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Implications of household-level evidence for policy models: the case of macro-financial linkages

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Abstract: Macroeconomic policy models should track the different channels of monetary transmission, providing a framework for Monetary Policy Committees. They should also be useful for assessing risks to financial stability, including for designing macroprudential stress tests and instrument settings in the new macroprudential toolkits. Current policy models, including the 'semi-structural' non-DSGE econometric models such as FRB-US, are seriously deficient in these respects, failing to capture the credit channel and the role of real estate in the financial accelerator that operated in the global financial crisis, and in key transmission channels in the recovery. Furthermore, developments in economic theory, greatly encouraged by new evidence, have rendered redundant the previously accepted micro-foundations for household behaviour in these policy models.

A multi-purpose policy model needs to include a household-housing sub-system. This should contain a consumption function broadly consistent with the micro-evidence with equations for permanent income, for the balance sheet drivers, and for residential investment. To capture the credit channel, this block of the model needs to embed common credit conditions in the equations. Sub-system estimation is required to impose the cross-equation restrictions implied by these common factors.

Keywords: macroeconomic policy models, micro foundations, consumption, finance and the real economy, financial crisis, credit constraints, household portfolios, asset prices.

JEL code: E17, E21, E44, E51, E52, E58, G01

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I. Introduction

Macroeconomic policy models are needed to assess the outlook for inflation and growth and help design fiscal and monetary policy by capturing the transmission to the economy of changes in fiscal policy and in interest rates and quantitative easing (QE). They should be helpful in tracking the effects of supply shocks and for understanding implications of structural policies affecting markets, including for labour and housing. After the global financial crisis, the mandates of most central banks have expanded to encompass financial stability. Macroeconomic policy models should therefore also be useful for assessing risks to financial stability, for example by tracking the build-up of financial vulnerabilities and capturing transmission of shocks between the financial system and the real economy. This would help find appropriate instrument settings in the new macroprudential toolkits as well as for monetary and fiscal policy. Macroeconomic policy models should also be capable of adaptation to incorporate the kinds of supply as well as demand shocks generated by the COVID-19 pandemic.

Stress tests of the financial system have now been adopted almost universally by financial regulators, see Anderson (2016), and are also being rolled out by the International Monetary Fund (IMF) under its Financial System Assessment Program on 5-yearly individual country assessments. Appropriate stress tests need to capture not only the adequacy of capital and liquidity and of resolution arrangements at the level of individual institutions, the 'bottom-up' approach, but need to take into account within-financial sector amplification of shocks and contagion, transmission from the financial sector to the real economy, and feedbacks from the real economy to the financial sector. In many economies, debt collateralized on housing accounts for 70 per cent or more of household debt, and housing wealth is the single biggest asset for middle-income households. Moreover, real estate has been central in most financial crises in the last 40 years. It is widely acknowledged that most macro-stress tests currently do not incorporate macro-financial linkages, given the weakness in this respect of the current generation of macro policy models, which still neglect real estate and debt, except in quite trivial ways. A multi-purpose policy model is needed to fulfil the ambition, as set out by the IMF, see Gopinath (2019) and Adrian (2019), for an 'Integrated Policy Framework'.

Finally, a macroeconomic policy model should be flexible enough to take into account both the time series evidence from macro data and be *qualitatively* consistent with the macro implications of the new micro-evidence that is transforming the profession's understanding of macroeconomics.

The existing monetary policy framework, based on the New Keynesian 'Science of Monetary Policy' (Clarida *et al*., 1999) has been under attack as never before, see the special issues in 2018 of the *Oxford Review of Economic Policy* and *Journal of Economic Perspectives*, and Posen (2019) for a recent critique, including of inflation targeting itself. The accumulation of evidence, both macro and especially micro, has undermined key elements of the framework, particularly as expressed in the representative agent New Keynesian DSGE models. Heterogeneous agent models, *in an incomplete market setting*, are shifting the conventional wisdom about monetary transmission with new focus on distributional effects with macro consequences. Note the emphasis on incomplete markets: Bullard and Di Cecio (2019) show that mere heterogeneity is insufficient to prevent conventional conclusions being drawn.

The present paper begins, in section II, by reviewing micro-theory, especially buffer-stock saving theory,[1] and evidence on the marginal propensity to consume out of transitory income, which underlies the size of the Keynesian multiplier, fiscal policy effectiveness, and monetary transmission, including via the redistribution and cash flow channels.[2] Monetary transmission can also occur through changes in asset prices. Theory and evidence on the consumption implications of changes in the value of different components of household portfolios, including residential real estate, is therefore considered. Jordà *et al*. (2016) have tracked the long-term evolution in bank lending: they show that post-war, lending has been far more based on real estate collateral than before. And the role of real estate in the global financial crisis has become obvious to all. In economies such as the US and the UK, an important channel of monetary transmission is via the housing market, affecting consumption and residential investment. Section III of the paper assesses this housing channel, while section IV examines the roles of real estate in the financial accelerator, and explains how institutional difference between countries and over time affect these roles. In some countries, macro-financial linkages are far less amplifying of risks than in others.

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[1] In this theory, households save to acquire a target level of liquid assets tuned to the degree of downside income uncertainty they face to help them 'buffer' or soften the impact of a short-term income loss.

Section V finds current policy models, including the 'semi-structural' non-DSGE econometric models such as FRB-US, seriously wanting in capturing monetary transmission and macro-financial linkages. Section VI puts forward a different approach. Aron *et al*. (2012) and Duca and Muellbauer (2013) generalize a textbook permanent-income model by setting out a 'credit-augmented consumption function'. They make four crucial extensions to the stylized textbook model to incorporate qualitative insights from the buffer-stock saving and heterogeneous agent literatures. First, the credit channel is made explicit by the inclusion of credit conditions indices for unsecured credit and for mortgage credit.[3] Second, household balance sheets are split into liquid assets and debt, illiquid financial assets, and housing wealth. This allows the more realistic measurement of different propensities to consume from the components of wealth rather than combining all into a single net worth sum. Third, a far higher discount rate is applied to future income streams than in the textbook model. Finally, there are short-term roles for income insecurity, proxied by the change in the unemployment rate, and cash flow effects on indebted households are captured by changes in interest rates.

Section VI shows that this generalized credit-augmented consumption function is consistent with the new microeconomic evidence on how the marginal propensity to consume out of transitory income varies with the structure of household balance sheets. It is highest for the asset-poor, intermediate for households poor in liquid assets but not in illiquid assets, and lowest for the doubly asset-rich. Section VI also discusses how this consumption function can be modified to incorporate supply and demand shocks triggered by the pandemic. This section concludes by sketching the other equations in the recommended household-housing subsystem and comments on desirable features of the rest of the policy model, especially for the banking sector.

Section VII draws brief conclusions. Appendix 1 addresses the trade-off between theoretical and empirical coherence in the debate about the design of policy models. Appendix 2 traces the historical development of the credit-augmented consumption function.

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[2] Changes in interest rates can affect household spending by directly affecting households' interest income and payments and, in turn, the amount of cash available to spend.

[3] The latter is interacted with housing collateral—as varying access to home equity credit determines the spending power of housing wealth. Fair (2020) neglects this interaction effect and reaches the conclusion that, for explaining consumption, housing and financial wealth can just be added up. His conclusion is disputed, both on the grounds of theory and of empirical evidence, in sections II and VI below.

II. Micro theory and evidence for the marginal propensities to consume out of current income and out of different types of wealth

The Keynesian revolution in macroeconomics emphasized the importance of policy, both fiscal and monetary, for stabilizing economies, particularly in dealing with effective demand failures resulting in widespread unemployment. A major reason for the belief in policy effectiveness rested on the expenditure multiplier, underpinned by a substantial marginal propensity to consume (MPC) out of current income.

(i) The life-cycle permanent income hypothesis

The first important post-war pushback against the Keynesian revolution came from Friedman's 'permanent income hypothesis' (PIH), which argued that the MPC out of current income was actually very low because intertemporally optimizing households focused instead on permanent income (Friedman, 1957). This is the income flow, which in discounted present value terms, is equivalent to the fluctuating profile of expected income into the far future. Generations of students wrote essays comparing a supposed 'Keynesian' and rather *ad hoc* consumption function driven by current income (and hence assuming a high MPC) with the sophisticated, rationally forward-looking life-cycle permanent income hypothesis (LCPIH) based on micro optimizing behaviour. Of course, both were straw men. The LCPIH made drastic assumptions about the absence of credit and liquidity constraints and transaction costs, even if one bought the assumption that most households were financially literate and capable of solving difficult problems of intertemporal optimization. In contrast, the *ad hoc* 'Keynesian' function implicitly assumed either extreme credit constraints or remarkably myopic behaviour.

The LCPIH was central to the New Classical counter-revolution of Lucas, Sargent, Kydland and Prescott, and Barro that drew its strength from the desire to provide micro-foundations for macroeconomics in individual optimizing behaviour. The real business cycle (RBC) model of Kydland and Prescott (1982) built on ideas in Lucas and Prescott (1971) advocating the study of business cycles using dynamic general equilibrium methods. The New Keynesian representative agent DSGE model was an extension of the RBC model adding adjustment costs and supposedly micro-founded price stickiness. In Muellbauer (2018) I argued that the representative agent NK-DSGE models were *not stochastic enough*—as they trivialized the role of uncertainty and heterogeneity; were not dynamic enough—as they missed key lags in relationships; and not really general equilibrium—as they ignored important transmission mechanisms and feed-back loops, seen for example in the global financial crisis. They were also scarcely new, being based on ideas made redundant by the asymmetric information revolution of the 1970s and 1980s, and hardly Keynesian, as they missed coordination failures in labour and financial markets.

As far as policy relevance is concerned, these models, which embody a rational expectations version of the LCPIH, necessarily imply that the MPC out of current income is extremely low. This means that the multiplier is weak and fiscal policy of doubtful efficacy.[4] Their view of monetary transmission is that it works mainly through the real interest rate and the intertemporal substitution channel: a higher real interest rate reduces current consumption by raising planned future consumption. As far as the financial sector is concerned, credit flows and asset prices are a sideshow—effectively 'memo items' which just proxy expectations of future growth but play no role in system dynamics or the long run. The global financial crisis has put paid to these last implications. The aggregate consumption Euler equation, which underlies the consumption smoothing implication (hence low MPC) of the PIH and the intertemporal substitution channel of monetary policy transmission, is, as Larry Christiano has admitted, 'the most rejected equation in economics'.[5] A spate of micro-evidence on the MPC, discussed below, has contradicted the hypothesis that the MPC out of current income is very low. This is an important conclusion for fiscal policy.

