Intratemporal Nonseparability between Housing and Nondurable Consumption: Evidence from Reinvestment in Housing Stock

Khorunzhina, Natalia

Copenhagen Business School

26 August 2018

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Natalia Khorunzhina[†]

Copenhagen Business School

February 4, 2020

Abstract

Using the data on maintenance expenditures and self-assessed house value, I separate the measure of individual housing stock and house prices, and use these data for testing whether nondurable consumption and housing are characterized by intratemporal nonseparability in households' preferences. I find evidence in favor of intratemporal dependence between total nondurable consumption and housing. My findings indicate the elasticity of intratemporal substitution between nondurable consumption and housing is higher than the elasticity of intertemporal substitution for composite consumption bundles. Moreover, assuming CES utility, my results are indicative about complementarity between nondurable consumption and housing in the intratemporal preferences.

JEL C51, D12, D13, E21, R21

Keywords: Intratemporal Nonseparability, Housing, Nondurable Consumption

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[*] Declarations of interest: none. This research did not receive any specific grant from funding agencies in the public, commercial, or non-profit sectors. I am grateful to Nils Gottfries and participants of the CESifo Conference on Macroeconomics and Survey Data for discussions and insightful comments. All errors are my own.

[†] Natalia Khorunzhina, Copenhagen Business School, Department of Economics, Porcelænshaven 16A, DK-2000 Frederiksberg, Denmark, phone: +45 3815 2403, email: nk.eco@cbs.dk.

1 Introduction

Nonseparability in preferences over nondurable consumption and housing is an important feature of many up-to-date consumption models with housing employed in economics and finance. In these models, the intratemporal tradeoff between durable and nondurable consumption and the strength of the intertemporal substitution is key to explaining a variety of important phenomena. Piazzesi et al. (2007) find the strength of the intratemporal elasticity of substitution is an important factor for predictability of excess stock returns, whereas the same modeling feature, to a large extent, allows Yogo (2006) to explain both the cross-sectional variation in expected stock returns and the time variation in the equity premium. Ogaki and Reinhart (1998) argue that accounting for the intratemporal substitution between nondurables and durables improves the estimates of the intertemporal elasticity of substitution. Subsequently, Flavin and Nakagawa (2008) rely on the limited intratemporal substitutability between housing and nondurable consumption in generating a low elasticity of intertemporal substitution to address the observed smoothness of nondurable consumption. Li et al. (2016) demonstrate that the intratemporal elasticity of substitution governs the impact of changes in house prices on household homeownership rates and nondurable consumption. These studies, however, offer little consensus about the strength of substitutability, ranging from the limited intratemporal substitutability between durable and nondurable consumption (Flavin and Nakagawa, 2008) to a rather flexible one (Piazzesi et al., 2007), which provides different implications about the relative importance between the intratemporal and intertemporal consumption tradeoffs.

In this paper, I test for the intratemporal nonseparability between nondurable consumption and housing in individual preferences. Without making assumptions about the functional form of the utility function, I formulate a consumption model, in which utility depends, probably nonseparably, on two goods: nondurable consumption and housing. Housing stock, from which households-homeowners derive utility, is not constant but is subject to depreciation and upkeep through maintenance and renovations. To investigate empirically the intratemporal dependence over homeowner choices of nondurable consumption and housing, I then exploit *within-household* variation in changes in the housing stock of homeowners who do not change their residence.

Residential housing stock is not constant over the length of the same homeownership and requires significant ongoing maintenance expenses. As measured based on the Panel Study of Income Dynamics (PSID), households spend, on average, around \$2,500 annually on improvement, maintenance, and repair expenditures, which constitutes about 1.6% of house value.[1] With the median maintenance expenditure of only \$600, the average cross-sectional and within-household variation in the maintenance effort is substantial, with the coefficient of variation being 252% and 108%, respectively. To the extent that homeowners expand, remodel, or fail to maintain their homes, fluctuations in both the quality and quantity of their housing stock can be nontrivial.

Although information on homeowners' maintenance effort is observed in various data sources, including the PSID used in this paper, testing whether consumption and housing are nonseparable in household utility is hindered by the inability to accurately observe individual housing stock and its variation over time. Even if a comprehensive set of home attributes is observed, these characteristics usually exhibit little variation or do not change over time. Lack of variation in observed housing characteristics makes it unsuitable for linking to individual variation in consumption. To gain information about variation in housing stock, I use the data on maintenance expenditures and self-assessed house value from the PSID to separate the measure of individual housing stock from house prices of that individual housing stock.[2] The average housing-stock growth index is somewhat under 1, suggesting that, on average, households' maintenance efforts do not fully offset gross depreciation of housing stock. At the same time, the imputed housing-stock growth varies reasonably over and within households, making it suitable for the analysis of the intratemporal dependence within consumption model. The average index of house-price growth, imputed from the PSID, is also measured with substantial variation. Both nationwide and across regions, it closely matches the level and the pattern of dynamics of the house-price indices, constructed by the U.S. Federal Housing Finance Agency, S&P Case-Shiller, and Zillow. These imputed individual housing-stock and house-price indices are used in estimation of the consumption model.

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[1] Gyourko and Tracy (2006) provide similar evidence from the American Housing Survey on the average annual maintenance and repair expenditures at \$2,051.

[2] The problem of separating price of housing per unit and the quality-adjusted amount of housing is also recognized and addressed in Combes et al. (2019).

Exploiting the structure of the consumption Euler equation, this study tests for and finds evidence of intratemporal nonseparability between total nondurable consumption and housing. This finding agrees with the literature that examines and provides evidence against additive separability in preferences over durable and nondurable consumption. Postulating a constant-elasticity-of-substitution (CES) utility function to represent intratemporal preferences over nondurable and durable consumption, intratemporal and intertemporal elasticities of substitution are estimated relying on different sources of variation in durable and nondurable consumption: Ogaki and Reinhart (1998), Pakoš (2011), Piazzesi et al. (2007), and Yogo (2006) exploit time-series variation in aggregated nondurable and durable consumption, Li et al. (2016) rely on cross-sectional variation in the households' house value and income, and Flavin and Nakagawa (2008) use household expenditure on food as a measure of nondurable consumption and discontinuous jumps in housing stock at the time of changing residence, while assuming constant housing stock until the household moves. Unlike these studies, I do not take a stand on the structure of preferences, which makes my findings robust to possible model misspecifications. Similar to Flavin and Nakagawa (2008) and Li et al. (2016), I use household data from the PSID in the test for the intratemporal nonseparability in preferences; however, I focus on the sample of homeowners who do not move and, unlike Flavin and Nakagawa (2008) and Li et al. (2016), rely on both between- and within-household variation in total nondurable consumption and housing stock. Therefore, my results complement and extend the findings of nonseparability between nondurable consumption and housing in those studies to the sample of homeowners who do not move. The economic significance of my findings is supported by the observation that the overwhelming majority of households are homeowners and only a small fraction of them moves at a time.[3] My findings are robust to proxying nondurable consumption with food expenditure, and indicate on some heterogeneity over time and householders' age, but not over education groups.

My results suggest the sign of the mixed partial derivative of the utility function is negative, indicating the marginal utility of nondurable consumption declines when housing consumption rises.

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[3] Detailed moving statistics for homeowners and renters from the PSID are reported in Bajari et al. (2013). In particular, these authors compute that the average homeowner moves about three times in life.

Under the assumption of power utility combined with the CES intraperiod utility from nondurable and durable consumption, this finding suggests the elasticity of intratemporal substitution between nondurable and durable consumption is higher than the elasticity of intertemporal substitution for composite consumption bundles. The implication is that intertemporal consumption smoothing is stronger and more important than intratemporal tradeoff between nondurable and durable consumption. Leading to countercyclical marginal utility, this property is central in the study of Yogo (2006) for reconciling the cross-sectional variation in expected stock returns and the time variation in the equity premium. This property, however, is maintained in most consumption models with housing, and in all above-mentioned studies that examine the structure of preferences over durable and nondurable consumption, with the exception of Flavin and Nakagawa (2008). There is much less consensus about the value of the intratemporal elasticity of substitution between nondurable and durable consumption in CES preferences. Although the value less than one is frequent in the surveyed literature (Flavin and Nakagawa, 2008; Li et al., 2016; Pakoš, 2011; Yogo, 2006 and the port-war sample estimate in Piazzesi et al., 2007), using the unit elasticity of intratemporal substitution between nondurable consumption and housing (e.g., Cocco, 2005; Yao and Zhang, 2005) and above (Ogaki and Reinhart, 1998, and the main parameterization in Piazzesi et al., 2007) is not uncommon. My estimation indicates the elasticity of intratemporal substitution is 0.67. Provided the intertemporal elasticity of substitution is usually low, my estimate is fully consistent with my other findings on nonseparability between nondurable consumption and housing, and the relative strength of the intertemporal consumption smoothing over the intratemporal one.

My findings also relate to a large literature that documents an empirical relationship between house-price changes and the households' consumption expenditure (see Aladangady, 2017; Browning et al., 2013; Campbell and Cocco, 2007; Cooper, 2013; Gan, 2010; Mian et al., 2013; Paiella and Pistaferri, 2017). An important channel for the relationship between house-price changes and consumption considered in these studies is the housing wealth effect, which suggests house-price appreciation may result in the perception of larger housing wealth and may lead to the increase of consumption expenditure by relaxing households' lifetime resource constraint. Other channels include the collateral borrowing channel, which, under house-price appreciation, relaxes the equity borrowing constraint for households who reached borrowing limits and allows for higher consumption-expenditure levels (DeFusco, 2017), and the channel of common factors that may simultaneously drive house prices and consumption (Attanasio et al., 2009). The intratemporal tradeoff between housing and nondurable consumption can give rise to yet another channel for the relationship between housing wealth and consumption. An increase in construction and maintenance costs may adversely affect the homeowners' demand for maintenance, and, as a result, the quality and quantity of housing stock, the housing wealth of homeowners, and through the intratemporal tradeoff, the consumption expenditure of households who are long in housing.

The remainder of the article is as follows. Section 2 sets up a theoretical model and develops the econometric model. Section 3 describes the data sample and presents a method of measuring unobserved housing stock from the data on maintenance expenditure and house value. Section 4 outlines the estimation strategy and presents the findings. Section 5 provides empirical evidence on the parameter of intratemporal substitution. Section 6 concludes. The further details on derivation of the econometric model and data-sample construction can be found in Online Appendices A-C.

