)	(0.054)	
Municipality and year FE	Yes	Yes	Yes	Yes
Household controls	Yes	Yes	Yes	Yes
F-Stat			42.345	
Observations	7,590,523	7,583,991	7,583,991	7,583,991
Panel B	**(1) Cash-Out Reduced Form**	**(2) Cash-Out OLS**	**(3) Cash-Out 2SLS**	**(4) Avg.Sqm(log) First Stage**
OPI	0.030***			0.139***
	(0.004)			(0.017)
Avg.Sqm(log)		0.085***	0.214***	
		(0.017)	(0.049)	
Municipality and year FE	Yes	Yes	Yes	Yes
Household controls	Yes	Yes	Yes	Yes
F-Stat			69.109	
Observations	369,179	368,886	368,886	368,886
R-squared	0.022	0.023	0.021	0.985

Source: Elaboration on microdata from Statistics Denmark, registries REAL, IND, FAM, BEF, 2009-2016. *Notes*: In the top panel the dependent variable is a binary value defining the probability of extraction. It takes value 1 if for a given household in a given year there is a new mortgage issuance and the outstanding mortgage balance increases by at least 20,000 DKK. In the bottom panel, the dependent variable is the percentage points change in mortgage debt outstanding from the previous year, conditional on a home-equity extraction decision (extraction=1). Household controls include lagged housing wealth, age of oldest household member, age squared, annual household income (logs) and income change from previous year, family size, and number of children. Standard errors in parentheses are clustered at the municipality level. *** p<0.01, ** p<0.05, *p<0.1.

channel depends largely on marginal propensity to consume out of wealth, rather than on ex-ante leverage ratios.

To discriminate between these two channels, Table 3 analyses how home-equity extraction decisions depend on the ex-ante loan-to-value (LTV) and loan-to-income (LTI) ratios of households.[5] Households with relatively low loan-to-income ratios (LTI lower than 4) are overall more likely to increase mortgage borrowing, but less likely to extract home equity in response

[5]Our definitions of LTV and LTI ratios include only total mortgage balances at the end of the year, and exclude other forms of debt.

to a positive development in house prices (column 1, Panel A). On the other hand, ex-ante loan-to-value ratios do not seem to have an effect on the extraction decision, and borrowers at different levels of LTV ratios react similarly to changes in house prices (column 2, panel A). On the other hand, the analysis on amounts extracted (Panel B, Table 3) suggests that collateral constraints work on both leverage dimensions. Homeowners with low LTV ratios are likely to extract 0.04 percentage points mortgage debt less than those with high LTV ratios who have similar characteristics and experience the same 1 per cent increase in house prices (column 2); a similar magnitude and direction of response is associated to home-equity extractors with low LTI ratios.

The choice of these particular thresholds of leverage ratios depends on some institutional and regulatory features of the Danish mortgage markets. Homeowners are allowed to finance home purchases with debt that takes the form of collateralised mortgage debt for up to 80 percent of the property value: the remaining amount needs to be financed through a down payment or using a more expensive bank loan. It is furthermore customary for banks to require the overall leverage not to exceed four times the annual household gross income. People at different values of these measures are likely to experience different degrees of limitation in their borrowing capacity. While the loan-to-income limit is a soft constraint, the loan-to-value limitation at 80 percent of the property value is mandated through the Danish mortgage institutions, which are the ultimate issuers of mortgage bonds. Therefore, it might seem surprising that households with LTVs that exceeds the 80 percent threshold are able to extract homeequity at all. However, our measure of leverage is measured ex ante in the year before the home-equity extraction takes places. Banks are likely to re-evaluate the property at the time of the mortgage request, which in a time frame of rising house prices (2010-2016) can easily lead to a substantial decline in LTVs with respect to what we observe in the administrative data: such discrepancies are unlikely to appear in the registry data if not with a significant lag. Furthermore, as Greenspan and Kennedy (2008) point out, a lot of home-equity extractions are requested to carry out home improvements, leading to an expected rise in property values and therefore to lower real LTV ratios than those observed in the data.

Table 4 exploits further household-level heterogeneity to observe whether there are any discontinuities in mortgage borrowing across more granularly defined LTI and LTV bins. Consistently with the evidence presented in Table 3, the borrowing response to house price changes is increasing in LTI ratios; however, this increase hits a limit at the point to which the existing debt outstanding reaches 5 times the annual household income (column 1). After this point, there is no additional response to changing house prices, possibly suggesting some restrictions in credit supply for borrowers that are more likely to face issues in servicing their debt.