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[4] Some *ad hoc* extensions, *not* micro-founded, tried to address this problem by assuming that a fraction of households just spend current income, rather than being guided by the LCPIH.

Important for monetary policy is the micro-evidence that has clarified the role of balance sheets in explaining consumption, including that of housing wealth. Moreover, research on the redistribution channel of monetary policy has shown that, depending on the structure of household balance sheets, the redistribution channel can substantially increase the power of monetary policy.

(ii) Buffer-stock saving and heterogeneous agent theory

It is puzzling that the NK-DSGE model remained so popular as an empirical policy model used at central banks when its micro-foundations had been comprehensively contradicted by the work on buffer-stock saving by Deaton (1991) and a spate of papers by Carroll, beginning with Carroll (1992). They showed that households facing liquidity or credit constraints and uncertain income engaged in buffer-stock saving. An important implication is that households lacking liquid assets tend to have shorter horizons and higher MPCs than the liquid asset rich. A partial explanation for the continued use of the NK-DSGE approach is that buffer-stock saving cannot be expressed in terms of analytical solutions linking consumption, income, income expectations, and balance sheets. Moreover, the approach necessarily results in heterogeneity in individual responses of consumption to these drivers, a further reason why it proved impossible to derive exact analytical expressions for aggregate behaviour. With buffer-stock saving, the individual MPC out of current income depends on income uncertainty, on the nature of credit and liquidity constraints, and, even in the simplest versions of Deaton and Carroll, on the stock of liquid assets previously accumulated by the household, all heterogeneous determinants. In contrast, the representative household assumption and absence of credit and liquidity constraints in the NK-DSGE approach made heterogeneity irrelevant.

An early extension of the buffer-stock model to introduce an illiquid asset, with a higher return but subject to trading costs, alongside a liquid asset, was by Otsuka (2004). Trading costs are also a key feature in Kaplan and Violante (2014) and Kaplan *et al*. (2014), who present theory and evidence on 'hand-to-mouth' consumption, corresponding to short-horizon behaviour by asset-rich consumers who face trading costs in the illiquid asset and a credit constraint. This household behaviour is integrated by Kaplan *et al*. (2018) into a general equilibrium model with an otherwise conventional New Keynesian production and pricing side of the economy. Kaplan *et al*. (2018)—see Kaplan and Violante (2018) for a non-technical overview—show that monetary policy conclusions are radically transformed in their 'heterogeneous agent New Keynesian' (HANK) model compared to the standard representative agent rational expectations LCPIH version of the NK-DSGE model. In the latter, intertemporal substitution is the key mechanism by which interest rate policy can affect output; but since permanent income is hardly affected, the overall effect tends to be small. By contrast, in the HANK model, the effects on income are more powerful, particularly for near-term income. In the Kaplan *et al*. (2018) version of a HANK model, the key element in monetary policy transmission is through the fiscal response of governments to a reduction in the interest rate. Their model does not incorporate endogenous asset prices, e.g. of equities and real estate, through which, in reality, monetary policy also operates, see below.

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[5] Christiano comment at the third Oxford–New York Federal Reserve Monetary Economics Conference, 27 September 2017. The Euler equation implies that consumption growth is driven by news about future income, which, under rational expectations, should be unpredictable. This is strongly rejected on aggregate data (see Campbell and Mankiw (1989, 1991), and for further powerful evidence from the UK, US, and Japan, Muellbauer (2010)). Deaton (1987) reviews evidence against the LCPIH.

(iii) Empirical evidence on the MPC out of current income

One major source of evidence on the reaction of consumer spending to transitory changes in income comes from natural experiments, for example from temporary tax cuts rolled out at different times for different households. A study by Johnson *et al*. (2006) examined data from the Consumer Expenditure Survey to examine the expenditure impact over a 3-month period of the 2001 US tax rebates. They find estimates of the average MPC in the range 0.2 to 0.4. Johnson *et al*. (2009) find around 0.25 for non-durable consumption within 3 months from the 2003 child tax credit. Carroll *et al*. (2017) survey a range of such studies, covering also 1936 tax cuts, the Reagan tax cuts, and the 2008 Economic Stimulus and for effects up to 3 months and 1 year, both for non-durables and total expenditure. There is quite a range of variation but, for total expenditure, no study finds an average MPC in the US below 0.33. As survey data on consumer expenditure are relatively noisy, some variation in estimates is not surprising. An Australian study, Leigh (2012) finds an average MPC of around 0.6 in data on the 2009 fiscal stimulus.

A recent study by Fagereng *et al*. (2016) of Norwegian tax and administrative data on income and assets, from which expenditure is derived, is based on reactions to lottery winnings, another type of natural experiment. With many more observations and a relatively low measurement error in the data, they can track how the MPC varies with different wealth ownership of households. They find that over a 6-month period, the MPC for households in the lowest quartile of liquid wealth is 0.61, and 0.45 for those in the highest quartile of liquid wealth. This is consistent with the qualitative implications of buffer-stock theory.

Crawley and Kuchler (2018) have access to similar registry data on income and assets for households in Denmark for the most comprehensive study to date of how the MPC varies with the asset position of households. Their study is based not on data from a natural experiment, but on an analysis imposing plausible covariance restrictions on income and expenditure shocks, to distinguish transitory from permanent income changes. They divide households into three types: those low in both liquid and illiquid assets (‘hand-to-mouth’), those low in liquid assets but wealthy in illiquid assets such as housing (‘wealthy hand-to-mouth’), and those wealthy in both liquid and illiquid assets (‘wealthy’). They find the highest MPCs of around 0.7 or 0.8 for hand-to-mouth households, intermediate MPCs of around 0.5 or 0.6 for wealthy hand-to-mouth, and the lowest, around 0.25, for the doubly wealthy. Their findings are consistent with earlier conclusions of Kaplan *et al*. (2014), finding far higher MPCs than would be implied by the LCPIH for households wealthy in illiquid assets but not in liquid assets.

(iv) The cash-flow and redistribution channels of monetary policy

There is a spate of new micro-evidence for the *cash flow channel*, originally explained by Jackman and Sutton (1982)—see La Cava *et al*. (2016) on Australia, and Cloyne *et al*. (2016) and Cloyne and Surico

(2017) for UK evidence, and Di Maggio *et al*. (2017) for US evidence. In floating interest rate environments, households with large debts increase their spending more strongly when rates fall, than savers cut their spending. Di Maggio *et al*. find strong evidence from data on adjustable rate mortgage resets that households with lower levels of income and of housing wealth have higher MPCs. Auclert (2019) argues that there are more general redistributive effects in the transmission channel of monetary policy to consumption resulting from the different MPCs of winners and losers. One effect comes from unequal income gains. As Coibion *et al*. (2017) show, lower-income households tend to benefit more from aggregate income gains, amplifying the effect of monetary policy if they also have higher MPCs. Auclert (2019) also considers differential effects that operate via different portfolio positions of households. He separates these into the impact of unexpected inflation, with nominal debtors gaining and nominal creditors losing, and of real interest rate changes on households, which affect asset prices, depending in part on the duration of the returns on those assets. For example, those with short-term deposits tend to lose relatively to those with long-term financial assets when interest rates fall. Slacalek *et al*. (2020) undertake a comprehensive but 'back of the envelope' calculation for the euro area of the impact of monetary policy shocks on household spending. They find substantial heterogeneity between countries. Consistent with this conclusion, Aron *et al*. (2012), based on work with Murata, present empirical evidence that in Japan, where household assets are dominated by deposits and equity market participation is exceptionally low, lower real interest rates actually *reduce* consumption, given aggregate labour income and financial asset prices. For the US and the UK, the reverse holds. Muellbauer and Murata (2011) discuss the lessons for monetary policy.

Auclert's theoretical framework makes a number of simplifying assumptions, including perfect foresight and the absence of liquidity and credit constraints, and so ignores the impact of buffer-stock saving. It does not take into account the special nature of most mortgage contracts, which specify a constant stream of nominal payments, at the given interest rate. As Kearl (1979) showed, when expected inflation and nominal interest rates increase, the life-time burden of real mortgage payments is tilted to be higher in the short run, straining the budgets of credit-constrained households. Auclert (2019) also does not take into account what determines the MPC out of housing wealth in the presence of credit and liquidity constraints, see section V, and the complex nature of house price determination in the presence of these constraints.

For macroeconomics, 'back of the envelope' calculations of monetary policy shocks for household spending, as in Auclert (2019) and Slacalek *et al*. (2020) have their place. However, missing dynamic general equilibrium effects limit insights from such models. Some of these come from outside the household sector, for example, from investment and exports, and some are slowly evolving. For example, debt and other components of household balance sheets are strongly affected in the long run by changes in interest rates and by unconventional monetary policy such as quantitative easing. Slacalek *et al*. take the distribution of household balance sheets as given, largely abstracting from these longer-term considerations. The vector autoregressions used to calibrate or estimate some of the transmission of monetary policy, for example, into house prices, suffer from the problems of omitted controls induced by the 'curse of dimensionality'. The present paper therefore argues in favour of improving large semi-structural macroeconometric models to capture better these dynamic general equilibrium effects.

(v) Monetary transmission to consumption through asset prices: theory and evidence

As noted above, the early buffer-stock models of saving of Deaton and Carroll made the simplifying assumption of a single liquid asset. Otsuka (2004) generalized these models by introducing household portfolio choice between liquid and illiquid assets under income uncertainty and a credit constraint on borrowing. Her model demonstrates that households optimally hold the majority of precautionary wealth in the illiquid form because of the higher returns, even though they have to pay transaction costs in changing illiquid asset positions upon adverse shocks. She also shows that the marginal propensity to consume, in the short run, out of illiquid wealth is much smaller than the MPC out of liquid wealth. Otsuka did not distinguish housing so that collateralized borrowing is not a possibility in her model. Because of the nature of the borrowing constraint in her model, there is no explicit role either for uncollateralized consumer credit.

An extension to incorporate housing is due to Berger *et al*. (2018). They present an optimizing model of a household facing collateral constraints and lumpy transactions costs, with a collateral effect of house prices on consumption, where the size of the effect increases as the down payment constraint is relaxed. This implies that the house price effect on consumption varies with credit conditions. While their theoretical framework is simplified, for example, not distinguishing the down payment constraints lenders impose on first-time buyers from possible constraints on home equity withdrawal by existing home-owners, the variation of the house price effect on consumption with credit conditions remains a robust conclusion.