2 Model

Consider households-homeowners who maximize a lifetime utility from consumption and housing:[4]

$$E_t \sum_{s=t}^{T} \beta^{s-t} U(C_s, H_s) \exp(\rho' z_s), \tag{1}$$

where E_t denotes expectation formed at time t, β is the time discount factor, $U(\cdot)$ is the per-period utility of consumption and housing, and $\exp(\rho' z_t)$ is the taste shifter, which may depend on demographic characteristics z_t. Households derive utility from consumption C_t, and, being homeowners, hold positive amounts of housing stock H_t (priced at P_t), which they manage. The

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[4] I maintain the assumption of preferences additively separable across time and states of the world. Recently, several studies employ more general Epstein and Zin (1991) preferences that provide the flexibility to disentangle the risk aversion from intertemporal substitution, a feature arguably important to better match the patterns in life-cycle housing decisions, wealth accumulation, and portfolio allocation (Fischer and Khorunzhina, 2019; Pelletier and Tunç, 2019).

size of the housing stock H_t is interpreted broadly as reflecting not only the physical size, but also its quality. The quantity and quality of housing stock is affected by the depreciation at the rate δ, and by the adjustments to housing stock m_t (also priced at P_t) due to maintenance, renovations, or home improvements:

$$H_t = (1-\delta)H_{t-1} + m_t. \tag{2}$$

Every period households receive income Y_t, consume C_t, and save B_t (or borrow if negative). If no trade of an existing home occurs, the flow of funds is given by

$$C_t + P_t m_t + B_t = Y_t + R_t B_{t-1}, \tag{3}$$

where R_t is the real interest rate in period t.[5]

Households choose consumption expenditure C_t and housing renovation and upkeep m_t optimally by maximizing (1) subject to (2)-(3). The household's problem implies the following consumption optimality condition:

$$U_C(C_t, H_t) = \beta E_t \left[R_{t+1} U_C(C_{t+1}, H_{t+1}) \exp(\rho' \Delta z_{t+1})\right], \tag{4}$$

where U_C is household marginal utility with respect to consumption. Under the assumption of rational expectations, equation (4) can be written as follows:

$$\beta R_{t+1} \frac{U_C(C_{t+1}, H_{t+1})}{U_C(C_t, H_t)} \exp(\rho' \Delta z_{t+1}) = 1 + e_{t+1},$$

where e_{t+1} is the expectation error. Assume marginal utilities U_C and U_H are continuously differentiable. Taking logs, and applying first-order Taylor-series expansion to $\ln U_C$, for household i I obtain the estimable Euler equation in log-linearized form:

$$\Delta c_{it+1} = \alpha_0 + \alpha_1 r_{t+1} + \alpha_2 \Delta h_{it+1} + \varrho \Delta z_{it+1} + \epsilon_{it+1}, \tag{5}$$

where r_{t+1} is the log real interest rate in period $t+1$, $\Delta c_{it+1} = \ln(C_{it+1}/C_{it})$, $\Delta h_{it+1} = \ln(H_{it+1}/H_{it})$,

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[5] The maintenance expenditure in the budget constraint could also be formulated to depend on housing stock (e.g., a house with a pool might be more expensive to maintain) without further affecting the consumption Euler equation.

and ϵ_{it+1} is the composite error term that includes the Taylor-series remainder and the expectation error (see Online Appendix A for more details).

Equation (5) allows us to test for intratemporal nonseparability between nondurable consumption and housing without specifying the structure of preferences for the goods that are separable under the null. Representing $-U_{CH}/U_{CC}$, the coefficient of interest α_2 in equation (5) can be informative about the intratemporal dependence between consumption and housing. Maintaining the standard assumption of $U_{CC} < 0$, the sign of α_2 corresponds to the sign of U_{CH}. Therefore, the coefficient α_2, statistically insignificantly different from zero, will be the evidence on additive separability between nondurable consumption and housing in contemporaneous utility ($U_{CH} = 0$).

Furthermore, the sign of the mixed partial derivative U_{CH} can be informative about substitutability or complementarity in the sense that nondurable consumption and housing are substitutes (complements) if an increase in housing stock decreases (increases) the marginal utility of nondurable consumption, such that $U_{CH} < 0$ ($U_{CH} > 0$).[6] In Flavin and Nakagawa (2008), who operate with this definition of complementarity, the sign of the mixed partial derivative of the utility function with respect to the two goods is an important factor determining how the transaction cost associated with trading homes affects the magnitude of the intertemporal elasticity of substitution of nondurable consumption.

Finally, consider the power utility function over a CES intraperiod utility from nondurable consumption and housing, which is the leading model in macroeconomic and finance applications with housing consumption:

$$U(C_t, H_t) = \frac{(C_t^{1-1/\varepsilon} + aH_t^{1-1/\varepsilon})^{\frac{1-1/\sigma}{1-1/\varepsilon}}}{1-1/\sigma}, \quad a > 0, \quad \varepsilon > 0, \quad \sigma > 0, \tag{6}$$

where ε governs the degree of intratemporal substitutability between nondurable consumption and housing, and σ is the intertemporal elasticity of substitution of the composite consumption bundles. The mixed partial derivative of the utility function captures both intratemporal and

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[6] This definition of complementarity, besides being not invariant to monotone transformations of the utility function (Hicks and Allen, 1934; Kannai, 1980), does not have to agree with other classifications of complementarity (see Samuelson, 1974, for an overview of the different complementarity concepts and interconnections between them).

intertemporal tradeoffs, and the sign of U_{CH} informs about the relative strength of these tradeoffs. The mixed partial derivative of the utility function (6) with respect to the two goods is negative when intertemporal consumption smoothing is more important than intratemporal smoothing ($\varepsilon > \sigma$). That is, households are more willing to substitute housing and nondurable consumption within a period than to substitute composite consumption bundles over different time periods (Piazzesi et al., 2007).

Before estimating equation (5), a number of issues need to be taken into consideration. One issue concerns the relevant data. Information on individual housing is usually observed in the form of the monetary value of a house and its physical characteristics. Reported house characteristics (number of rooms, area size in square meters, various housing features, such as patios, balconies, a private garden, etc.) are normally fixed, exhibit little variation over time, and therefore can hardly be used in measuring changes in housing stock. House value in monetary terms is a fusion of many elements, where major factors are the level of local real estate prices and the degree of upkeep implemented by the homeowner to defeat natural wear and tear, and perhaps to even improve the existent quality of housing stock. Equation (5) requires the measure of housing stock in both its quantity and quality; that is, housing stock must be singled out from the price per unit of housing stock, which equivalently influences the value of a house. I deal with this issue in the next section.

Another issue is related to the possible endogeneity problem in equation (5) from the simultaneous choice between a household's consumption and housing and from the Taylor-series approximation used to derive this equation. To deal with this issue, equation (5) is estimated using the instrumental variable (IV) technique. The choice of instruments is discussed in section 4.

3 Data

I construct the data on consumption expenditures, the measure of changes in housing stock, and house-price growth using biennial longitudinal survey observations of households in the US in the Panel Study of Income Dynamics. In particular, from the survey on the level of households, I take variables on household consumption, housing wealth, home repairs and maintenance, and demographic characteristics.

3.1 Expenditures

The PSID is a longitudinal survey that follows a nationally representative random sample of families and their extensions since 1968. Since its start, the survey routinely collects information about food expenditures. The set of categories on consumption expenditures expanded significantly in 1999 to include spending on healthcare, education and childcare, transportation, and utilities. With an addition of new spending information on clothing, trips, vacations, entertainment, and the expenditure on home repairs and maintenance in 2005, the PSID currently contains all essential consumption categories. I use data on all these consumption categories, namely, spending on food, clothing, transportation, utilities, trips and vacations, entertainment, healthcare, education, and childcare, and construct total non-housing consumption expenditure as a sum of them. Data on consumption spending are deflated using the consumer price index (CPI) from the CPI releases of the Bureau of Labor Statistics applicable for each spending category (see Online Appendix C).

Housing information includes data on the number of rooms in a dwelling, house value for homeowners, and spending on home repairs and maintenance. The PSID collects information on home repairs and maintenance by asking, "How much did you spend altogether on home repairs and maintenance, including materials plus any costs for hiring a professional?" Homeowners are also asked to provide an assessment of the present value of their house and the lot by giving the value of the home as if it would be sold at the time of survey. Monetary values of housing data are deflated using the CPI index (see Online Appendix C for details). All monetary values are in 2009 dollars.

Motivated by the availability of data on home repairs and maintenance, and a more comprehensive set of consumption categories, from the PSID at the household level, I extract the sample of data on homeownership and housing starting in 2003 and consumption expenditures starting in 2005 and covering biennial observations up to 2015.[7] Focusing on homeowners, the average homeownership

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[7] Nondurable consumption and maintenance expenditures at the household level are also available in the Consumer

rate in the PSID for this period is remarkably close to the 66.5% reported for these years by the US Census Bureau. The initial sample consists of the continued homeowners ages 22-65 who reside in the US during the time of the interview and do not change residence. I require that a household has non-missing observations over at least three consecutive periods, which imposes a substantial restriction on the initial sample and provides me with 8,009 observations on households starting from 2007. Following a common practice in the literature on estimation of consumption models, observations for which total nondurable consumption grows by more than 400% or falls by more than 75% are excluded, which results in further reduction of the sample by 44 observations. Next, observations for which the house reportedly lost more than two thirds of its value or more than doubled its value between consecutive periods, and the increase in house value was not supported by sizable maintenance expenditures, are dropped, which lowers the sample by 121 observations. Observations for which the home was virtually rebuilt, as measured by an unusually high level of maintenance expenditures, are also dropped, which results in omitting 88 observations. Finally, 12 observations for Alaska are not included because housing supply elasticity used in estimation cannot be computed for this state (Chetty et al., 2017).

Altogether, I obtain 7,744 observations on homeowners between 2007 and 2015. The consumption Euler equation holds for households who can freely borrow to finance consumption expenditure, and including homeowners who can potentially borrow against their home equity could be adequate to control for liquidity constraints (Runkle, 1991). Following Zeldes (1989) and the recent literature on estimation of consumption models using asset-based sample separation (Alan et al., 2009; Gayle and Khorunzhina, 2018), I also construct a restricted sample by excluding households who do not have a positive balance of financial liquidity (cash, stock, and bond holdings), which results in 6,378 observations for 2007-2015.[8] Finally, the debt-service ratio (DSR) of Johnson and Li (2010) has

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Expenditure Survey over a longer period of time, but at the finer, quarterly frequency. After being recorded for four consecutive quarters, households leave the sample and are replaced by new households. Therefore, one cannot construct lower-frequency (annual or biennial) changes in expenditure variables, as in the PSID. Using the PSID is also advantageous for comparing the findings with the related PSID-based studies on the relationship between nondurable consumption and housing, such as Flavin and Nakagawa (2008) and Li et al. (2016).