Conditional on a positive home-equity extraction decision, borrowing as a response to house price changes increases almost linearly in loan-to-value ratios: borrowers with loan-to-value

Table 3: Equity extraction interacted with leverage categories

	(1)	(2)
	Extraction	Extraction
Panel A	IV probit	IV probit
Avg.Sqm(log)	0.927***	0.776***
	(0.065)	(0.064)
Avg.Sqm(log) × Low LTI	-0.159***	
	(0.019)	
Low LTI	1.417***	
	(0.194)	
Avg.Sqm(log) × Low LTV		0.017
		(0.022)
Low LTV		-0.142
		(0.204)
Municipality and year FE	Yes	Yes
Household controls	Yes	Yes
F Stat	24.31	24.36
Observations	7,583,991	7,583,991
	Cash-Out	Cash-Out
Panel B	2SLS	2SLS
Avg.Sqm(log)	0.231***	0.154***
	(0.043)	(0.042)
Avg.Sqm(log) × Low LTI	-0.029***	
	(0.006)	
Low LTI	0.384***	
	(0.062)	
Avg.Sqm(log) × Low LTV		-0.035***
		(0.004)
Low LTV		0.483***
		(0.040)
Municipality and year FE	Yes	Yes
Household controls	Yes	Yes
F Stat	46.1	45.2
Observations	368,886	368,886
R-squared	0.031	0.121

Source: Elaboration on microdata from Statistics Denmark, registries REAL, IND, FAM, BEF, 2009-2016. *Notes*: In panel A, the dependent variable is a dummy defining the probability of extraction. It takes value 1 if for a given household in a given year there is a new mortgage issuance and the outstanding mortgage balance increases by at least 20,000 DKK. In panel B, the dependent variable is the percentage points change in mortgage debt outstanding from the previous year, conditional on a positive home-equity extraction decision (extraction=1). Household controls include lagged housing wealth, age of oldest household member, age squared, annual household income (logs) and income change from previous year, family size, and number of children. Low loan-to-value (LTV<0.8) and loan-to-income (LTI<4) ratios are defined at the household level in the year prior to the extraction decision. Standard errors in parentheses are clustered at the municipality level. *** p<0.01, ** p<0.05, *p<0.1.

ratios between 0.8 and the unit react to a 1 percent increase in house prices by extracting almost 60 percent more than borrowers with LTVs lower than 0.4 (column 2). The effect of house prices is even stronger for borrowers who have more leverage than housing equity: those with LTVs

higher than unit borrow 65 percent more given the same change in house prices than borrowers with LTVs lower than 0.4.

Table 4: Percentage extraction: leverage categories

VARIABLES	(1) Cash-Out	(2) Cash-Out
Avg.Sqm(log)	0.190***	0.101***
	(0.046)	(0.039)
Avg.Sqm(log) × 3<LTI<=4	0.029***	
	(0.006)	
Avg.Sqm(log) × 4<LTI<=5	0.037***	
	(0.004)	
Avg.Sqm(log) LTI>5	0.010	
	(0.011)	
Avg.Sqm(log) × 0.4<LTV<=0.6		0.008**
		(0.004)
Avg.Sqm(log) × 0.6<LTV<=0.8		0.032***
		(0.003)
Avg.Sqm(log) × 0.8<LTV<=1.0		0.058***
		(0.003)
Avg.Sqm(log) × LTV>1.0		0.065***
		(0.006)
Leverage bin FE	Yes	Yes
Municipality and year FE	Yes	Yes
Household controls	Yes	Yes
F Stat	23.12	23.36
Observations	368,705	368,787
R-squared	0.052	0.257

Source: Elaboration on microdata from Statistics Denmark, registries REAL, IND, FAM, BEF, 2009-2016. *Notes*: The dependent variable is the percentage points change in mortgage debt outstanding from the previous year, conditional on a positive home-equity extraction decision (extraction=1). Household controls include lagged housing wealth, age of oldest household member, age squared, annual household income (logs) and income change from previous year, family size, and number of children. Loan-to-value (LTV and loan-to-income (LTI) ratios are defined at the household level in the year prior to the extraction decision. Standard errors in parentheses are clustered at the municipality level. *** p<0.01, ** p<0.05, *p<0.1.