Garriga and Hedlund (2020) present an incomplete markets model with other housing features. These include tenure choice between renting and owning, portfolio choice between liquid assets, housing, and long-term mortgage debt with a default option, and a frictional housing market. Specifically, directed search in the housing market makes liquidity endogenous by creating a tension between trading at a desirable price, low for buyers, high for sellers, versus trading quickly. This liquidity responds to changing macroeconomic conditions, including to shifts in credit conditions, resulting in time-varying selling delays. They apply the model to the global financial crisis—see section IV.

Hedlund *et al*. (2016) incorporate housing with such search and trading costs, in a sticky price heterogeneous agent model with monetary policy, introducing a potentially important monetary transmission channel via housing to consumption.

In this area, micro theory has lagged behind the empirical evidence. Muellbauer and Lattimore (1995) had examined the housing wealth effect in optimizing models of intertemporal choice, which otherwise made all the other assumptions of the LCPIH. They showed that the effect was different from that of financial wealth because housing is a consumption item as well as an asset, and the aggregate effect on consumption was likely to be small, a theme taken up by Buiter (2010) among others—see Appendix 2 for further discussion. Micro-evidence on the so-called *housing wealth effect* on consumption has, for some time, confirmed that, at least in countries with home equity withdrawal options, it is much more of a collateral effect than a classical wealth effect (see Hurst and Stafford (2004), Browning *et al*. (2013), Atalay *et al*. (2014), Mian and Sufi (2014), Windsor *et al*. (2015), Andersen *et al*. (2016), Burrows (2018), and Zhang (2019)). In contrast to a pure wealth effect, a collateral effect will necessarily vary over time (as confirmed in the formal model of Berger *et al*. discussed above) and between countries, with credit conditions that govern the ease with which households can access home equity withdrawal. Time-series macro-evidence consistent with this view had already been provided in Muellbauer and Murphy (1989) and later research discussed in Appendix 2.

III. Housing and monetary policy: channels and institutions

Consumption and residential investment are the two components of aggregate demand that provide potential housing-related links to monetary policy. As a fraction of GDP, consumption in the UK in the last half-century has varied from around 59 to 70 per cent. For residential investment, the fraction of GDP has varied from under 3 per cent to around 6 per cent in the UK. In the US, the decline in residential investment from 2006 to 2012 accounted for between 3 and 4 per cent of GDP.

The 2007 Jackson Hole symposium of the Federal Reserve was devoted to 'Housing, Housing Finance and Monetary Policy', a subject previously largely neglected, as Leamer (2007) observed.[6] The NK-DSGE models, popular with central banks at the time, completely excluded consideration of housing and housing finance. Bernanke (2007) noted at the same conference that the record-breaking house-price booms in many countries, radical changes in the structure of US mortgage finance, and worrying signs of mounting defaults in US sub-prime mortgages had combined to trigger a necessary re-examination of the issues. A useful overview by Mishkin (2007) of housing and monetary transmission noted the state of uncertainty among economists on these channels of transmission. He remarked:

> "By raising or lowering short-term interest rates, monetary policy affects the housing market, and in turn the overall economy, directly or indirectly through at least six channels: through the *direct* effects of interest rates on (1) the user cost of capital, (2) expectations of future house-price movements, and (3) housing supply; and *indirectly* through (4) standard wealth effects from house prices, (5) balance sheet, credit-channel effects on consumer spending, and (6) balance sheet, credit-channel effects on housing demand."

His classification for the US is useful and can be applied to other countries. However, three further channels of influence on the overall economy should be added to this analysis. These operate through the *indirect effects* of interest rates on (7) income expectations, which affects the demand for housing, on (8) real estate prices and rents, and hence on inflation, and on (9) the exchange rate.

We turn to a discussion of the above channels. The first *direct* channel is through user cost, and its influence on residential construction. User cost is defined by an adjusted real interest rate given by the tax-adjusted mortgage interest rate minus the expected rate of house price inflation, plus the depreciation rate for housing, the tax rate on property, and a risk premium. Mishkin notes the wide variety of empirical estimates of the responsiveness of US residential construction to user cost. This reflects disagreement on the most relevant horizon for expectations of appreciation, and on which factors drive those expectations. Moreover, the linkage between the policy rate and the mortgage rate is not one-for-one, given the prevalence of fixed-rate mortgages in the US, and studies again make different assumptions about the feedthrough. The second *direct* channel of transmission is through expectations of house price appreciation. Mishkin points to evidence that lagged house price changes are a useful proxy for these hard-to-measure expectations. Then significant lags in the transmission of the policy rate to house prices will arise. This is because current house prices depend on house price expectations, which themselves depend on the recent history of the policy rate. The third *direct* channel influences housing supply via the cost of financing construction, mainly through relatively short-term interest rates (likely to be almost one-for-one with the policy rate). Hence there is a fast and full feed-through from the policy rate to the interest rate relevant for financing construction.

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[6] Leamer noted that the best-selling US textbook on macroeconomics published in 2007 had no links between housing and the business cycle, and that no other textbook gave a central role to real estate. In contrast, Carlin and Soskice (2014) give proper attention to collateral constraints and to linkages between the financial sector and the real economy in which real estate plays an important role.

Turning to the first of Mishkin's *indirect* channels of transmission, Mishkin refers to standard life-cycle models of consumption with an aggregate wealth effect defined on net worth.[7] However, he also discusses evidence available at the time that the effect of housing wealth itself might be *different* from that of other wealth components. On balance, Mishkin assesses from this evidence that housing wealth is *not* different from other types of wealth, a conclusion disputed in section II(v) above. Moreover, the life-cycle theory abstracts from credit and liquidity constraints. Both assumptions will understate the effect of housing on the US economy. Mishkin is more agnostic about separating out housing wealth when interpreted as a collateral effect in his fifth channel, the balance sheet/credit channel for consumption. This channel operates mainly through home equity withdrawal, where homeowners can borrow against their current housing collateral. If house prices rise, collateral rises too, and borrowing can be increased through equity withdrawal, raising consumption. There has been considerable disagreement among economists about the importance of this channel. In countries with more developed mortgage finance systems, where rules allow equity withdrawal, the correlation of consumption growth with house price changes is higher (evidence in Calza *et al*. (2007, 2013)). Mishkin (2007) argues that the cost of home equity withdrawal in the US has declined since the 1980s, potentially increasing the responsiveness of consumption to house prices. Mounting evidence for this collateral channel noted in section II(v) implies that his scepticism about its strength was misplaced.

Mishkin's sixth and final channel is effectively the cash flow channel on housing demand. Higher nominal interest rates for borrowers, even when the real rates are unchanged, reduces their cash flows (after deducting mortgage service costs), as the real stream of interest payments is 'tilted to the present' (Kearl, 1979). For credit-constrained borrowers, the size of the mortgage they can apply for falls, reducing housing demand. An implication is that nominal interest rates as well as real interest rates, through user cost, affect the demand for housing. When mortgage interest rates are variable, as is the case in some countries, the greater responsiveness of these rates to the policy rate induces a stronger monetary transmission effect. As noted in section II above, with adjustable rate mortgages, this cash flow channel also operates on consumption as debt service costs fall with lower nominal mortgage rates.

Mishkin concluded by examining simulation evidence from the Federal Reserve's FRB-US model on monetary policy transmission—see section V.

Of the three channels of influence on the macroeconomy that Mishkin did not distinguish, operating through the *indirect effects* of interest rates, the first is the income expectations channel. Greater optimism about future income increases consumption and is likely to raise house prices. If household expectations can be approximated by a reduced-form income forecasting model, e.g. Chauvin and Muellbauer (2018), it is possible to estimate the strength of this channel. The second channel links interest rates to inflation via real estate prices and rents. Evidence for this channel comes from a forecasting model for US inflation by Aron and Muellbauer (2013*b*), showing a strongly significant effect of higher house prices on the price level 1 year ahead. This probably operates mainly through the rent component of the price level, given that rents respond with a lag to real estate prices. The third channel operates via the exchange rate and is relevant in countries reliant on foreign-currency debt, affecting cross-border mortgage repayments. For example, repayments on foreign currency mortgage loans in Hungary and some of the Baltic countries rose sharply during the financial crisis when their exchange rates depreciated.

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[7] Net worth is the sum of liquid and illiquid financial assets minus debt plus the value of housing wealth. This aggregation of the different components implies the same influence of each component in a model of consumption.

IV. The financial accelerator and housing: why countries differ

The increasing role of real estate collateral in lending in most advanced countries, and in financial crises has been noted by Jordà *et al*. (2016). Many financial crises begin with a serious *over-valuation* of asset prices, especially of housing and commercial real estate, in a context of highly leveraged lenders, some of whom made risky loans. A case in point is the US sub-prime crisis of 2008–11, which we use below to illustrate institutional channels of the financial accelerator that drove financial instability. Since institutional features vary across countries, financial accelerator channels can differ in the degree to which they amplify or even dampen shocks. This variation points to the need to adapt stabilization policy to local circumstances.

(i) General causes of overvaluation of housing and real estate prices

There are three broad sources of asset price overvaluation relative to values consistent with sustainable fundamentals and hence leading to large house price corrections. The first is exogenous macroeconomic shocks shifting those fundamentals. The second is the discovery that what had been thought to be financial sector and fiscal fundamentals were in fact fragile, i.e. unsustainable. The third cause of overvaluation can arise from endogenous dynamic processes.

Unexpected exogenous macroeconomic shocks to economic fundamentals are one reason why housing and real estate prices can be overvalued. Such shocks include a deterioration in the terms of trade, a rise in oil prices for net oil importers (as in the 1970s), a collapse of export markets (e.g. in Finland just after the collapse of the Soviet Union), political risk, natural disasters, global pandemics, a rise in global interest rates, or an external credit supply shock (particularly for a small open economy dependent on international credit flows).[8] For a small open economy, an exogenous credit supply shock could result from a crisis erupting elsewhere, for example, resulting from excess risk-taking elsewhere, for instance, in shadow-banking in China or in the collateralized loan market in the US. Such shocks are arguably unforeseeable.