[8] Jappelli (1990) selects liquidity-unconstrained individuals, using direct information on borrowing constraints obtained from the Survey of Consumer Finances (SCF). Because the PSID does not provide direct indicators of credit constraints, Jappelli et al. (1998) combine information from the SCF and the PSID to asses the likelihood of a constraint

Table 1: Summary Statistics

	2005	2007	2009	2011	2013	2015
Consumption	37,054	37,846	35,537	34,419	34,341	36,730
Food	8,534	8,665	7,892	7,988	8,161	7,966
Clothing	2,112	2,080	1,787	1,821	1,600	1,700
Entertainment	1,174	1,233	1,206	1,125	1,109	1,083
Telecommunications	2,044	2,349	2,646	2,765	3,036	3,298
Utilities	3,269	2,933	3,070	3,146	2,935	2,952
Trips, vacations	2,232	2,566	2,495	2,531	2,537	2,596
Transportation	9,950	10,069	9,045	8,113	8,283	10,802
Education	3,103	3,047	2,573	2,387	2,324	2,227
Childcare	662	595	688	639	633	479
Healthcare	3,975	4,309	4,135	3,905	3,724	3,625
House value	276,241	288,350	247,366	237,279	224,669	214,302
Maintenance	2,795	2,927	2,464	2,428	2,216	2,270
Home size	7.1	7.1	7.0	6.9	6.9	6.8
Age	46.3	48.3	48.3	48.9	49.3	49.6
Years of education	13.8	13.8	14.0	14.1	14.2	14.1
Family size	3.1	3.0	3.0	3.0	3.0	2.9
Household income	85,290	87,430	88,343	81,578	84,729	85,524
Debt Service	20,179	19,505	18,963	21,167	17,109	18,373
Fin.liquidity	90,938	112,030	106,518	90,243	84,958	94,856
H_t/H_{t-1}	0.976	0.974	0.975	0.977	0.978	0.980
	(0.057)	(0.053)	(0.051)	(0.056)	(0.060)	(0.059)
P_t/P_{t-1}	1.168	1.101	0.932	0.989	1.000	1.045
	(0.286)	(0.257)	(0.224)	(0.228)	(0.219)	(0.240)
N homeowners	1,261	1,261	1,554	1,622	1,691	1,616
N with pos.liquidity	1,039	1,039	1,314	1,325	1,385	1,315
N with low DSR	1,053	1,053	1,296	1,354	1,427	1,326

NOTE: All monetary values are in 2009 dollars. Standard deviations are reported in parentheses for imputed data.

been shown to predict the likelihood of being denied credit and is increasingly used as a measure of credit constraints. I construct the ratio between debt-service payments and household income using information on mortgage payments, taxes, insurance payments on primary residences and other real estate, automobile loan and lease payments, and vehicle insurance payments. Following

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for households in the PSID. A subsequent study of Domeij and Flodèn (2006), however, finds the indicators of liquidity constraints built around the asset-based sample separation rule of Zeldes (1989) and direct information on borrowing constraints in Jappelli (1990) select to a large extent the same households.

Johnson and Li (2010), I remove households in the top quintile of DSR as constrained, which results in 6,455 observations on households with a low DSR for 2007-2015.

Table 1 presents summary statistics for the data sample. Transportation, food, and health care constitute the three largest consumption-expenditure categories, amounting to about 29%, 22%, and 11% of total consumption expenditures, respectively. Child care, entertainment, and clothing are the three smallest consumption-expenditure categories, amounting to less than 10% of total consumption expenditures, altogether. Expenditure on maintenance is sizable, amounting to 1.58% of house value. Financial contributions to improvements and maintenance are routine periodic expenditures for about 79% of households in the sample.

3.2 Housing-stock and house-price growth

Equation of interest (5) requires a measure of changes in a household's housing stock H_t/H_{t-1}, which, in general, is not observable to an econometrician. Instead, the observables include current and lagged house values (P_tH_t and $P_{t-1}H_{t-1}$) and the maintenance expenditure (P_tm_t). Knowing these quantities, using the law of motion for housing stock, given by equation (2), and maintaining an assumption that the renovation and maintenance expenditure P_tm_t fully goes into the value of the home, for household i I compute the quantities H_{it}/H_{it-1} and P_{it}/P_{it-1} in the following way:

$$\frac{H_{it}}{H_{it-1}} = \frac{H_{it}}{H_{it}-m_{it}}\cdot(1-\delta) = \frac{P_{it}H_{it}}{P_{it}H_{it}-P_{it}m_{it}}\cdot(1-\delta), \tag{7}$$

$$\frac{P_{it}}{P_{it-1}} = \frac{P_{it}}{P_{it-1}}\cdot\frac{H_{it}-m_{it}}{(1-\delta)H_{it-1}} = \frac{P_{it}H_{it}-P_{it}m_{it}}{P_{it-1}H_{it-1}}\cdot\frac{1}{(1-\delta)}. \tag{8}$$

In both equations, the second expression substitutes $(1-\delta)H_{t-1}=H_t-m_t$ from equation (2). Whereas computation of P_{it}/P_{it-1} in equation (8) relies on longitudinal data on house value, computation of housing-stock growth in equation (7) exploits only the cross-sectional dimension of the data on house value and maintenance expenditure. This way of recovering housing-stock growth can be useful in providing a dynamic element to some data sets limited within the cross-sectional dimension. Another important feature of computation of housing-stock growth and house-price growth from equations (7) and (8) is that the depreciation rate enters both equations in a multiplicative way, which limits its effect in estimations that exploit log-transformations of these variables.

Table 1 reports the average values of housing-stock growth and house-price growth, computed from equations (7) and (8), and their standard deviations. For exposition, I set the depreciation rate at 5.0%, which doubles the 2.5% depreciation rate found in Harding et al. (2007) to account for biennial frequency in the data. Also to account for biennial frequency, maintenance expenditures, reported in the survey for a year, are doubled. The average housing-stock growth index is somewhat under 1, suggesting that, on average, households' maintenance efforts do not fully offset gross depreciation of housing stock. This quality drift of residential housing stock is in agreement with housing literature documenting the depreciation rate *net of maintenance and repair expenditure* between 1% (as in Chinloy, 1979) and 2% (as in Harding et al., 2007) per year. The imputed measure of housing-stock growth also has a sizable standard deviation, which indicates the imputed index varies reasonably over households. The average within-household standard deviation of the housing-stock growth index is 0.03, a value of a similar magnitude to the cross-sectional standard deviation, reported in Table 1. The average index of house-price growth is also measured with substantial variation.

The house-price growth index imputed from the PSID is calculated based on the self-reported value of the house, priced by homeowners given the quantity and quality of their housing stock, and therefore may not be directly comparable to the house-price indices (HPIs) used in the literature. Nevertheless, the computed house-price growth from the PSID in Table 1 compares reasonably well to the established HPIs. I compare the imputed house-price growth index from the PSID with the weighted, repeat-sales HPI based on transactions involving single-family homes, constructed by the US Federal Housing Finance Agency (FHFA HPI), and with methodologically similar S&P Case-Shiller HPI. I also use the Zillow Home Value Index (Zillow HVI) for comparison, whose methodology differs from the two aforementioned HPIs, mainly because it does not rely on repeat sales. Instead, it utilizes the Z-estimate, an estimated value of a home based on its proprietary machine-learning algorithm. Zillow's Z-estimate uses multiple sources of data, including prior sales, county records, tax assessments, real estate listings, mortgage information, and geographic

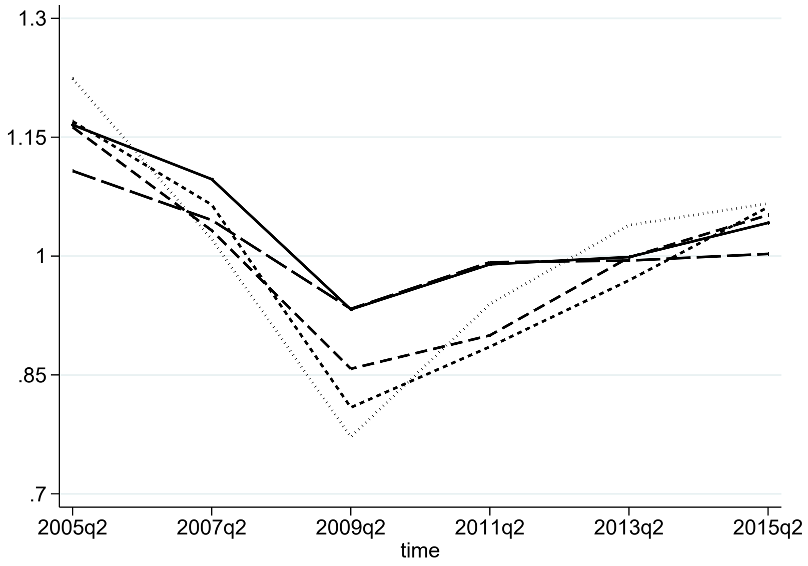

Figure 1: House-price indices. The solid line shows average house-price growth imputed from the PSID, the long-dashed line shows median house-price growth imputed from the PSID, the dotted line represents S&P Case-Shiller HPI, the dashed line represents FHFA HPI, and the short-dashed line corresponds to the Zillow index.

information-system data. Importantly, Zillow's website allows homeowners to view the entire history of Z-estimates and to report home improvements, which makes the Zillow HVI index relevant for comparison. The comparative analysis is presented in Figure 1. This figure reports the average and median house-price growth index imputed from the PSID, S&P Case-Shiller HPI, FHFA HPI, and Zillow HVI for the second quarter of the odd years between 2005 and 2015. During the sample years, the PSID is a biennial survey, in which the overwhelming majority of the interviews are conducted in the second quarter, which explains the choice of the second quarter for comparisons. S&P Case-Shiller HPI, FHFA HPI, and Zillow HVI are adjusted accordingly to show house-price growth for the second quarter of the year relative to the same quarter two years ago. The three well-known HPIs and the one constructed from the PSID paint the same qualitative picture during the observed period. The imputed house-price growth closely matches the level and the pattern of dynamics in house prices over the observed period. The lower volatility of the imputed house-price growth compared to the S&P Case-Shiller HPI, FHFA HPI, and Zillow HVI is consistent with the findings in Davis and Quintin (2017) that, whereby, on average, homeowners