This evidence suggests that lenders constrain households strongly on the LTI margin, but they might be more lenient on households that are over-leveraged only in the loan-to-value dimension. In order to test which of the constraints is more binding for households, Table 5 studies how LTIs and LTVs interact. Column 1 studies the differential effects of house prices on households with high LTIs (greater than 4) but low LTVs (smaller than 0.8). These households increase leverage more in response to changes in house prices (column 1); the result is similar, but with a stronger magnitude, for households that have the opposite characteristics: high LTVs and low LTIs (column 2). The magnitude of this coefficient is almost twice as large as the one in

column 1, confirming that the LTV constraint is significantly "softer" than the LTI constraint, for a given house prices change. Finally, column 3 shows that households that are highly leveraged in both dimensions (LTV and LTI) display a similar home-equity extraction behavior to that of households that are only constrained on LTI, possibly suggesting that loan-to-income is the dimension in which consumers face real limitations in their access to credit. Given the LTVs are endogenous to home valuations at the time of mortgage issuance, this should not in itself be too surprising, as loan-to-value ratios will decline automatically as house prices rise. One possible implication is that limitations in mortgage lending focused on debt-to-income ratios might be more capable of stabilising the credit cycle than those purely focused on loan-to-value ratios, in which the stabilising capacity is endogenously weakened by rising house prices.

Table 5: Percentage extraction-interaction between lending constraints

	(1)	(2)	(3)
VARIABLES	Cash-Out	Cash-Out	Cash-Out
Avg.Sqm(log)	0.213***	0.136***	0.201***
	(0.049)	(0.047)	(0.048)
Avg.Sqm(log) × High LTI-low LTV	0.014**		
	(0.006)		
High LTI	-0.205***		
	(0.055)		
Avg.Sqm(log) × High LTV-Low LTI		0.033***	
		(0.004)	
High LTV		-0.467***	
		(0.035)	
Avg.Sqm(log) × High LTI-High LTV			0.017***
			(0.003)
High Leverage			-0.286***
			(0.028)
Municipality and year FE	Yes	Yes	Yes
Household controls	Yes	Yes	Yes
F Stat	45.7	45.3	40.1
Observations	368,886	368,886	368,886
R-squared	0.024	0.112	0.028

Source: Elaboration on microdata from Statistics Denmark, registries REAL, IND, FAM, BEF, 2009-2016. *Notes*: The dependent variable is the percentage points change in mortgage debt outstanding from the previous year, conditional on a positive home-equity extraction decision (extraction=1). Household controls include lagged housing wealth, age of oldest household member, age squared, annual household income (logs) and income change from previous year, family size, and number of children. High LTI is a dummy indicating a household with LTI above 4 and LTV below 0.8; High LTV indicates a household with low LTI (<4) but high LTV (>0.8). High leverage indicates households with LTI higher than 4 and LTV higher than 0.8. Loan-to-value (LTV and loan-to-income (LTI) ratios are defined at the household level in the year prior to the extraction decision. Standard errors in parentheses are clustered at the municipality level. *** p<0.01, ** p<0.05, *p<0.1.

The choice of mortgage typology allows a further test of the extent to which collateral

constraints are binding. For example IO mortgages are more likely to be chosen by credit-constrained households (Kuchler (2015); Larsen et al. (2018)); conditional on a choice of extracting home equity, if collateral effects are dominating, owners who have IO mortgages will extract more housing wealth than other homeowners, even if this implies a higher cash-flow spending in the future. This is indeed the case: column 1 of table 6 shows that borrowers with similar characteristics who decide to extract equity and choose IO mortgages increase their balances more than other borrowers, in response to changes in house prices. Fixed-rate mortgage borrowers, on the other hand, face higher costs given the same mortgage amount but are willing to do so possibly to lock-in the historically low interest rates affecting consumer-credit markets in this period, and are likely to be wealthier and less sensitive to house price changes, or less credit-constrained. This category indeed responds less than other households to changes in house prices (column 2), and no differential effect is visible among adjustable-rate mortgage borrowers (column 3). Overall, the evidence suggests that collateral constraints mediated the home-equity extraction decisions of Danish homeowners, during this time frame.

4.1 Expenditure and house prices

House prices can affect spending through two main channels: wealth and collateral effects. In the former, the increase in house prices generates a spending response that is simply a result of the rising value of one's portfolio, with a mechanism that is similar to that associated to the growth in income: people are richer, and expect to be so also in the future, therefore they spend more, in absolute terms. However, if collateral effects are the driving force, rising house prices simply lift the credit constraint associated with individuals. In this case, mortgage borrowing will be mediating the spending response to rising house prices.