The exposure of fragility in financial and fiscal fundamentals, of which experience should have warned, can be a second source of asset price overvaluation, increasing vulnerability to other shocks. Examples of fragile financial fundamentals include a duration mis-match in credit supply (e.g. mortgage funding in Ireland and the UK was disrupted by a sudden stop in the money-markets in August 2007), unsustainably weak financial regulation leading to over-leveraged lenders and borrowers (as in the US in the years preceding 2008), and poor lending quality as illustrated by the concomitant fraud and misuse of securitization in the US. The IMF has long been concerned with the vulnerability of some countries to external debt—particularly with currency mismatch of debt[9]—and with sustainable fiscal policy and levels of public debt, IMF (2002, 2011). A prime example of fiscal fragility was Greece's unsustainable fiscal and sovereign debt position, which, when exposed in 2009–10, triggered the EU's sovereign debt crisis.

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[8] Examples of external credit supply shocks putting upward pressure on global interest rates include the ‘Reagan fiscal shock’ in the early 1980s and the German unification shock of the early 1990s. Such shocks have particularly strong effects for economies where floating rate debt dominates.

A third source of overvaluation can arise from endogenous dynamic processes in which 'noise-traders' push prices away from sustainable fundamentals. One such example stems from extrapolative expectations of capital gains, as illustrated by the empirical equilibrium-correction house price model of Abraham and Hendershott (1996). In this model there are positive effects on house prices from *recent rises* in house prices (the so-called 'bubble-builder' effect) and negative effects from *the current high levels of real house prices relative to their fundamentals* (the so-called 'bubble-burster' effect). That recent rises can further elevate house prices can be explained by some market participants—noise-traders—basing their expectations of future capital gains on recent gains rather than on fundamentals, thus increasing the demand for housing. But if house prices become too expensive relative to their fundamentals, seen by other market participants, house prices will tend to fall. Such fundamentals include a combination of long-term demand factors—income, population, interest rates, and credit conditions—relative to the stock of housing. If the extrapolative element in expectations of capital gains is strong, a series of positive shocks can cause a substantial overshoot of house prices. When the positive shocks cease, and even without any negative exogenous shocks, house prices will eventually fall, and may overshoot on the downside.

Another endogenous dynamic process affecting housing is articulated by Geanakoplos (2010) in his theory of the leverage cycle in housing and other asset markets.[10] Leverage rises when house prices fall, thereby tightening leverage constraints. This, in turn, can force investors to sell into a declining market, causing prices to fall further. These dynamics can give rise to a deflationary feedback loop. Analogously, positive news about house prices can induce lower perceptions of risk, loosening leverage constraints, which causes further house price increases.

(ii) The consequences of overvalued housing and commercial real estate prices: the case of the US

Notable real estate overvaluation eventually leads to falling prices. While endogenous dynamic processes give rise to overvaluation, they also *amplify* the impact of exogenous shocks. There may also be short-term contagion within the financial system, medium-term transmission from the financial system to the real economy, and feedbacks from the real economy to the financial system and real estate prices. The power and direction of these different channels depend on an economy's institutional and market structure. Section VI explains how the structure of a policy model could articulate these transmission and feedback mechanisms.

Figure 1 illustrates the example of the US sub-prime crisis, triggered by the weakening of house prices in 2006 from overvalued levels, followed by weaker commercial real estate prices. All three of the reasons for overvaluation discussed above applied. First, macroeconomic conditions became less favourable. Real oil prices rose from $31 in 2002, to $71 in 2006, and to a peak of $104 in 2008.[11] The impact on household real income resembled a rise in tax rates. Another factor was rises in the federal funds rate—from 1 per cent in mid-2003 to 5.25 per cent in 2006—to contain inflation. After the Fed signalled in 2003 that it would slowly raise interest rates, the rate path was not surprising. However, the preceding low trough of the policy rate and the first signal of the path probably were surprises.[12] The increasing numbers of households experiencing rising mortgage payments eventually put downward pressure on house prices by 2006 and 2007.[13]

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[9] For example, the Baltic republics and Hungary borrowed in foreign currency before their currencies collapsed in the global financial crisis, as did Indonesia and South Korea before the Asian financial crisis of the late 1990s.
[10] Leverage is defined as the debt used to purchase an asset divided by the buyer's equity stake or down-payment.
[11] These are annual averages of the prices per barrel deflated by the CPI (on a base of July 2017).

A second source of overvaluation stemmed from the recognition of the increasing fragility of the financial system after 2000. The combination of highly leveraged households—heavily indebted prior homeowners and greater incidence of less creditworthy new homeowners—and a highly leveraged banking sector made both sectors more vulnerable to income and house price shocks. Three legislative interventions fuelled the rise in leverage: the Financial Futures Modernisation Act of 2000;[14] the lowering of bank capital requirements on 'investment grade, non-prime, mortgage-backed securities' in the mid-2000s (see Stanton and Wallace (2018)); and the Securities and Exchange Commission's easing of leverage restrictions on investment banks and other banks in 2004 (see Duca and Ling (2020)). Rajan (2005) had warned at Jackson Hole that the proliferation of derivative contracts and their global spread, combined with increased financial leverage, had made the global financial system much more fragile. This contrasted with the conventional wisdom that the diversification of risks had increased the safety of the system. By 2007, the poor practices of mortgage issuers and credit-rating agencies in rating mortgages and derivatives were coming to light [15] and Rajan's warning was becoming more widely accepted.

A third source of overvaluation arose from endogenous dynamic processes. One type of evidence comes from time-series models of US house prices that fit well only if they assume many buyers were projecting past capital gains into the future (Duca *et al*., 2011, 2016). As described by Geanakoplos (2010), see above, the upswing of the leverage cycle plausibly also contributed to overvaluation, made more extreme by the above regulatory changes.

The transmission channels from falling real estate prices to the real economy are shown in the first three green transmission arrows in Figure 1. Lower prices *directly* reduced construction by lowering the profitability of building (far left of diagram). A second *indirect* channel on construction arose as more pessimistic expectations about real estate prices, based on extrapolation of recent falls, reduced the demand for real estate and pushed up unsold inventories.[16] Ultimately, many home builders, faced with the collapse of cash flow and the value of their land banks, went bust. These features should be reflected in the residential investment equation discussed in section VI. Moreover, as indicated in the narrow brown feedback arrow from lower real estate demand to the top, lower demand amplified earlier price declines. A third *direct* demand channel is via weaker consumer spending (the third green transmission arrow). Lower house prices lowered consumer spending, as housing collateral is an important driver of consumption in economies such as the US (see section II for evidence).[17] This is a feature of the credit-augmented consumption function discussed in section VI. Also, lower demand for real estate lowered consumption of services associated with real estate transactions and probably of durable good purchases associated with moving homes. In consequence of weaker consumption and construction, GDP declined. For economies with sticky prices, the usual multiplier process implies rapid, but not instantaneous, transmission from expenditure measures of consumption and construction to the output measure of GDP. Macroeconometric policy models should be able to capture this dynamic process, with variations in inventories, capacity utilization, and the unemployment rate representing temporary disequilibria between aggregate demand and output.

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[12] Observers, including Taylor (2007), argued that interest rates were set too low in 2003 and that the signalled pace of subsequent rises was too slow, so contributing to the later over-valuation.

[13] Many recent non-prime mortgages had been issued with low initial interest rates and reset clauses to raise initial rate to market rates, and the impact became especially onerous as mortgage rates increased.

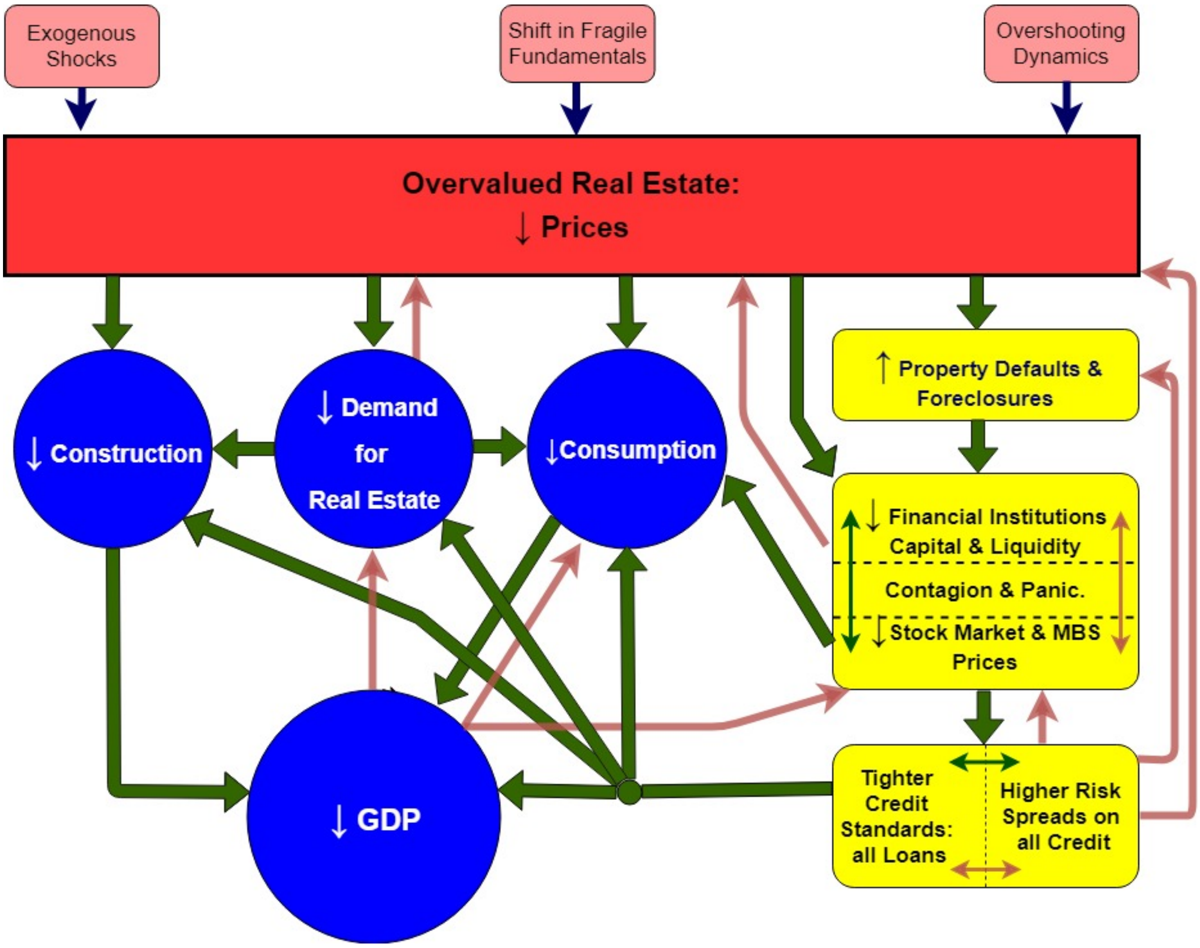
[14] This legislation gave priority to settling derivatives claims on a company's assets ahead of other claims, thus promoting the use of derivatives to back the expansion of mortgage-backed securities.