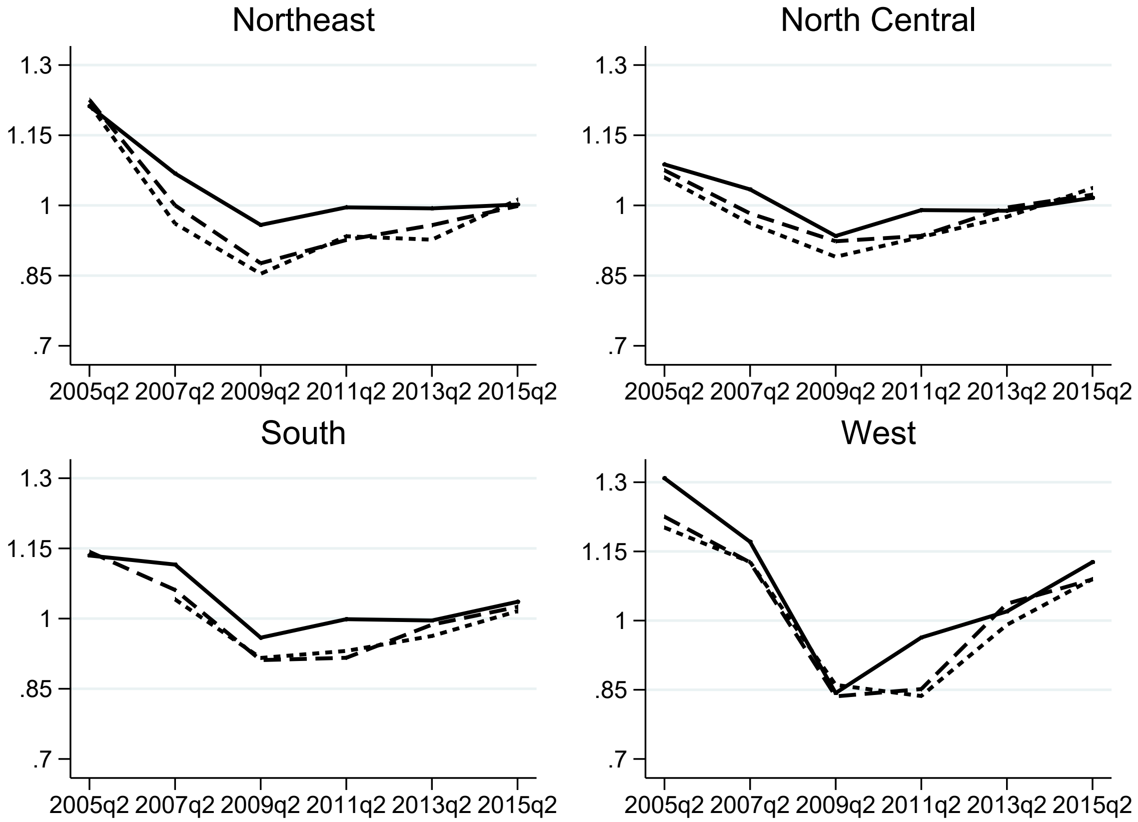

Figure 2: House-price indices over four regions. The solid line shows average house-price growth imputed from the PSID, the dashed line represents FHFA HPI, and the short-dashed line corresponds to the Zillow index.

tend to report accurate estimates of the current value of their home, during the boom and the bust households update the assessments of their homes gradually, such that self-assessed house prices do not decline as severely as house-price indexes during the bust.

Further analysis shows that similarities between indices' values are even stronger on a regional level. The PSID provides information about a state of residence, which I use in constructing a state and regional measure of the house-price growth index. I compare the imputed house-price growth index from the PSID to HPIs, available on a state level – FHFA HPI and Zillow HVI. Figure 2 shows the HPIs imputed from the PSID housing data, and the HPI's by the US Federal Housing Finance Agency and Zillow over four major regions: Northeast, North Central, South, and West (see Online Appendix C for the state composition of these regions). State comparisons can be found in Online

Appendix C, Figure C1. Overall, the house-price growth index, computed from equation (8), is remarkably close to the HPIs reported by Zillow and the US Federal Housing Finance Agency.

4 Estimation and empirical findings

When consumption and re-investment in housing are simultaneous choices, the choice to reinvest in housing stock may be directly affected by the consumption choice and correlated with the unobserved shocks that drive consumption. This possibility creates an endogeneity problem in simultaneous decision-making, and ordinary least-squares estimation of equation (5) could result in biased estimates. The remedy is to find instruments, such that they are not affected by nondurable consumption but are correlated with changes in housing stock and use an IV estimation technique for obtaining consistent estimates of the parameters in equation (5).

As argued in Harding et al. (2007), home attributes tend to be correlated with maintenance and therefore with the changes in housing stock. Indeed, in my data sample, the correlation between house size and level of maintenance expenditures is positive, significantly different from zero at the 1% significance level, and equal to 0.13. Also, home attributes have no natural role in the consumption-model specification (5). Even if home attributes could have affected the consumption level, the observed physical characteristics of the home are usually constant over time and therefore drop out of the model in first differences. Hence, the observed attributes of a home, such as house size, can be used as instruments for reinvestment in equation (5).

Household's optimization problem can be supplemented by one more restriction describing the optimal choice of reinvestment in housing stock. The resulting demand for housing stock, along with its dependance on consumption, also depends on house prices (equation (A4) in Online Appendix A). Homeowners manage their housing stock by implementing home improvements, taking prices as given exogenously. House prices have no natural role in the consumption model (see equations (A3)-(A4) in Online Appendix A), and being exogenous to nondurable consumption choice, house prices are relevant for explaining changes in housing stock, making a good instrument.

Housing-stock growth and house-price indices (both the imputed individual house-price index and the state-level FHFA HPI) are negatively correlated. For example, the correlation between housing-stock growth and the imputed house-price index in locality is -0.20 and significantly different from zero at the 1% significance level. The negative correlation between housing stock and house prices is in agreement with the restrictions of the demand theory, whereby home improvements are expected to react negatively to the increase in prices.[9]

Lastly, I use the housing supply elasticity measure of Saiz (2010), aggregated to the state level by Chetty et al. (2017), interacted with the real interest rate as an instrument (also used in Aladangady, 2017; Chaney et al., 2012).[10] Since the housing-stock growth is correlated with the local house-price growth, the intuition for using this instrument in the consumption model (5) is similar to the one in Aladangady (2017): changing interest rates affect the user cost of housing and shift housing demand, however its effect can be mitigated or intensified by local geography and land use regulations. This instrument is valid as long as consumption responses to interest-rate shocks do not vary systematically with the housing-supply shifters. Thus, the instruments include house size, the lagged imputed house-price index, which measures house prices specific to the locality of residence, the lagged locality-specific house-price index interacted with the state house-price index, and the housing supply elasticity interacted with the lagged real interest rate.[11]

To capture the utility taste shifter, in estimation of equation (5) I include a set of demographic variables, such as the level of education, change in age squared, and change in family size. Following Mazzocco (2007) and Meghir and Weber (1996), I also include conditioning variables of the change in a dummy if the husband works and the change in a similar dummy for the wife, to capture a possible nonseparability between modelled choices of consumption and housing, and the choice of leisure that is not formally modelled in this paper. Year dummies capture aggregate macroeconomic and financial shifters.

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[9] See empirical estimates of price elasticity of the demand for housing consumption in Rosen (1979), Hanushek and Quigley (1980), Goodman and Kawai (1986), and more recently in Goodman (2002) and Ioannides and Zabel (2003).

[10] State-level housing supply elasticity is available from the replication file for the study of Chetty et al. (2017). I am grateful to the anonymous referee for pointing out this data source.

[11] In a similar instrument construction Chetty et al. (2017) and Graham (2018) use housing supply elasticity interacted with house prices (national or regional). For the current study I found this instrument has insufficient power.

Table 2: Estimation results

	(1)	(2)	(3)
First stage			
House size	-0.00078^{*}	-0.00087^{**}	-0.00090^{*}
	(0.00044)	(0.00043)	(0.00046)
Lagged local house-price index	-0.00980^{***}	-0.00887^{***}	-0.00964^{***}
	(0.00217)	(0.00310)	(0.00205)
Lagged local house-price index interacted with lagged state house-price index	-0.03550^{**}	-0.03888^{*}	-0.03607^{*}
	(0.01675)	(0.02011)	(0.02015)
Lagged interest rate interacted with Saiz elasticity index	0.03925^{*}	0.04223^{**}	0.04645^{**}
	(0.02076)	(0.01827)	(0.01913)
Robust F-statistic	10.55	13.11	11.90
Second stage			
Δh_{it}	-2.12^{**}	-1.43^{*}	-2.21^{**}
Confidence set	[-4.67, -0.28]	[-2.84, 0.15]	[-4.55, -0.56]
Kleibergen-Paap rk LM statistic	14.34	14.87	14.86
p-value	0.006	0.005	0.005
Hansen J-statistic	3.46	4.58	2.22
p-value	0.33	0.21	0.53
Observations	7,744	6,378	6,455

NOTE: The first-stage results report coefficients; their standard errors are reported in parentheses, clustered by state level, and the Kleibergen-Paap Wald rk F-statistic, adjusted for clustering by state level. Significance levels: 1%***, 5%**, 10%*. The second-stage results report the CUE point coefficient estimates for the housing-stock growth. Weak-instrument-robust confidence sets in square brackets are based on a linear combination (LC) test of 5% K and AR statistics. Instruments include house size, lagged local house-price index computed as in equation (8), lagged local house-price index interacted with the lagged state house-price index, and the housing supply elasticity interacted with the real interest rate. All regressions include year dummies, change in a dummy if the husband works, change in a similar dummy for the wife, and demographic controls.

Table 2 reports the estimation results for homeowners (column(1)), homeowners with positive liquidity (column (2)), and homeowners with a low DSR (column (3)). The results from a first-stage regression of housing-stock growth, reported in Table 2, confirm a negative relationship between house prices and housing stock. According to the first-stage results, the estimated coefficients on lagged house-price growth in locality and the same interacted with the lagged house-price index in the state of residence are negative and statistically significant. The coefficients on house size are also negative, suggesting that after controlling for the house-price dynamics, smaller homes experience faster growth in housing stock. Provided that larger homes spend more on repairs and renovation and, per the American Housing Survey of the US Census Bureau, on average, maintain more adequate home quality than smaller homes, their housing stock may not grow as fast.