In table 7 the dependent variable is the level change in annual imputed household expenditure. While there is no clear relationship between the level change in value of the households' housing stock from the year before and change in expenditure levels (column 1), instrumenting house price change with origin-push migration yields a positive and significant coefficient (column 2). Column 2 implies that for a 1 DKK increase in the value of household housing wealth, annual household expenditure increases by 0.065 DKK on average, a magnitude very close to that estimated by Aladangady (2017) who focuses on the US case in similar years.

This result might in principle be interpreted as suggesting that pure wealth effects are driving the expenditure response to changing house prices if extrapolated to the entire distribution of households. However, once we condition the expenditure response to a binary variable indicating whether a home-equity extraction decision has taken place for the household, the direct effect of house price change on expenditure turns insignificant (column 3). Rather than the change in home value it is the decision of home-equity extraction that drives the change in expenditure for homeowners, on average increasing it by 140,000 DKK within the same year

Table 6: Amount extracted conditional on mortgage typology

VARIABLES	(1) Cash-Out	(2) Cash-Out	(3) Cash-Out
	2SLS	2SLS	2SLS
Avg.Sqm(log)	0.219***	0.218***	0.195***
	(0.046)	(0.043)	(0.048)
Avg.Sqm(log) × IO	0.018***		
	(0.005)		
IO	-0.215***		
	(0.049)		
Avg.Sqm(log) × FRM		-0.013**	
		(0.005)	
FRM		0.100*	
		(0.051)	
Avg.Sqm(log) × ARM			0.003
			(0.002)
ARM			0.017
			(0.020)
Municipality and year FE	Yes	Yes	Yes
Household controls	Yes	Yes	Yes
Observations	368,886	368,886	368,886
R-squared	0.031	0.024	0.030

Source: Elaboration on microdata from Statistics Denmark, registries REAL, IND, FAM, BEF, 2009-2016. *Notes*: The dependent variable is the percentage points change in mortgage debt outstanding from the previous year, conditional on a positive home-equity extraction decision (extraction=1). Household controls include lagged housing wealth, age of oldest household member, age squared, annual household income (logs) and income change from previous year, family size, and number of children. IO, FRM and ARM are dummies indicating whether a household is borrowing on an interest-only, fixed rate or adjustable rate mortgage respectively. Standard errors in parentheses are clustered at the municipality level. *** p<0.01, ** p<0.05, *p<0.1.

(column 3). Conditional on a positive home-equity extraction decision, households convert into spending 0.31 DKK for each additional DKK extracted in home equity (column 4). The effect of housing wealth increase remains statistically insignificant. The magnitude of the consumption response rises to 0.38 if instead of controlling for the instrumented change in value of the household's property, we control for house price development using the municipality-based measure of house price growth over the year (column 5).

Using PSID data over the 1990s, Hurst and Stafford (2004) find that two-thirds of extracted home-equity amounts are spent among low-liquidity households, while there is no effect for households with high liquidity. Our estimated elasticity is somewhat lower than theirs, suggesting that Danish households might be spending these amounts over subsequent years, but also that they could be using home-equity extraction in mortgages to pay off other typologies of debt, such as bank or other personal loans. Danish mortgage institutions lend to home buyers

up to 80 percent of the property value, while the remaining amount needs to be financed either through a down payment or through a bank loan, which tends to have substantially higher interest rates. Using mortgage borrowing to pay down more expensive bank loans would be consistent with an attempt at deleveraging already documented among Danish consumers over this time frame (Hviid and Kuchler, 2017).

Table 7: Spending and House Prices

VARIABLES	(1) Δ Expend. OLS All	(2) Δ Expend. 2SLS All	(3) Δ Expend. 2SLS All	(4) Δ Expend. 2SLS Extract only	(5) Δ Expend. 2SLS Extract only
House price change	-0.025	0.065***	0.029	-0.102	
	(0.028)	(0.019)	(0.018)	(0.124)	
Extract			139,788.281***		
			(5,659.907)		
Extracted amount				0.305***	0.382***
				(0.018)	(0.054)
Avg.Sqm(log)					-50,297.93
					(44,127.47)
Municipality and year FE	Yes	Yes	Yes	Yes	Yes
Household controls	Yes	Yes	Yes	Yes	Yes
F Stat		52.65	52.41	37.9	64.73
Observations	7,546,007	7,546,007	7,546,007	395,202	398,323
R-squared	0.001	0.001	0.001	0.021	0.028

Source: Elaboration on microdata from Statistics Denmark, registries REAL, IND, FAM, BEF, 2009-2016. *Notes*: The dependent variable is the change in annual spending imputed at the household level from the previous year. Household controls include lagged housing wealth, age of oldest household member, age squared, annual household income (logs) and income change from previous year, family size, and number of children. House price change defines the change in house value from the year before (cols 1-4); Avg.Sqm(log) defines the average square-meter price at the municipality level. Extract is a dummy that takes value 1 if a household takes up a new mortgage and increases its mortgage balance by more than 20,000 DKK. Extracted amount defines the value in DKK in home-equity extraction within the same year, conditional on a positive home-equity extraction decision. Time and municipality-fixed effects are included. Standard errors in parentheses are clustered at the municipality level. *** $p<0.01$, ** $p<0.05$, *$p<0.1$.