[15] I recall, preparing for the 2007 Jackson Hole conference, the *Wall Street Journal*'s revelation in August that Standard and Poor had been rating 'piggy-back' mortgages, where multiple loans were taken out on the same property, as no more risky than single-loan mortgages!

[16] In the short run, house prices are sticky so that part of the fall in demand *directly* lowered residential investment.

[17] In a closely related argument, Mian and Sufi (2011) and Kaplan *et al*. (2017) suggest that lower house prices made credit constraints more binding. Another aspect of the collateral channel operates through investment expenditure of entrepreneurs who put up their own home as collateral for a business loan; see Black *et al*. (1996) and Bahaj *et al*. (2018).

Figure 1: The financial accelerator in the US sub-prime crisis


Exogenous Shocks
Shift in Fragile Fundamentals
Overshooting Dynamics
Overvalued Real Estate:
↓ Prices
↓ Construction
↓ Demand for Real Estate
↓Consumption
↑ Property Defaults & Foreclosures
↓ Financial Institutions Capital & Liquidity
Contagion & Panic.
↓ Stock Market & MBS Prices
↓ GDP
Tighter Credit Standards: all Loans
Higher Risk Spreads on all Credit

Key: Transmission towards lower GDP ➡

Feedback towards lower real estate prices →

Real economy components ● Financial sector aspects 🟨

Source: Devised and constructed by Janine Aron, John Duca, and John Muellbauer, taken from Duca *et al*. (2020). Copyright AEA; reproduced with permission of the *Journal of Economic Literature.*

The transmission channels from falling real estate prices into the financial sector are shown on the right-hand side of Figure 1. With the decline of prices and the concomitant rise of many mortgage payments (due to reset clauses), mortgage delinquencies and foreclosures rose, shown in the small top yellow rectangle.

The consequence was a reduction in the capital base and in the liquidity of the financial sector, seen in the middle lower yellow rectangle. Real estate losses mounted at financial intermediaries, particularly on commercial mortgage-backed securities and private label (residential) mortgage-backed securities. The combination of losses on commercial and residential real estate undermined the capital positions of commercial and investment banks, including lightly regulated shadow banks, which had accumulated large real estate positions. The regulatory changes, which had permitted the rise in leverage—including sharply lowering the capital needed to fund mortgage-backed securities—made the financial sector far more sensitive to mounting losses at financial intermediaries. Contagion within the financial system soon *amplified* these shocks. This contagion is indicated in the lower half of the middle yellow rectangle on the right of Figure 1.

One example of contagion is if asset fire sales by one firm lower the prices of these and related assets, and negatively affect the balance sheets of other firms holding such assets; see Cont and Schaanning (2017). These short-run effects amplified one another. Funding constraints arising through a liquidity crisis spread to other banks in the system, generating amplifying feedbacks in both directions between funding constraints and asset fire sales. Bernanke (2018) describes the result as a panic.

There were further effects on credit availability and risk spreads, depicted by the transmission channel from the middle to the lower yellow rectangle on the right. Bernanke (2018) explains that:

> "as investors refused to fund even non-mortgage securitizations, driving up the yield on non-mortgage credit . . . the expansion of the panic to include non-mortgage credit as well as mortgages was arguably a turning point of the crisis, with broad ramifications for both firm and household borrowers."

Thus, lower capital, contagion, and finally panic lowered financial asset prices and induced tighter credit standards on all loans and higher credit risk spreads. The wealth effect on consumption of lower asset prices is depicted in Figure 1 by the sideways green transmission arrow from the middle yellow rectangle on the right. The four sideways transmission arrows from the bottom rectangle on the right represent *the impact of credit conditions* on the real economy components of real estate demand, construction, and consumption, and directly to GDP. Credit conditions figure strongly in the consumption and house price equations discussed in section VI and therefore feed into real estate demand and construction. Gertler and Gilchrist (2018) support Bernanke on the *crucial* impact of these credit conditions in the dynamics of the global financial crisis. In their stylized micro-founded model, Garriga and Hedlund (2020) argue that in the global financial crisis (GFC), the deterioration in housing liquidity along with falling house prices made ownership riskier and damaged household balance sheets. The imbalances that arose between assets and liabilities created debt overhangs that triggered rising selling delays and higher foreclosures, which in turn induced lenders to contract credit. The twin collapses in housing and credit liquidity generated substantial macroeconomic amplification and propagation.

In addition to the direct transmission channels discussed above, and the effects from financial sector constraints and contagion to GDP, transmission also operated through several feedback effects. As Bernanke (2018) remarks:

> "Powerful feedback effects operated throughout, for example, among the solvency of mortgage lenders, the supply of mortgage credit, household balance sheets, and house prices, with each affecting the others. There were also strong feedbacks between financial

> and economic developments, as financial disruptions slowed the economy, which in turn worsened financial and credit conditions."

The feedback effects are shown in Figure 1 by thin brown arrows. From the financial sector, reduced credit availability and higher risk premia fed back to real estate prices and defaults and foreclosures, for example, because borrowers were less able to refinance to avoid payment delinquency and foreclosure. Endogenizing the effects of defaults on measures of credit conditions in a policy model is discussed in section VI.

An important set of feedbacks linked the real economy with the financial sector. Lower GDP (and hence lower household income and company revenue) fed back on to demand for real estate and consumption and, in turn, lower demand for real estate fed back to real estate prices (in the wide red box at the apex of the figure). For a macro policy model to capture these transmission mechanisms, it needs to have realistically high estimates of the marginal propensity to consume in line with the evidence discussed in section II. As explained in section VI, the credit-augmented consumption function has the flexibility to estimate the MPC and also to make adjustments in line with plausible distributional effects. Feedback from lower GDP to the capital of financial institutions occurred as their profitability fell, with less demand for their services (shown in the green arrow to the middle yellow rectangle on the right). Finally, because of the large size of the US economy and links between its financial markets and the rest of the world, there was powerful international transmission of shocks emanating from the US. The resulting collapse in asset prices, credit availability, and economic activity in other countries during 2008–9, led to a major contraction of trade flows, which fed back on to US aggregate demand.

For the US, Figure 1 can also help illustrate the *boom phase* of a business cycle, with the directions of movements of, for example, real estate prices and defaults reversed. Thus, higher real estate prices bolster consumption and construction activity, raising GDP. Higher bank profits and lower defaults bolster capital in the financial sector, allowing it to ease credit conditions and reduce risk spreads, with further transmission to consumption, construction, and GDP, and then feedbacks to real estate prices. However, transmission effects on the right-hand side of Figure 1 tend to be more muted in the upswing. One reason is that when defaults are low, a further decline in defaults in a boom does not much affect the availability of credit; in contrast, the large increases in defaults that can occur in a bust may sharply reduce credit availability. Another reason is the asymmetry between cautious optimism about future profits and a pervasive, debilitating fear of bankruptcy and poverty. Downside risk has a stronger effect on behaviour than upside potential, a phenomenon termed 'loss aversion' in behavioural economics. This is consistent with evidence that business cycles usually have long upswings, punctuated by shorter, sharper contractions.

Figure 1 focuses on the transmission of real estate shocks in the context of high leverage and the US experience. We now consider variations in transmission channels across countries: how some channels may stabilize rather than amplify shocks, so reducing the risk of overvaluation and the damage done in a downturn.

(iii) The experience of other countries: the importance of institutional differences

Institutional variations in the financial sector, and other factors influencing household and business leverage, affect the strength of some channels of transmission from real estate prices to the real economy. The housing and mortgage crises of 2008–9 in Ireland, Spain, and, to a lesser degree, the UK, shared many characteristics with the 2007–8 crisis in the US. The banking crises suffered by Norway, Finland, and Sweden in the early 1990s, after their credit and house price booms of the 1980s, also resembled the US experience.[18] In these countries there were large falls in property prices and losses on real estate loans, especially to developers. However, while the US sub-prime crisis had negative spillover effects on global credit markets, even on German banks,[19] many countries did *not* experience a deep crisis due to the different nature of their banking and credit market structures. Examples are lower leverage of household, business, and banks than in the US and less reliance on securitized funding. Such institutional contrasts, and other differences in housing, pension, tax, and legal systems, can cause major variations in the transmission of shocks. They may even preclude the conditions for a substantial real estate overvaluation.

The mechanisms in Figure 1, as noted above, can be translated for an *upswing* of a business cycle. The linkages between *higher* real estate prices and higher construction (the first transmission arrow of Figure 1), can differ among countries. For countries with severe planning constraints or a slow planning process (e.g. the UK), this transmission effect is likely to be small, at least in the short run. Caldera and Johansson (2013) measure the responsiveness of residential investment to variations in house prices across OECD countries. They put the UK near the bottom in responsiveness and the US near the top in the international rankings; see Duca *et al.* (2020) for a review of econometric models of residential investment.

If construction responds strongly to higher real estate prices, there will be a long-run feedback effect in the reverse direction. As the stock of homes expands relative to demand, real estate prices are dampened—a feature of the house price equation explained in section VI, and new construction demand will eventually diminish—as implied by the equation for residential investment, see section VI. In slow upswings, this is stabilizing. However, in booms, the stabilizing effect can be overwhelmed by the forces of expansion such as easing credit conditions, so that a stock overhang only emerges in the subsequent downturn. This occurred in the US, Ireland, and Spain, where construction then took a very long time to recover. Leamer (2015) confirmed his previously expressed view that, for the US: 'housing *is* the business cycle'. The general point is that the impact on financial stability of potentially stabilizing transmission mechanisms depends on the lags with which they operate relative to amplifying mechanisms.

The transmission from *higher* real estate prices to demand for real estate (the second transmission arrow of Figure 1), depends on whether the 'bubble builder' or 'bubble burster' aspects dominate. In the 'bubble builder' mechanism, recent capital gains, reducing the user cost of real estate, are extrapolated into future expectations. This is an important feature of the house price equation explained in section VI. A series of positive shocks that fuel real estate price appreciation, for example shocks to credit standards or interest rates, will subsequently lower user cost. This bolsters the demand for real estate, which feeds back positively to prices. This mechanism, a key contributor to the over-valuation of US house prices in the mid-2000s,[20] depends on the leverage provided by the private sector, as higher leverage amplifies prospective returns and risk. The degree of amplification will be time-varying as loan conditions are eased and leverage rises.[21] In countries where bank regulations prevent high leverage, or the tax system does not favour debt, or mortgages are 'full recourse' so that defaulting is painful for borrowers, the 'bubble builder' mechanism will be relatively weak. Then the potentially stabilizing effect on real estate demand of real estate prices becoming high relative to fundamentals is more rapid in an upswing. Without the amplification of a US-style 'bubble builder', the risk of serious overvaluation is lower.