The F-statistics for the test of the hypothesis that the coefficients on the excluded instruments are zero, reported in Table 2, are between 10.6 and 13.1, which is arguably just outside of the problematic range (Staiger and Stock, 1997; Stock and Yogo, 2005). Nevertheless, the moderate values of the F-statistics can suggest the instruments may potentially be weak. In addition to the robust F-statistics, for each estimation, I report the robust-to-clustering Kleibergen-Paap rk LM test of underidentification and Hansen's J-test of overidentifying restrictions. The main parameter of interest is estimated with the GMM continuously updated estimator (CUE), following the evidence in Hahn et al. (2004) that the CUE estimator is more robust to the presence of weak instruments, and in that case, performs better than the IV or two-step GMM estimators. For all estimations, the Kleibergen–Paap underidentification test rejects the null hypotheses at the 95% level, suggesting the instruments are adequate to identify the equation. Furthermore, Hansen's J-statistic is far from rejection of the null that the overidentifying restrictions are valid, providing me with confidence that the instrument set is appropriate. Finally, for the estimated parameter of interest, I report a weak-instrument-robust confidence set, developed by Andrews (2016). The confidence set is based on a linear combination (LC) test of K-statistic (a score statistic based on the continuously updating GMM objective function as in Kleibergen, 2005) and S-statistic that is a Lagrange multiplier version of the Anderson–Rubin (AR) weak-instruments-robust test (Stock and Wright, 2000).

The presentation of the estimation results keeps the focus on the coefficient on housing-stock growth Δh_{it}, which tests whether an intratemporal nonseparability exists between nondurable consumption and housing stock. Estimation results in Table 2 show this coefficient is negative and statistically significant for all samples of homeowners. Overall, the estimation results reject separability in preferences over nondurable consumption and housing. The negative sign of the estimated coefficient provides information about the sign of the mixed partial derivative of the utility function and indicates the marginal utility of nondurable consumption declines when housing consumption rises. In the context of power intertemporal utility combined with the CES intratemporal utility, the negative sign on the mixed partial derivative U_{CH} indicates intertemporal consumption smoothing is more important than intratemporal smoothing ($\varepsilon>\sigma$ in equation (6)). This result agrees with empirical findings on the joint estimation of the parameters of intratemporal and intertemporal elasticity of substitution (Li et al., 2016; Ogaki and Reinhart, 1998; Pakoš, 2011; Yogo, 2006). It supports parameterizations of preferences in the life-cycle housing literature (e.g., the influential studies of Cocco, 2005; Yao and Zhang, 2005) and financial literature (Piazzesi et al., 2007).[12]

Because the results for the full sample of homeowners and the restricted subsamples in columns (2)-(3) of Table 2 do not differ substantially, the following set of estimations is conducted on the full sample of homeowners. I test whether an intratemporal dependence exists between separate categories of nondurable consumption and housing stock. This test is possible under the assumption that in the utility, distinct categories of consumption are additively separable but may be pairwise dependent on housing stock. I estimate 10 different models for distinct nondurable consumption categories and report the findings in Table 3. The results indicate the coefficient on housing-stock growth in regressions for most consumption categories is not precisely estimated. Consumption of food, trips and vacations, and utility services (gas, heating fuel, electricity, water and sewer, etc.) are notable exceptions. For these categories of nondurable consumption, the coefficients on housing-stock growth are negative and statistically different from zero at the 5% significance level for food consumption and the 10% one for vacations and utility services, and the magnitude of the estimated coefficients is similar to the ones estimated with total nondurable consumption in Table 2. The finding of nonseparability between housing stock and consumption of utility services is probably not surprising, because home improvements often target a more efficient usage of water and sewer, gas, heating fuel, and electricity. Until the relatively recent expansion of the consumption questionnaire, the PSID survey collected merely the information about food expenditure, which prompted many authors to use it as a proxy for nondurable consumption. Flavin and Nakagawa (2008) estimate

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[12] Because detecting the relative importance of the intratemporal and intertemporal tradeoffs through the sign of the mixed derivative of the utility does not allow me to capture the individual strengths of the intratemporal or intertemporal substitutions, my findings also agree with the unit elasticity of intratemporal substitution between nondurable consumption and housing (e.g., Davis and Ortalo-Magnè, 2011; Cocco, 2005; Yao and Zhang, 2005) and the limited intratemporal substitution between nondurable consumption and housing (such as the main result in Li et al., 2016, and the post-war sample estimate in Piazzesi et al., 2007, Table C1) as long as the intertemporal elasticity of substitution of the composite consumption bundles over different time periods is low.

Table 3: Estimation results for the distinct categories of nondurable consumption

	food (1)	health (2)	education (3)	child care (4)	clothing (5)	vacations (6)	transport (7)	tel./internet (8)	utilities (9)	vacations (10)
Δh_{it}	-1.87^{**}	1.21	-10.89	2.94	-1.22	-2.87^{*}	-0.99	-3.49	-2.04^{*}	0.49
	[-3.9,-0.6]	[-3.6,7.2]	[-27.8,18.6]	[-15.9,38.3]	[-5.1,1.9]	[-6.7,0.5]	[-6.7, 2.3]	[-9.2, 2.8]	[-4.3,0.1]	[-4.4,4.8]
First-stage robust F-test	10.54	11.65	3.42	4.24	9.98	17.50	10.38	10.19	11.05	13.83
rk LM test	14.34	14.31	9.04	8.94	13.58	16.80	14.19	14.02	14.60	16.30
p-value	0.006	0.006	0.060	0.062	0.009	0.002	0.006	0.007	0.005	0.003
J-test	5.77	2.45	0.19	0.95	1.87	2.58	1.21	4.45	1.13	1.41
p-value	0.12	0.48	0.98	0.81	0.60	0.46	0.75	0.22	0.77	0.70
Obs.	7,744	7,348	1,796	852	7,368	6,434	7,575	7,700	7,601	5,349

NOTE: The table reports the CUE point coefficient estimate for the housing-stock growth, weak-instrument-robust confidence sets in square brackets based on a linear combination (LC) test of 5% K and AR statistics, the Kleibergen-Paap Wald rk F-statistic, adjusted for clustering by state level, the Kleibergen-Paap rk LM test of underidentification, and Hansen's J-test of overidentifying restrictions. Significance levels: 5%**, 10%*. Instruments include house size, lagged local house-price index computed as in equation (8), the lagged local house-price index interacted with the lagged state house-price index, and the housing supply elasticity interacted with the real interest rate. All regressions include year dummies, change in a dummy if the husband works, change in a similar dummy for the wife, and demographic controls.

Table 4: Estimation results for heterogeneous effects over demographic and cyclical components

	Heterogeneous effects over:		
	age (1)	education (2)	cyclical component (3)
Δh_{it}	-3.05^{**}	-1.97^{*}	-2.96^{**}
	[-4.07,-0.02]	[-2.93,0.92]	[-7.24,-1.30]
Δh_{it}×Old	1.21^{**}		
	[0.70,2.21]		
Δh_{it}×College		0.26	
		[-0.17,0.69]	
Δh_{it}×Bust			2.42^{**}
			[1.91,3.34]
First-stage robust F-test	5.67	6.78	7.42
Kleibergen-Paap rk LM statistic	14.86	17.61	18.32
p-value	0.038	0.014	0.011
Hansen J-statistic	5.63	5.37	11.63
p-value	0.45	0.50	0.07
Observations	7,744	7,341	7,744

NOTE: The table reports the CUE point coefficient estimate for the housing-stock growth, weak-instrument-robust confidence sets in square brackets based on a linear combination (LC) test of 5% K and AR statistics, the Kleibergen-Paap Wald rk F-statistic, adjusted for clustering by state level, the Kleibergen-Paap rk LM test of underidentification, and Hansen's J-test of overidentifying restrictions. Significance levels: 5%**, 10%*. Instruments include house size, lagged local house-price index computed as in equation (8), lagged local house-price index interacted with the lagged state house-price index, and the housing supply elasticity interacted with the real interest rate. The instruments are accordingly interacted with the relevant dummies for age, education, and bust. All regressions include year dummies, change in a dummy if the husband works, change in a similar dummy for the wife, and demographic controls.

a model that nests intratemporal nonseparability between nondurable consumption and housing and a habit-formation component, formulating preferences using the power intertemporal utility and the CES intratemporal utility and using food-consumption data from the PSID. Unlike the findings in the literature cited above, and the results reported in this article, Flavin and Nakagawa (2008) find support for the positive mixed partial derivative of the utility, which, as argued in their study, in the presence of a transaction cost on housing, is needed for the empirically relevant limited responsiveness of nondurable consumption to the interest rate. Distinct to this study, the assumption on constant housing stock for households who do not move is a notable feature of the analysis in Flavin and Nakagawa (2008), which can possibly explain the differences in findings.

Finally, equation (5) is estimated, allowing for testing heterogeneous effects in the parameter of interest over age, education, and cyclical component. I divide the sample of homeowners by age groups and interact Δh_{it} with a dummy for households older than 45 (denoted as “Old” in Table 4). Next, I divide the sample between households with only a high school diploma and those with a college degree, and interact Δh_{it} with a dummy for households with a college degree (denoted as “College” in Table 4). Here, I dropped 403 observations for households with less than a high school education. Lastly, to explore the effect of the cyclical component, I construct a dummy variable for the period when house prices declined steeply as opposed to periods of non-declining house prices, and interact Δh_{it} with the bust dummy (denoted as “Bust” in Table 4). The instruments are interacted accordingly with the relevant dummies as well. The results suggest some heterogeneity is present in the estimates. The nonseparability between nondurable consumption and housing is largely present for both young and old households, although it is somewhat weaker for the old households. No decisive heterogeneity is detected over education groups. The results for the cyclical component reveal possible heterogeneity in nonseparability over time, and suggest separability between nondurable consumption and housing may not be rejected during the bust period. This finding, however, is based on only one episode of declining house prices, observed over the sample period, and calls for a further analysis of the factors behind it. It can be affected by the relative strength of the intratemporal and intertemporal consumption-smoothing motives; however, among other factors, it also is affected by the structure of preferences over households’ nondurable consumption and housing stock and by the growth rates in those consumption goods, which may also maneuver over business cycles.