Whenever home-equity extraction is used to finance expenditure, rather than to pay down existing debt, this usually takes the form of home improvements or durables spending (Greenspan and Kennedy, 2008). In absence of detailed information on the spending categories, we proxy for durables consumption using car purchases (Table 8), the only category of durables consumption that we observe in the administrative registries.

While house prices seem to have no effect on the probability of purchasing a new car in any given year, the decision to extract increases the probability to buy a new car significantly (column 1). Conditional on a positive home-equity extraction decision, the probability of purchasing a car is increasing in the amount extracted (column 2). For each additional DKK extracted of home equity, only 0.01 is spent on cars within the same year and 0.02 over a period

of two years (columns 3 and 4, respectively).

Overall, these estimates suggest that wealth effects alone cannot explain the co-movement between house prices and expenditure so widely documented in the literature. It appears that housing affects consumption predominantly through its role as collateral via home-equity-based borrowing, consistently with the empirical results presented across different institutional contexts by Cooper (2012) and Cloyne et al. (2017) more recently. Average home-equity extraction, conditional on positive extraction decision, is roughly 230,000 DKK per extraction occurrence over this time frame. A back-of-the-envelope calculation based on the coefficients presented in tables 7 and 8 suggests that these converts into an average change in household-level expenditure worth about 70,000 DKK per household/year (230k *0.3) of which 2,500 DKK on car purchases. These amounts suggest that a large fraction of home-equity extraction is used for purposes other than current expenditure.

Table 8: Car Purchase and House Prices

VARIABLES	(1) Buy car IV Probit	(2) Buy car IV Probit	(3) Car expenditure 2SLS	(4) Car expenditure - 2 year 2SLS
Avg.Sqm(log)	0.034	0.060*	7,475.077	11,696.118
	(0.028)	(0.033)	(13,142.034)	(50,467.221)
Extract	0.129***	0.085***		
	(0.003)	(0.005)		
Extracted amount		0.152***	0.010***	0.022***
		(0.001)	(0.002)	(0.006)
Observations	7,583,991	4,770,544	72,260	7,287
R-squared			0.059	0.117

Source: Elaboration on microdata from Statistics Denmark, registries REAL, BIL, IND, FAM, BEF, 2009-2016.
Notes: The dependent variable is the purchase of a new car (columns 1-2) or car expenditure (columns 3-4) as a change from the previous year. Household controls include lagged housing wealth, age of oldest household member, age squared, annual household income (logs) and income change from previous year, family size, and number of children. Extract is a dummy that takes value 1 if a household takes up a new mortgage and increases its mortgage balance by more than 20,000 DKK. Extracted amount defines the value in DKK in home-equity extraction within the same year, conditional on a positive home-equity extraction decision. Time and municipality fixed effects are included. Standard errors in parentheses are clustered at the municipality level. *** $p<0.01$, ** $p<0.05$, *$p<0.1$.

5 Conclusions

We study how house price developments affect home-equity extraction and expenditure of Danish households in recent years (2009-2016). We find that a 1 percent increase in local house prices increases home-equity extraction by 0.21 percentage points, conditional on a positive extraction decision. For each additional DKK of home-equity extraction, only 0.31 DKK are used

to finance current spending, and the direct effect of house prices, absent home-equity extraction, is null. Furthermore, credit-constrained consumers, particularly those with high loan-to-value ratios, increase home-equity extraction amounts significantly more than other households in response to a positive development in house prices, while the probability of home-equity extraction is unaffected. Our results suggest that house prices affect home equity extraction mainly through collateral effects, rather than through wealth effects, consistently with recent evidence on the UK and the US (Cloyne et al. (2017); Cooper (2012); Aladangady (2017)). The unique features of our data allow us to study all these developments at the household-level in a unified framework for the population of Danish homeowners, providing a useful intuition regarding the role that housing collateral plays in boom-bust cycles on real economic activity.

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DANMARKS NATIONALBANK
HAVNEGADE 5
DK-1093 COPENHAGEN K
WWW.NATIONALBANKEN.DK

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