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[18] The combination of tax relief on mortgage interest and high marginal tax rates had encouraged Scandinavian households to become highly leveraged after credit was liberalized in the 1980s. However, real estate loans in these countries were funded more by banks and less by asset-backed securities than in the US. The within-financial sector amplification mechanisms were thus less complex than in the US, and the international spillovers far smaller.

[19] Some German banks had purchased US mortgage-backed securities, initially rated as 'investment grade', that later were downgraded.

[20] Quarterly household surveys of the house price expectations could detect the risk of extrapolative expectations. Case and Shiller's expectations surveys led to their real-time judgement of US overvaluation in the mid-2000s (see Case *et al.*, 2012).

The transmission from higher real estate prices to consumption (the third transmission arrow of Figure 1), varies with credit conditions in the US and the UK. This provides a potentially serious source of amplifying *non-linearity* (Aron *et al*., 2012; Duca and Muellbauer, 2013). With liberal credit conditions, there will be a powerful effect of housing collateral on consumption, reflecting the *double effect* of credit: first, in raising house prices, and second, from the stronger effect of house prices on consumption. This interaction effect is an important aspect of the credit-augmented consumption function discussed in section VI. The collateral effect is greater in countries where down-payment constraints are light and household leverage is high, access to home equity loans is easy, and home-ownership is high (as in the US). Cross-country evidence also indicates that housing spillovers to the rest of the economy are larger where it is easier to access mortgages and to use homes as collateral (Cardarelli *et al*., 2008). In Germany, where homeownership is low and home equity loans are rare, Geiger *et al*. (2016) find that higher house prices lower aggregate consumption, given income, credit conditions, interest rates, and the non-housing balance sheet. Thus, given the large rental sector in Germany, increased spending by homeowners is overwhelmed by increased saving by renters for a down-payment or because rising house prices signal future rent rises. In economies where property taxes are based on recent real estate market values, such as Denmark (Danmarks Nationalbank, 2019), higher tax-payments dampen consumer spending in rising markets.

Another link between house prices and consumption runs from house prices to debt, and hence to spending. Higher house prices tend to increase mortgage borrowing,[22]an important feature of the mortgage stock equation discussed in section VI. Higher debt, *ceteris paribus*, lowers consumption (transmission is from the bottom right-hand side of Figure 1 to consumption). This negative drag on consumption built up throughout the US housing boom as debt mounted. However, initially it was more than offset by a positive spending effect of higher housing collateral and easier credit. The burden of accumulated debt on consumption, while always there, only later became obvious after house prices began to fall and credit supply contracted (Duca and Muellbauer, 2013). The high negative coefficient on debt, and the interaction of credit conditions and housing collateral in the credit-augmented consumption function, discussed in section VI, both absent in conventional models, quantify this mechanism. It is another example of how apparently stabilizing forces can be destabilizing if long enough delayed. In France, mortgage credit was liberalized from 1997 to 2007 and house prices rose strongly. Chauvin and Muellbauer (2018) find that liberalization's positive effect on aggregate consumption and the small effect of increased housing wealth on consumption were neutralized by the restraining effect of higher debt and increased saving by renters. This helped to stabilize the French economy.

Financial regulation and financial structure also greatly affect the *within-financial system* amplifying transmission channels (the right-hand side of Figure 1). As house prices rise, lenders may be more willing to lend to new borrowers, since the collateral that secures loans rises relative to bank capital. Existing borrowers experience increased housing equity, making new loans to these borrowers safer from the lenders' perspective. Moreover, in a rising market, lending becomes more profitable as previous bad loans shrink, enhancing a lender's capital. Financial regulation and legal and tax regimes that restrict incentives for leverage for lenders and for households, can mitigate the severity of such a leverage cycle. Countries such as Germany and France, with relatively tight regulation of mortgage lending, especially of securitized products, were far less prone to within-financial system amplification than the US during the 2000s.

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[21] Empirical evidence for this comes from Muellbauer and Murphy (1997) and Chauvin and Muellbauer (2018).

[22] However, where down-payment constraints are severe, higher house prices relative to income could result in fewer borrowers meeting the constraint, even if those successful in obtaining a mortgage borrow more. In aggregate, it is possible that mortgage debt relative to income could then fall unless the improved collateral of existing borrowers encourages lenders to relax the down-payment constraint.

Much of the post-crisis literature on macroprudential policy has focused on dampening within-financial system transmission and contagion. Prudential financial regulation, both micro and macro, is justified, as Gai (2017) argues, because

> "the costs of financial system failure . . . far exceed the private costs to the managers, creditors, and shareholders of the failing entities. This is a consequence of negative externalities—the private benefits of the socially destructive behaviour exceed the private costs."

The discussion above has highlighted the roles of leverage and macroprudential controls on leverage. Macro-evidence has mounted about how leverage and real estate contribute to financial instability (Cerutti *et al*., 2017; Mian *et al*., 2017). The IMF's October 2017 *Financial Stability Report* (IMF, 2017) provides further evidence, highlighting the critical role of mortgage debt and non-linearities, finding more pronounced effects at high debt ratios, and larger effects in countries with open capital accounts, fixed exchange rates, less transparent credit registries, and weaker financial supervision. The IMF also finds that easy monetary policy during a credit boom likely exacerbates the subsequent downturn when booms turn into busts.

V. How well do central bank models capture channels of monetary transmission and the credit channel?

Macroeconomic policy models should be able to capture the many country-specific linkages between finance, credit, and the real economy explained in the previous section. Keynesian DSGE models, until recently fashionable with central banks, fail in this regard. They ignored the financial frictions highlighted by the Information Economics Revolution, to which Joseph Stiglitz made seminal contributions. Claessens and Kose (2018) observe:

> "In many of these models . . . financial intermediation is largely irrelevant because there are no financial frictions. This means, in turn, that important channels by which interest rate changes could affect the real economy are left out. While this deficiency has been widely acknowledged following the GFC (global financial crisis) . . . progress with modelling has been slow."

These models have also failed to assimilate important research insights on the encompassing of alternative theories, model selection, and the implications of structural breaks (e.g. Hendry and Mizon, 2014). A recent evaluation of New Keynesian, representative agent, DSGE models can be found in the 2018 (Spring) issue of the *Oxford Review of Economic Policy* (vol. 34 no. 1–2), marking 10 years since the global financial crisis.

Hendry and Muellbauer (2018) argue that the conventional practices in how the macro-profession can learn from data have contributed to a lack of progress on the above modelling concerns.[23] The profession has been forced into a schizophrenic condition. On one hand, the combination of the Lucas critique and the demand for tractable micro-foundations for full general equilibrium forces heavy restrictions on models. These restrictions are imposed by the omission of major economic sectors (e.g. the housing or the banking sector), applying Bayesian priors in model estimation, and, at the extreme, resorting to calibration. On the other hand, Sims' 'incredible restrictions' critique of large econometric policy models in his 1980 paper on 'Macroeconomics and Reality', proposed to let data speak, with minimal *a priori* restrictions, by estimation of loosely parameterized VAR models. Unfortunately, the 'curse of dimensionality' then leads to making restrictive assumptions by limiting both the set of relevant variables and the lag-length, and once again resorting to Bayesian restrictions to reduce the impact of that curse. Both these methodological options create mis-specified models through omissions, and limit heavily what can be learned from the data.

As explained in section II, buffer-stock saving theories and a mountain of microeconomic evidence contradict the representative agent NK-DSGE models. Moreover, what Mian and Sufi (2018) call the 'credit-driven household demand channel', is now recognized to have been a crucial element of the global financial crisis.

Many central banks[24] have therefore de-emphasized their DSGE models and have developed or are developing semi-structural models, often on the lines of the US Federal Reserve's FRB-US model structure. The consumption functions in these policy models typically summarize household asset and debt portfolios in a single net worth measure and neglect shifts in credit conditions. These assumptions greatly restrict the interactions of the household and financial sectors: they limit the avenues of monetary transmission, greatly reduce the possibility of a financial accelerator in the model, and compromise an understanding of risks to financial stability.

The FRB-US model is the leading example of this type. One very positive feature of the model is the incorporation of explicit income expectations for each of three types of income: labour, transfer, and property income. Income expectations are missing in the consumption functions in the Fair model (Fair, 2018), and in central bank models for a number of countries including the Netherlands[25], Australia, and South Africa, which otherwise share the above-mentioned defects of FRB-US. The consumption function in the Federal Reserve Board's FRB-US model adopted the approach from the survey by Muellbauer and Lattimore (1995) in assuming two types of agents, one following a textbook 'micro-founded' life-cycle model albeit with a higher risk-adjusted discount rate to compute permanent income, and the other simply spending current labour and transfer income. Other features are the split of aggregate consumption into durables, housing services, and non-durable goods and non-housing services. The model's net worth concept plays an important role in the overall model's interest rate transmission via a calibrated effect of long bond yields on corporate equity valuations, rather than via housing wealth.

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[23] For a more detailed discussion, see Muellbauer (2018) for the Festschrift of Vítor Constâncio at the ECB.

[24] This includes central banks in Canada, Australia, and the Netherlands, and the ECB, which is constructing semi-structural models for the five largest euro-area economies.

[25] The consumption function in the Dutch central bank's DELFI 2.0 model, Berben *et al.* (2018), does split housing and financial wealth. The long-run MPC out of financial wealth (excluding pension wealth) is around 0.04 while that on housing wealth is around 0.058. Pension wealth has a small indirect influence as the funding ratio of pension funds affects consumer confidence whose change enters the short-term dynamics of the consumption function along with changes in the unemployment rate, and in rates of change of real house prices and equity prices A recent unpublished upgrade newly distinguishes household debt (private communication from Robert-Paul Berben).