5 Estimation of the Intratemporal Elasticity of Substitution

Postulating a CES utility function to represent intratemporal preferences over nondurable and durable consumption, Ogaki and Reinhart (1998), Pakoš (2011), Piazzesi et al. (2007), and Yogo (2006) pin down intratemporal elasticity of substitution using the cointegrating regression of Ogaki and Reinhart (1998). This approach is based on equating marginal rate of substitution between the

Table 5: GMM Estimation of Intratemporal Elasticity

	(1)	(2)	(3)
ε	0.67	0.78	3.97
	(0.14)	(0.22)	(0.29)
J-statistic	8.81	8.89	19.66
p-value	0.55	0.18	0.03

NOTE: Number of households 5,141, a reduced sample by one period due to lags and leads in estimation of equation (9). The instrument set for orthogonality conditions includes lagged (that is, $t-1$) local house-price index interacted with the housing supply elasticity index and the lagged state house-price index, lagged household income growth, lagged growth in hours worked by the husband and wife, and dummy variables for ranges of lagged growth in food consumption expenditure. Standard errors, clustered at the state level, are in parenthesis.

durable and nondurable consumption goods to the user cost of the service flow for the durable good via the intratemporal first-order condition. Whereas the exact estimation of the intratemporal first-order condition for the CES utility function in microdata framework of this study is challenging because of the variable construction, where housing stock and house prices are measured in growth indices, its approximation is possible. Under perfect foresight on aggregate quantities, the intratemporal first-order condition for the utility function, formulated in equation (6), can be represented as $a(H_t/C_t)^{-1/\varepsilon}=P_t\Phi_{t+1}$, where $\Phi_{t+1}=(1-(P_{t+1}/P_t)(1-\delta)/R_{t+1})$ (see Online Appendix B for details).[13] After taking logs and first differences, this expression for household i can be written as:

$$\Delta c_{it} - \Delta h_{it} = \varepsilon(\Delta p_{it} + \Delta\phi_{it+1}), \tag{9}$$

expressed in terms of the observable consumption growth, housing-stock growth, and local house-price index $\Delta p_{it}=\ln(P_{it}/P_{it-1})$, computed from equation (8). The term $\Delta\phi_{it+1}=\ln(\Phi_{it+1}/\Phi_{it})$ depends on the aggregate interest rate and house-price index local to homeowner i and conditional on housing depreciation rate δ. Equation (9) can be estimated using a minimum distance estimator.

The results are reported in Table 5. Column (1) reports the benchmark estimate of ε, column (2) shows the results after controlling for time fixed effects in equation (9), and column (3) shows the results on the specification omitting the term $\Delta\phi_{it+1}$ from equation (9). The benchmark estimate of the parameter of intratemporal substitution implied by the CES utility is 0.67, indicating that housing

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[13] Iacoviello (2004), Kiyotaki et al. (2011), Poterba (1984), Skinner (1989) among others allow for a similar treatment of the aggregate quantities in the models with housing.

and nondurable consumption are characterized by limited substitutability. A similar conclusion has been reached in the literature across various levels of data aggregation: for household data in Flavin and Nakagawa (2008) and Li et al. (2016), and for aggregated data in Pakoš (2011) and Yogo (2006). The magnitude of the estimated parameter is close to the values reported in Li et al. (2016), Yogo (2006) and the postwar sample estimate of Piazzesi et al. (2007), whereas Flavin and Nakagawa (2008) and Pakoš (2011) find substantially more limiting substitutability. The standard error by this estimate indicates that the utility function is not likely to be Cobb-Douglas, and ε is not likely to be above one. Whereas the estimate of the intertemporal elasticity of substitution σ for the utility (6) is rather low (as low as $0.02 - 0.04$ in Pakoš 2011; Yogo 2006, but up to 0.5 in Ogaki and Reinhart 1998) in studies in which ε and σ are estimated jointly, the value of 0.67 for the intratemporal substitution is greater than these values for σ. This is fully consistent with the findings in the previous section that intertemporal consumption smoothing is more important than intratemporal smoothing.

The conclusion about complementarity between nondurable consumption and housing in the intratemporal preferences holds when controlling for time fixed effects in column (2), although the estimate of ε increases to 0.78, and its standard error is also larger. Once the term $\Delta\phi_{it+1}$ capturing aggregate-quantity effects is dropped from equation (9), the estimate of ε becomes much larger than one, however, this modification results in a model misspecification as detected by the J-test.

6 Conclusion

I test for and find evidence of the intratemporal nonseparability between total nondurable consumption and housing. My results contribute to the relatively sparse literature investigating the structure of households' preferences over durable and nondurable consumption, and the importance of understanding the preferences over housing and nondurable consumption for academic research and economic policy warrants further research on this topic. For example, my findings are relevant for testing the housing wealth effect on consumption. Because I do not rule out intratemporal nonseparability between housing and consumption, the tests for other channels between housing prices and consumption expenditure (wealth effect, collateral channel, common factors) for homeowners may likely be hindered by the intratemporal tradeoff between housing and consumption. The results may also be relevant for the life-cycle literature that often relies on preferences over consumption and housing being additively separable. The evidence on nonseparability in preferences over consumption and housing, found in this paper, suggests that if economic-policy conclusions strongly rely on the assumption of additive separability over consumption and housing in an agent's preferences, then on the disaggregated level, these conclusions may be sensitive to the composition of the target group, in particular in relation to households who are long in housing.

References

Aladangady, A. 2017. Housing wealth and consumption: Evidence from geographically-linked microdata. American Economic Review, 107(11), 3415–3446.

Alan, S., Attanasio, O., and Browning, M. 2009. Estimating euler equations with noisy data: two exact gmm estimators. Journal of Applied Econometrics, 24(2), 309–324.

Andrews, I. 2016. Conditional linear combination tests for weakly identified models. Econometrica, 84(6), 2155–2182.

Attanasio, O. P., Blow, L., Hamilton, R., and Leicester, A. 2009. Booms and busts: Consumption, house prices and expectations. Economica, 76(301), 20–50.

Bajari, P., Chan, P., Krueger, D., and Miller, D. 2013. A dynamic model of housing demand: Estimation and policy implications. International Economic Review, 54(2), 409–442.

Browning, M., Gørtz, M., and Leth-Petersen, S. 2013. Housing Wealth and Consumption: A Micro Panel Study. The Economic Journal, 123(568), 401–428.

Campbell, J. Y. and Cocco, J. F. 2007. How do house prices affect consumption? Evidence from micro data. Journal of Monetary Economics, 54(3), 591–621.

Chaney, T., Sraer, D., and Thesmar, D. 2012. The collateral channel: How real estate shocks affect corporate investment. American Economic Review, 102(6), 2381–2409.

Chetty, R., Sàndor, L., and Szeidl, A. 2017. The effect of housing on portfolio choice. The Journal of Finance, 72(3), 1171–1212.

Chinloy, P. 1979. The estimation of net depreciation rates on housing. Journal of Urban Economics, 6(4), 432 – 443.

Cocco, J. F. 2005. Portfolio choice in the presence of housing. The Review of Financial Studies, 18(2), 535–567.

Combes, P.-P., Duranton, G., and Gobillon, L. 2019. The production function for housing: Evidence from France. Working paper.

Cooper, D. 2013. House price fluctuations: the role of housing wealth as borrowing collateral. Review of Economics and Statistics, 95(4), 1183 – 1197.

Davis, M. A. and Ortalo-Magnè, F. 2011. Household expenditures, wages, rents. Review of Economic Dynamics, 14(2), 248 – 261.

Davis, M. A. and Quintin, E. 2017. On the nature of self-assessed house prices. Real Estate Economics, 45(3), 628–649.

DeFusco, A. A. 2017. Homeowner borrowing and housing collateral: New evidence from expiring price controls. The Journal of Finance, 73(2), 523–573.

Domeij, D. and Flodèn, M. 2006. The labor-supply elasticity and borrowing constraints: Why estimates are biased. Review of Economic Dynamics, 9(2), 242 – 262.

Epstein, L. G. and Zin, S. E. 1991. Substitution, risk aversion, and the temporal behavior of consumption and asset returns: An empirical analysis. Journal of Political Economy, 99(2), 263–286.

Fischer, M. and Khorunzhina, N. 2019. Housing decision with divorce risk. International Economic Review, 60(3), 1263–1290.

Flavin, M. and Nakagawa, S. 2008. A model of housing in the presence of adjustment costs: A structural interpretation of habit persistence. American Economic Review, 98(1), 474–495.

Gan, J. 2010. Housing Wealth and Consumption Growth: Evidence from a Large Panel of Households. Review of Financial Studies, 23(6), 2229–2267.

Gayle, W.-R. and Khorunzhina, N. 2018. Micro-level estimation of optimal consumption choice with intertemporal nonseparability in preferences and measurement errors. Journal of Business & Economic Statistics, 36(2), 227–238.

Goodman, A. C. 2002. Estimating Equilibrium Housing Demand for “Stayers”. Journal of Urban Economics, 51(1), 1–24.

Goodman, A. C. and Kawai, M. 1986. Functional form, sample selection, and housing demand. Journal of Urban Economics, 20(2), 155–167.

Graham, J. 2018. House prices and consumption: A new instrumental variables approach. Working paper.

Gyourko, J. and Tracy, J. 2006. Using home maintenance and repairs to smooth variable earnings. Review of Economics and Statistics, 88(4), 736 – 747.

Hahn, J., Hausman, J., and Kuersteiner, G. 2004. Estimation with weak instruments: Accuracy of higher-order bias and MSE approximations. The Econometrics Journal, 7(1), 272–306.

Hanushek, E. A. and Quigley, J. M. 1980. What Is the Price Elasticity of Housing Demand? The Review of Economics and Statistics, 62(3), 449–54.

Harding, J. P., Rosenthal, S. S., and Sirmans, C. 2007. Depreciation of housing capital, maintenance, and house price inflation: Estimates from a repeat sales model. Journal of Urban Economics, 61(2), 193 – 217.

Hicks, J. R. and Allen, R. G. D. 1934. A reconsideration of the theory of value. Part I. Economica, 1(1), 52–76.

Iacoviello, M. 2004. Consumption, house prices and collateral constraints: a structural econometric estimation. Journal of Housing Economics, 13(4), 304–320.