Since net worth gives equal weight to all assets, FRB-US did not take on board evidence in the survey by Muellbauer and Lattimore that the MPC is higher for liquid assets than illiquid assets and that the MPC for debt is large and negative. It also overlooked the theoretical explanation in the survey of why a housing wealth effect is different from a financial wealth effect and why financial liberalization will shift the collateral effect of housing wealth on consumption. Micro evidence on the so-called *housing wealth effect* on consumption has since confirmed that, at least in countries with home equity withdrawal options, this is much more of a collateral effect than a classical wealth effect, see section II (v).

The claimed micro-foundations of the FRB-US consumption function have not saved it from parameter instability. The estimated speed of adjustment for the non-durable goods and non-housing service component of consumption of 0.19 (i.e. 19 per cent per quarter) for data up to 2009 fell to 0.10 for data up to 2013 and rose to 0.16 for data up to 2017, for a sample for 1970–2017. Tetlow (2015) documents parameter instability in the model over longer periods. Such parameter instability is a typical symptom of a mis-specified model.

Omitting important variables linking housing and credit to the economy (e.g. by using a single net worth measure and ignoring the amplification effects of the credit channel), meant the FRB-US model did not give proper warning of risks faced by the US economy after 2007. At the Jackson Hole conference in 2007, Mishkin (2007) reported the results of FRB-US simulations of a 20 per cent decline in real house prices spread over 2007–8. The standard version of the model simulated GDP lower than the baseline by 0.25 per cent in early 2009 and consumption lower by 0.6 per cent in late 2009 and 2010. Both simulated falls were implausibly low. The simulations further suggested a rapid recovery of residential investment, given the lowering of the policy rate in response to the slowing economy. This erroneous conclusion partly followed because the residential investment equation included house prices in a very limited form, so completely missing the depressing effect of lower house prices.[26] This omission distorts the understanding of the dynamics of monetary transmission. Further, the house price equation within the FRB-US model omits credit, and has a very low speed of adjustment (0.012 per quarter, a factor of ten lower than expected, linking house prices to rents); thus, the feedback from the credit crunch back on to house prices is absent.[27] Moreover, in neglecting credit conditions, it bypasses the implication of the 'state-dependence' of monetary transmission; that is, it misses the variation of interest rate effects with changing credit conditions.

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[26] In the FRB-US model, residential investment is treated as a component of household expenditure. The equation is an equilibrium correction around a target. The target ratio of residential investment relative to the target level of consumption depends on the house price index relative to the consumption deflator, and on a real mortgage interest rate (using expected consumer price inflation). House prices play no role in the dynamics, though the change in the mortgage interest rate, and the deviation between the policy interest rate and its long-run expectation, enter the dynamics. Thus, residential investment hardly responds to house prices in the long run, and they are absent from the dynamics. House prices play almost no role in the transmission mechanism from the policy interest rate to residential investment.

[27] This was modelled by Duca *et al*. (2011, 2016). Consistent with this time series evidence, Favara and Imbs (2015) and Anundsen and Heeboll (2016) provide strong micro-evidence for the causal link between credit supply and house prices in the US. Unusual among central bank models, this link *is* present in the Dutch DELFI 2.0 model: the mortgage stock is strongly affected by dummies for credit conditions, and, in turn, drives house prices.

The ECB is developing country models of broadly the FRB-US type for the five largest euro-area countries, but has begun with a prototype model, ECB-BASE, for the euro area as a whole, Angelini *et al*. (2019), estimated for 2000–17. The equation for aggregate consumption, like FRB-US, distinguishes labour, transfer, and property income but aggregates household balance sheets into a single net worth measure, though it is not statistically significant. Around one-third of households just spend income, and the speed of adjustment for aggregate consumption is 0.22. There is a small interest rate effect but no effect from shifting credit conditions.

The residential investment equation is superior to its FRB-US counterpart, with strong monetary transmission via very significant effects from house prices and mortgage rates, via a user cost term and a (plausible) speed of adjustment of around 0.1 per quarter so that almost two-thirds of the adjustment takes place within 4 quarters. The Dutch central bank's DELFI 2.0 model shares these features.

Unlike the asset pricing approach of FRB-US, where the long-run house price to rent ratio is driven by a real interest rate, the ECB-BASE house price model is derived from inverting a demand equation for housing, given the previous period's housing stock. In their model, real house prices in the long run depend on income and population relative to the housing stock and a user cost term, which incorporates extrapolative expectations based on past house price appreciation. The speed of adjustment, at 0.034, is better than that in FRB-US but low enough to suggest omitted variables, such as credit conditions.

A new policy model from the Bank of France, Lemoine *et al*. (2019) omits all household balance sheets, even net worth, as well as credit conditions, in the consumption function, which is driven by permanent income, based on aggregate household disposable income, and interest rates. It does not adopt the device, used in FRB-US and ECB-BASE, of assuming that some households just spend income, to introduce a larger role for current income. The remarkably low speed of adjustment of 0.12 is symptomatic of specification problems, also an issue for the Dutch DELFI 2.0 model, with an adjustment speed of 0.11.[28]

The residential investment equation is broadly on the lines of ECB-BASE with significant house price and interest rate effects and a plausible speed of adjustment at 0.08. However, as the house price equation is just an AR2 in growth rates (i.e. the growth rate explained by two lags in the growth rate), there is no channel from interest rates, let alone credit conditions, via house prices to residential investment.

For Australia, the Reserve Bank of Australia (RBA)'s new model MARTIN (Ballantyne *et al*., 2019) omits income expectations and credit conditions from its consumption equation, whose long-run solution depends on household disposable income and net worth and a calibrated real interest rate effect. The speed of adjustment for aggregate consumption of only 0.08 is a symptom of major mis-specification.

The residential investment equation in the long run is driven by aggregate real consumption, the relative investment deflator with an assumed elasticity of 1, and a calibrated real interest rate effect, though the change in the nominal mortgage rate and lagged house price appreciation are in the short-term dynamics. The speed of adjustment is a plausible 0.09.

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[28] However, that model has a powerful short-term effect on consumption of the growth rate of real house prices, which therefore transmits some credit and monetary policy shocks.

The house price equation in MARTIN, like that in FRB-US, is based on the asset price arbitrage approach. In the long run, real house prices depend on the rent index and on a real interest rate, taking no account of varying credit conditions. The short-term dynamics does include a calibrated effect from the change in the nominal mortgage interest rate. The speed of adjustment is a remarkably low 0.02, a clear sign of omitted variables, and far from the equally implausible instantaneous adjustment assumed in DSGE models such as Iacoviello and Neri (2010). With such sluggish adjustment to the long run, estimates of monetary transmission from the full model will hinge on the transitory impact of interest rates changes in short-term dynamics.

In the 2018 version of the Fair model, consumption is split into non-durables, services, and durables, all driven by disposable income and net worth and including three demographic trends and nominal interest rates in the long-run solution, with speeds of adjustment of 0.16, 0.10, and 0.09, respectively. Since relative prices of these three consumption categories have altered greatly, the omission of relative price effects in these models is a problem. There is no role for income expectations or credit conditions, though it is possible that demographic trends may be part-proxies for the shifting credit market architecture (or indeed relative prices) in the estimation period, 1954 to 2017. However, there is evidence of considerable instability in estimates of these variables over different samples. Even if one thought that net worth was appropriate for capturing wealth effects, the log net worth formulation is a worse approximation to a life-cycle model than using a wealth to income ratio, as does FRB-US (one of the things FRB-US picked up from Muellbauer and Lattimore (1995)). Fair (2020) finds little evidence in his model that the effect of housing wealth on consumption is different from that of financial wealth. However, as the model omits major variables likely to be correlated with asset prices of both housing and financial assets, such conclusions from a mis-specified model are premature.

In Fair’s model, housing wealth, income, and nominal mortgage rates are major drivers of residential investment. However, as net worth and housing wealth are effectively assumed to be random walks, there is no interest rate channel via house prices, not separately modelled, nor via stock market valuations.

In none of the models discussed, with the partial exception of the Dutch central bank model, is there an explicit credit channel that operates via changes in non-price credit conditions applied by lenders to borrowers. Introducing credit conditions explicitly into a household and housing sector would provide linkages with the asset and revenue base of banks, and with regulatory ratios, which affect the ability of banks to extend credit. This would allow central banks to develop a better understanding of risks to financial stability. As explained further below, household-sector equation systems for consumption, balance sheets, and asset prices together with a residential investment equation, can distinguish the shock amplification mechanisms that put some countries at greater risk of financial instability for the reasons discussed in section IV.

VI. Key ingredients of better models: the credit channel and the household-housing sector

It has been argued in defence of, for example, the LCPIH consumption function and New Keynesian DSGE models, that they represent a choice towards the theory-consistent end of a trade-off on a frontier between micro theory and consistency with evidence. Appendix 1 considers the nature of this trade-off and the importance of shifts in the frontier, drawing parallels in the history of science. Micro evidence and theory discussed in section II have shifted the frontier, leaving behind the LCPIH consumption function and the NK-DSGE model. The revolution in theory and evidence points to qualitative characteristics of a consumption function that relaxes the restrictions used in current large policy models—the net worth restriction on balance sheet effects and the omission of the credit and cash flow channels. Appendix 2 traces the development of the specification from its origins in 1989 to the formulations in Aron *et al*. (2012), Duca and Muellbauer (2013), and Chauvin and Muellbauer (2018).

(i) The credit-augmented consumption function

To incorporate shifts in credit constraints such as the down-payment constraint for a mortgage, the disaggregation of balance sheets, a role for house prices, income uncertainty, interest rates, and demography, the long-run version of this credit-augmented aggregate consumption function is:

$$\log(c_t/y_t) = \alpha_{0t} + \alpha_{1t}r_t + \alpha_2\theta_t + \alpha_{3t}\log(y_t^P/y_t) + \gamma_1 NLA_{t-1}/y_t + \gamma_2 IFA_{t-1}/y_t$$
$$+\gamma_{3t}\, log(hp_{t-1}/y_{t-1}) + \gamma_{4t}HA_{t-1}/y_t + \gamma_5 demog_t + \varepsilon_t \tag{1}$$

Here c is consumption, y is income, r is a real interest rate, θ is an indicator of income uncertainty, y^p/y is the ratio of permanent to current income, *NLA* is liquid assets minus debt,[29] *IFA* is illiquid financial assets, *hp* is an index of house prices, *HA* is gross housing wealth, and *demog* captures the effect of demography on consumption. Some coefficients are time varying functions of indices of shifts in credit conditions.