Ioannides, Y. M. and Zabel, J. E. 2003. Neighbourhood effects and housing demand. Journal of Applied Econometrics, 18(5), 563–584.

Jappelli, T. 1990. Who is credit constrained in the U.S. economy? The Quarterly Journal of Economics, 105(1), 219–234.

Jappelli, T., Pischke, J.-S., and Souleles, N. S. 1998. Testing for liquidity constraints in euler equations with complementary data sources. The Review of Economics and Statistics, 80(2), 251–262.

Johnson, K. W. and Li, G. 2010. The debt-payment-to-income ratio as an indicator of borrowing constraints: Evidence from two household surveys. Journal of Money, Credit and Banking, 42(7), 1373–1390.

Kannai, Y. 1980. The alep definition of complementarity and least concave utility functions. Journal of Economic Theory, 22(1), 115 – 117.

Kiyotaki, N., Michaelides, A., and Nikolov, K. 2011. Winners and losers in housing markets. Journal of Money, Credit and Banking, 43(2-3), 255–296.

Kleibergen, F. 2005. Testing parameters in gmm without assuming that they are identified. Econometrica, 73(4), 1103–1123.

Li, W., Liu, H., Yang, F., and Yao, R. 2016. Housing over time and over the life cycle: a structural estimation. International Economic Review, 57(4), 1237 – 1260.

Mazzocco, M. 2007. Household intertemporal behaviour: A collective characterization and a test of commitment. The Review of Economic Studies, 74(3), 857–895.

Meghir, C. and Weber, G. 1996. Intertemporal nonseparability or borrowing restrictions? A disaggregate analysis using a U.S. consumption panel. Econometrica, 64(5), 1151–1181.

Mian, A., Rao, K., and Sufi, A. 2013. Household Balance Sheets, Consumption, and the Economic Slump. The Quarterly Journal of Economics, 128(4), 1687–1726.

Ogaki, M. and Reinhart, C. M. 1998. Measuring intertemporal substitution: The role of durable goods. Journal of Political Economy, 106(5), 1078–1098.

Paiella, M. and Pistaferri, L. 2017. Decomposing the wealth effect on consumption. The Review of Economics and Statistics, 99(4), 710–721.

Pakoš, M. 2011. Estimating intertemporal and intratemporal substitutions when both income and substitution effects are present: The role of durable goods. Journal of Business & Economic Statistics, 29(3), 439–454.

Pelletier, D. and Tunç, C. 2019. Endogenous life-cycle housing investment and portfolio allocation. Journal of Money, Credit and Banking, 51(4), 991–1019.

Piazzesi, M., Schneider, M., and Tuzel, S. 2007. Housing, consumption and asset pricing. Journal of Financial Economics, 83(3), 531–569.

Poterba, J. M. 1984. Tax Subsidies to Owner-Occupied Housing: An Asset-Market Approach. The Quarterly Journal of Economics, 99(4), 729–752.

Rosen, H. S. 1979. Owner occupied housing and the federal income tax: Estimates and simulations. Journal of Urban Economics, 6(2), 247–266.

Runkle, D. E. 1991. Liquidity constraints and the permanent-income hypothesis: Evidence from panel data. Journal of Monetary Economics, 27(1), 73 – 98.

Saiz, A. 2010. The geographic determinants of housing supply. The Quarterly Journal of Economics, 125(3), 1253–1296.

Samuelson, P. A. 1974. Complementarity: An essay on the 40th anniversary of the hicks-allen revolution in demand theory. Journal of Economic Literature, 12(4), 1255–1289.

Skinner, J. 1989. Housing wealth and aggregate saving. Regional Science and Urban Economics, 19(2), 305 – 324.

Staiger, D. and Stock, J. H. 1997. Instrumental variables regression with weak instruments. Econometrica, 65(3), 557–586.

Stock, J. and Yogo, M. 2005. Testing for weak instruments in linear IV regression. In: Andrews, D. W. (Editor), Identification and Inference for Econometric Models. Cambridge University Press, New York.

Stock, J. H. and Wright, J. H. 2000. GMM with weak identification. Econometrica, 68(5), 1055–1096.

Yao, R. and Zhang, H. H. 2005. Optimal consumption and portfolio choices with risky housing and borrowing constraints. Review of Financial Studies, 18(1), 197–239.

Yogo, M. 2006. A consumption-based explanation of expected stock returns. The Journal of Finance, 61(2), 539–580.

Zeldes, S. P. 1989. Consumption and liquidity constraints: An empirical investigation. Journal of Political Economy, 97(2), 305–346.

Intratemporal Nonseparability between Housing and Nondurable Consumption: Evidence from Reinvestment in Housing Stock
– Supplementary Online Appendix –

Natalia Khorunzhina*

Copenhagen Business School

A Log-linearized Euler equations

Denote $\bar{C}$ and $\bar{H}$ as the expected values of nondurable consumption and housing stock. Let $\hat{C} = \ln(C/\bar{C})$ and $\hat{H} = \ln(H/\bar{H})$. The subsequent derivations closely follow Mazzocco (2007).

Let φ_1 and φ_2 be defined as follows:

$$\varphi_1(\hat{C},\hat{H}) = \ln\left\{U_C(\exp\{\hat{C}\}E[C],\exp\{\hat{H}\}E[H]\right\},$$

$$\varphi_2(\hat{C},\hat{H}) = \ln\left\{U_H(\exp\{\hat{C}\}E[C],\exp\{\hat{H}\}E[H]\right\},$$

where U_C and U_H are household marginal utilities with respect to consumption and housing. Assume marginal utilities U_C and U_H are continuously differentiable. Let the one-variable functions $\vartheta_1 : I_1 \to \mathbb{R}$ and $\vartheta_2 : I_2 \to \mathbb{R}$ be defined as $\vartheta_1(k) = \varphi_1(k\hat{C},k\hat{H})$ and $\vartheta_2(k) = \varphi_2(k\hat{C},k\hat{H})$, where $I_1 = (-a,a)$ and $I_2 = (-b,b)$. Applying the one-variable Taylor expansion formula with remainder, I get

$$\vartheta_i(k) = \vartheta_i(0) + \vartheta_i^{'}(0)k + r_i(k) \qquad \text{for} \quad i = 1,2 \tag{A1}$$

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*Natalia Khorunzhina, Copenhagen Business School, Department of Economics, Porcelænshaven 16A, DK-2000 Frederiksberg, Denmark, phone: +45 3815 2403, email: nk.eco@cbs.dk.

with

$$r_i(k) = \int_0^k (k-t)\vartheta_i^{''}(t)dt.$$

From (A1) and the definition of $\vartheta_i(k)$ with $k = 1$, I get

$$\varphi_i(\hat{C},\hat{H}) = \varphi_i(0) + \frac{\partial\varphi_i(0)}{\partial\hat{C}}\hat{C} + \frac{\partial\varphi_i(0)}{\partial\hat{H}}\hat{H} + R_i(\hat{C},\hat{H}) \qquad \text{for} \quad i = 1,2. \tag{A2}$$

Under the assumption of rational expectations, the households' Euler equations can be written as

$$\begin{aligned} \beta R_{t+1}\frac{U_C(C_{t+1},H_{t+1})}{U_C(C_t,H_t)}\exp(\rho'\Delta z_{t+1}) &= 1 + e^C_{t+1}, \\ \beta R_{t+1}\frac{P_t}{P_{t+1}}\frac{U_H(C_{t+1},H_{t+1})}{U_H(C_t,H_t)}\exp(\rho'\Delta z_{t+1}) &= 1 + e^H_{t+1}, \end{aligned}$$

where e^C_{t+1} and e^H_{t+1} are the expectation errors. Taking logs, using $\varphi_1 = \ln U_C$ and $\varphi_2 = \ln U_H$, I have

$$\begin{aligned} \varphi_1(\hat{C}_{t+1},\hat{H}_{t+1}) - \varphi_1(\hat{C}_t,\hat{H}_t) &= -\ln\beta - \ln R_{t+1} - \rho\Delta z_{t+1} + \ln(1+e^C_{t+1}), \\ \varphi_2(\hat{C}_{t+1},\hat{H}_{t+1}) - \varphi_2(\hat{C}_t,\hat{H}_t) &= -\ln\beta - \ln R_{t+1} - \rho\Delta z_{t+1} + \ln(P_{t+1}/P_t) + \ln(1+e^H_{t+1}). \end{aligned}$$

By definition of $\varphi_i(\hat{C},\hat{H})$, I have $\partial\varphi_1/\partial\hat{C} = U_{CC}/U_C$, $\partial\varphi_1/\partial\hat{H} = U_{CH}/U_C$, $\partial\varphi_2/\partial\hat{C} = U_{HC}/U_H$, and $\partial\varphi_2/\partial\hat{H} = U_{HH}/U_H$. Then from (A2),

$$\frac{U_{CC}}{U_C}\ln\frac{C_{t+1}}{C_t} + \frac{U_{CH}}{U_C}\ln\frac{H_{t+1}}{H_t} = -\ln\beta - \ln R_{t+1} - \rho\Delta z_{t+1} - \Delta R_1 + \ln(1+e^C_{t+1}), \tag{A3}$$

$$\frac{U_{HC}}{U_H}\ln\frac{C_{t+1}}{C_t} + \frac{U_{HH}}{U_H}\ln\frac{H_{t+1}}{H_t} = -\ln\beta - \ln R_{t+1} + \ln\frac{P_{t+1}}{P_t} - \rho\Delta z_{t+1} - \Delta R_2 + \ln(1+e^H_{t+1}), \tag{A4}$$

where ΔR_i for $i = 1,2$ is the Taylor-series remainder. Equation (5) follows from rearranging equation (A3) and writing the resulting equation one period back.

B Framework for the Estimation of the Intratemporal Elasticity of Substitution

Consider households who choose consumption expenditure C_t, savings B_t, housing renovation m_t and housing stock H_t optimally by maximizing (1) subject to (2)-(3). The Lagrangian is:

$$\max_{C_t,B_t,m_t,H_t} \mathcal{L} = E_o\Big(\sum_{t=o}^{T} \beta^t \{U(C_t,H_t) - \mu_t(C_t + P_t m_t + B_t - Y_t - R_t B_{t-1}) - \lambda_t(H_t - (1-\delta)H_{t-1} - m_t)\}\Big) \tag{B1}$$

Solving the problem yields the following first-order conditions:

$$\frac{\partial \mathcal{L}}{\partial C_t} = 0 \Leftrightarrow U_C(C_t,H_t) = \mu_t, \tag{B2}$$

$$\frac{\partial \mathcal{L}}{\partial B_t} = 0 \Leftrightarrow \mu_t = \beta E_t R_{t+1} \mu_{t+1}, \tag{B3}$$

$$\frac{\partial \mathcal{L}}{\partial m_t} = 0 \Leftrightarrow \lambda_t = \mu_t P_t, \tag{B4}$$

$$\frac{\partial \mathcal{L}}{\partial H_t} = 0 \Leftrightarrow U_H(C_t,H_t) - \lambda_t + \beta(1-\delta)E_t \lambda_{t+1} = 0,. \tag{B5}$$

Assuming perfect foresight on aggregate quantities and using equations (B2)-(B4), equation (B5) can be transformed as:

$$\begin{aligned} & U_H - \mu_t P_t + \beta(1-\delta)P_{t+1} E_t \mu_{t+1} \\ = \; & U_H - \mu_t P_t + (1-\delta)\frac{P_{t+1}}{R_{t+1}}\mu_t \\ = \; & U_H - U_C P_t \left(1 - \frac{1-\delta}{R_{t+1}}\frac{P_{t+1}}{P_t}\right) = 0, \end{aligned} \tag{B6}$$

which can take a form of $U_H/U_C = P_t \Phi_{t+1}$, where $\Phi_{t+1} = (1 - (P_{t+1}/P_t)(1-\delta)/R_{t+1})$ captures housing depreciation and non-constant housing stock. Under the assumption of the CES intraperiod utility from nondurable consumption and housing, formulated in equation (6), (B6) can be represented as $a(H_t/C_t)^{-1/\varepsilon} = P_t \Phi_{t+1}$.

C Data Construction

C.1 Deflating

Consumption categories reported in the PSID include food, clothing, transportation, utilities, trips and vacations, entertainment, healthcare, education, and childcare. Deflating of the consumption expenditures and housing data is closely related to the timing of the relevant survey question. Some questions ask about expenditures in the month when the interview occurred, whereas others are asked about the previous year.

Food. Food-consumption expenditures include food consumed at home, away from home, delivered food, and the value of food stamps. Data on food consumed at home and the value of food stamps are deflated using the CPI for food at home. Data on food consumed away from home and delivered food are deflated using the CPI deflator for food away from home. Food-consumption data are deflated according to the month and year when the interview occurred, whereas data on food stamps and income are deflated using the CPI for the end of the year before the interview was conducted.

Clothing. Spending on clothing and apparel is deflated using CPI for apparel for the end of the year before the interview was conducted.

Utility. Utility data include payments for gas or other types of heating fuel, electricity expenses, payments for water and sewer, and other utilities. Each of these utility spending categories is deflated using CPI appropriate for the category (utility fuels and gas service, electricity, water, and sewerage maintenance) according to the month and year when the interview occurred.

Communication. Data on telecommunication include payments for telephone, cable or satellite TV, and internet service. Telecommunication data are deflated using CPI for communication according to the month and year when the interview occurred.

Healthcare. Healthcare spending includes payments for health insurance, prescriptions, in-home medical care and special facilities, doctors, outpatient surgery, dental bills, hospital bills, and nursing homes. At the time of the interview, the PSID collects healthcare expenditures combined over two previous years. The total healthcare expenditures are divided by 2 to obtain the value at

Table C1: Data Sources used in the paper

Data Source	Variables
Panel Study of Income Dynamics	Variables on household consumption, housing wealth, home repairs and maintenance, financial wealth, debt-service payments, income, working histories, state of residence, and demographic characteristics for 2003 - 2015
U.S. Bureau of Labor Statistics	CPI deflators for all items and for separate categories of expenditure
FRED, Federal Reserve Bank of St.Louis	Treasury bill rate U.S. Federal Housing Finance Agency HPI by state S&P/Case-Shiller U.S. National Home Price Index
Zillow.com	Zillow Home Value Index by state, all homes, per square meter
Data replication file for Chetty et al. (2017), made available in the *Journal of Finance* website	State-level housing supply elasticity measure of Saiz (2010)

the annual frequency, comparable with other expenditure categories. Total spending on healthcare is deflated using CPI for medical care for the end of the year before the interview was conducted.

Education and childcare. School-related expenses are deflated using CPI for education, whereas childcare expenditures are deflated using CPI for childcare and nursery school for the end of the year before the interview was conducted.

Entertainment and vacations. Recreation and entertainment spending and expenditures on vacations and trips are deflated using CPI for recreation. Vacations and trips data are deflated according to the month and year when the interview occurred, whereas recreation and entertainment data are deflated using the CPI for the end of the year before the interview was conducted.

Transportation. Transportation expenditures are deflated using CPI for transportation. Many of the transportation categories (expenses on gasoline, parking, bus and train, cab fare, vehicle repair, additional car or lease payments, and other transportation-related spending) are reported for the month before the interview was conducted and are deflated according to the previous month of the current year when the interview occurred.

Housing. Housing-related data (home repairs and maintenance, and house value) are deflated using

CPI for owners' equivalent rent of primary residence. House-value data are deflated according to the month and year when the interview occurred, whereas data on home repairs and maintenance are deflated using the CPI for the end of the year before the interview was conducted.

C.2 US Regions

Figure 2 reports comparisons of the imputed house-price growth from the PSID and the HPIs by the US Federal Housing Finance Agency and Zillow over four major US regions: Northeast, North Central, South, and West. Following the regional assignment of the states in the PSID, states were grouped into regions as follows:

1. Northeast: Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont
2. North Central: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin
3. South: Alabama, Arkansas, Delaware, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia, Washington DC, West Virginia
4. West: Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, Wyoming

The price-growth indices for the fifth region, which includes Alaska and Hawaii, are not reported due to a small number of observations in the PSID for these states.

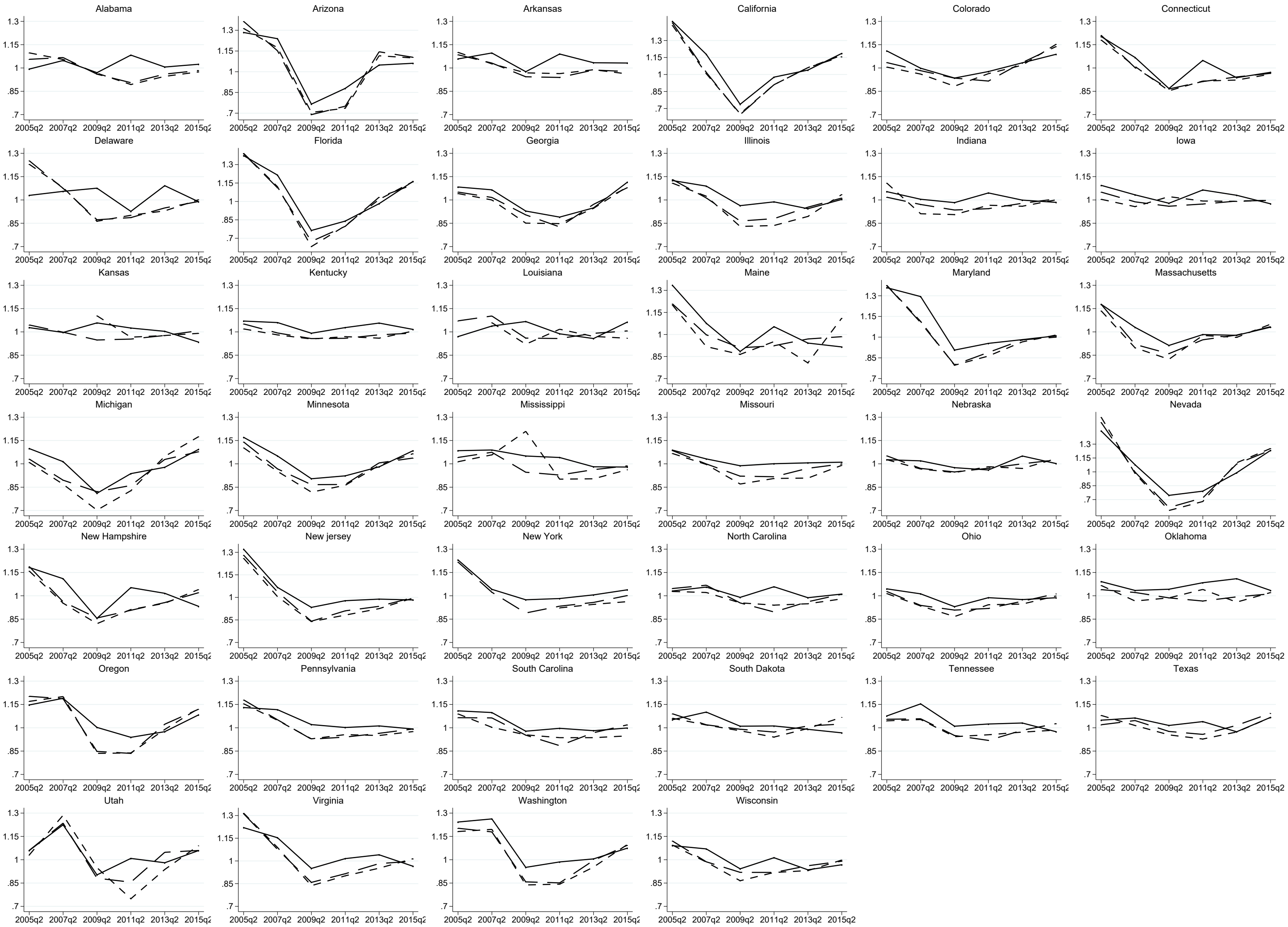

Figure C1: House-price indices over states. The solid line shows average house-price growth imputed from the PSID, the dashed line represents FHFA HPI, and the short-dashed line corresponds to the Zillow index. Alaska, Delaware, District of Columbia, Hawaii, Idaho, Montana, New Hampshire, North Dakota, Rhode Island, Vermont, West Virginia, and Wyoming are not reported due to a small number of observations (less than 10 per period).

References

Chetty, R., Sàndor, L., and Szeidl, A. 2017. The effect of housing on portfolio choice. The Journal of Finance, 72(3), 1171–1212.

Mazzocco, M. 2007. Household intertemporal behaviour: A collective characterization and a test of commitment. The Review of Economic Studies, 74(3), 857–895.

Saiz, A. 2010. The geographic determinants of housing supply. The Quarterly Journal of Economics, 125(3), 1253–1296.