The intercept α_{0t} increases with greater availability of non-housing loans and of mortgages, as the need to save for a down-payment is reduced. However, for a given level of access to mortgage credit, higher house prices relative to income increase the size of required down-payments. The coefficient measuring the sensitivity of down-payment requirements to house prices relative to income, γ_{3t}, should become less negative if lenders relax the down-payment constraint. However, if the focus of credit easing by lenders instead is on relaxing debt-to-income or debt service ratios, this reduction in minus γ_{3t} would be absent.[30] If access to home equity loans increases, the coefficient, γ_{4t}, measuring the marginal propensity to spend out of housing wealth, should increase. One might also anticipate that expectations of future income growth, captured in α_{3t}, would have a larger effect on consumption when credit constraints ease. It is also possible that α_{1t}, the sensitivity of consumption to the real interest rate, might be affected by credit conditions. However, the direction of the effect is unclear a priori, with greater access to credit and higher levels of debt pulling in opposite directions. The full dynamic specification incorporates partial adjustment, and changes in the unemployment rate to proxy income insecurity, and changes in income and in nominal interest rates for countries where floating rate debt is prominent.[31]

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[29] It is possible to disaggregate net worth into four, instead of three, main elements, with a separate coefficient on debt. However, relative to a common alternative restriction, the assumption that mortgage debt can just be netted off gross housing wealth, the restriction that the coefficient on debt is minus that on liquid assets is better supported by the data.

[30] It is even possible that, to preserve the overall level of risk, lenders could tighten the loan-to-value constraint to offset a loosening of the debt service constraint. Evidence of such behaviour in the setting of loan-to-value and loan-to-income constraints by mortgage lenders for UK first-time buyers was found by Fernandez-Corugedo and Muellbauer (2006). One might then observe an increase in minus γ_{3t} as the debt service constraint is relaxed.

[31] In the estimated UK version of the equation, see Aron *et al*. (2012), the change in nominal interest rates is weighted by the debt/income ratio as one would expect larger cash flow effects when debt burdens are higher.

Estimates for a range of countries including the UK, US, France, Germany, South Africa, and Canada suggest quarterly speeds of adjustment of 0.35 to 0.55. Note that a speed of 0.35 would imply that 82 per cent of the adjustment to a shock would be complete within one year and higher speeds imply even higher percentages. The coefficient α_{3t} on the ratio of permanent to current income is typically in the range 0.4 to 0.7, sometimes with mild evidence of increases with ease of credit.[32] Estimates of the coefficient γ_1 on liquid assets minus debt are mostly in the range 0.09 to 0.16, while estimates of the coefficient γ_2 on illiquid financial wealth are typically 0.02 to 0.025. Estimates of the time-varying housing collateral effect for the US, UK, and South Africa are around zero in the 1970s, and later positive but fluctuating with credit conditions, reaching peaks in the mid-2000s, e.g. around 0.06 in the US. In contrast, no collateral effects could be found for Germany and only a very small one for France, and for both countries, significant negative effects for the log house price to income ratio, consistent with a substantial down-payment constraint encouraging saving.

To make the consumption model more concrete, consider the use by Muellbauer (2020) of a slightly stylized version of the US consumption function as a framework to discuss the consumption consequences of the COVID-19 pandemic and the government and private responses to it, such as temporary lockdowns and increased social distancing. The credit-augmented consumption function as estimated for the US (see Duca and Muellbauer (2013)) is presented as follows (all in constant prices).[33]

$$\log c_t = constant + 0.6 \log c_{t-1} + 0.2 \log y_t + 0.2 \log yperm_t + 0.04\, NLA_{t-1}/y_t$$
$$+0.008\, IFA_{t-1}/y_t + 0.016\, HLI_t \times HA_{t-1}/y_t + 0.04\, CCI_t - 0.005\, \Delta UR_t + \varepsilon_t \quad (2)$$

Here $yperm_t$ is permanent non-property income, applying a quarterly discount rate of 5 per cent to quarterly income flows. HLI_t is a time-varying measure of mortgage credit conditions which drives the marginal propensity to consume out of housing wealth HA_{t-1}, and CCI_t is a time-varying measure of consumer credit conditions based on the FRB's Senior Loan Officer Survey. ΔUR_t is the change in the unemployment rate, proxying income insecurity. ε_t is a consumption shock not mediated through any of the other variables. In the context of the incidence of the pandemic in 2020, this consumption shock would have been of an entirely unprecedented magnitude as consumers drastically cut spending on, for example, travel and hospitality, in part because such consumption was, for some of the time, no longer available. The equation offers a useful framework for discussing the consequences for spending of a short-term fiscal stimulus combined with massive increases in employment insecurity and of declines in permanent income through longer-term implications of the pandemic on the global economy and on important sectors of the US economy. Consequences of potential changes in asset prices and credit

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However, when credit conditions are easy, households can refinance to ameliorate the strain on cash flow when nominal rates rise. This explains an offsetting interaction effect with credit conditions of the weighted nominal interest rate change.

[32] Increases in income inequality tend to increase the fraction of households with high MPCs, see section II, reducing the average value of α_{3t}. Rajan (2010) argues that pressure for financial deregulation in the US leading to credit liberalization came from increasing income inequality and the lack of income growth for the lower half of the distribution. This could explain why empirical evidence for an increase in α_{3t} with credit conditions is not stronger.

[33] The numerical estimates have been rounded and come from an update of the equation published in Duca and Muellbauer (2013). All estimates are significant at least at the 99 per cent level. The terms for real interest rate and changes in nominal rates on floating rate debt are not shown, taking the view that no major changes of consequence were likely to occur in 2020.

conditions, partly offset by Federal Reserve actions, can also be discussed. Muellbauer (2020) argues for a historic short-term mismatch between changes in consumption and in current income, with the former more negative than the latter.

To interpret the model, note that the log of lagged consumption appears on the right-hand side of equation 2 with a coefficient of 0.6. Hence, to obtain the long-run solution, this requires division of the coefficients on log y and all other terms (apart from the change in the unemployment rate) by $1 - 0.6 = 0.4$. This is known as the *speed of adjustment.*[34] The speed of adjustment here suggests plausibly that almost 90 per cent of adjustment to a shock occurs within one year. By contrast, in inadequately specified consumption equations in the structural econometric policy models at some central banks, speeds of adjustment are mostly below 0.2, as noted above, implying an implausibly slow adjustment to policy changes or exogenous shocks. Quite apart from slow adjustment, many of these models also omit another important variable, the effect of changes in unemployment.

The equation imposes long-run homogeneity. That is, if income and all components of wealth double, then consumption doubles as well. This is achieved by imposing that the sum of the two income coefficients is 1 in the long-run, and that the wealth terms are expressed as ratios to income.

Translated into the notation of equation 1, equation 2 implies that the relative weight on permanent income α_{3t} = 0.5, the MPC out of net liquid assets γ_1 = 0.1, the MPC out of illiquid financial assets γ_2 = 0.02, and the MPC out of gross housing wealth γ_{4t} = 0.04 when HLI is normalized at 1 (where the peak of the mortgage credit conditions indicator HLI in 2005 would have been around 1.3).

The interaction effect between mortgage credit conditions and housing wealth in the US and the UK was important in explaining the drastic collapse in the consumption to income ratio during the global financial crisis. There was a sharp contraction in credit availability as explained in the discussion of Figure 1. There was also a sharp fall in the housing wealth to income ratio, even more pronounced in the US than the UK. The interaction between the two then produced a ‘double whammy’ of an effect on consumer spending. Models omitting this kind of non-linearity have little chance of explaining the observed data. DSGE models based on the consumption Euler equation would have to assume unprecedented and persistent shifts in exogenous technology and preference shocks to explain the dynamics of the consumption and output data. Moreover, the important role in short-term dynamics that the credit-augmented consumption function attributes to employment insecurity proxied by changes in the unemployment rate could have no role in representative agent DSGE models founded on the consumption Euler equation.

Turning to the aggregate estimates for the total of consumers, the equation parameters suggest that the marginal propensity to consume out of aggregate current income is around 0.2 within the quarter, and around 0.45 after 4 quarters. This could have implications, for example, for how quickly a fiscal ‘helicopter money drop’ is spent. Of course, this is an approximation for aggregate data. The weight on current income ($1 - \alpha_{3t}$ in equation 1) compared to permanent income (α_{3t} in equation 1) is likely to be higher for less affluent households. Therefore, a fiscal transfer disproportionately benefitting the less affluent will result in larger short-term increases in spending. For policy simulations, equation 2 provides a framework for adjusting aggregate effects for distributional incidence. Microeconomic evidence on how the parameters of equation 2 vary between households with different characteristics would be a useful complement for undertaking such distributional adjustments.

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[34] This is more evident when rewriting the model as: Δlog c = 0.4 (0.5 log y + 0.5 log yperm + etc. – log c_{-1}). The 0.5 weight on permanent income in the long-run solution is far below that implied by the LCPIH.

(ii) Consistency of the credit-augmented consumption function with micro-evidence

Equations 1 and 2, and plausible assumptions on how the relative weights on current and permanent income vary across households, are nicely consistent with the findings of Crawley and Kuchler (2018) on how the MPC out of current income varies according to the structure of household balance sheets. The marginal propensity to spend is highest for asset-poor households, intermediate for those with illiquid assets (such as housing wealth) but no liquid assets, and lowest for the doubly asset rich. As noted in section II, these findings grossly contradict the LCPIH.

Equation 1 implies the following MPC:

$$\frac{\partial c}{\partial y} = c/y[1 - \alpha_{3t} - \gamma_1 NLA_{t-1}/y_t - \gamma_2 IFA_{t-1}/y_t - \gamma_{4t} HA_{t-1}/y_t]$$

For the asset-poor, termed ‘hand-to-mouth’ by Crawley and Kuchler, since NLA, IFA, and HA are close to zero, the MPC is $c/y[1 - \alpha_{3t}]$. One would expect the ratio of consumption to current income to be around 1 and α_{3t} to be below the population average since these households find intertemporal smoothing of consumption difficult except through unsecured borrowing. Crawley and Kuchler find MPCs out of transitory income of around 0.8, which would be consistent with a plausible value of α_{3t} of around 0.2.

According to Crawley and Kuchler, the wealthy hand-to-mouth households with an MPC out of transitory income of around 0.5 typically have mortgage and other debts, own housing wealth, but have very little liquid assets. Most such households are likely to have some illiquid pension wealth also. A household in the middle of its career profile with debt around twice annual income (NLA/y = –2), pension wealth around annual income (IFA/y = 1) and housing wealth four times annual income (HA/y = 4) would be typical in the US and UK middle classes. Such households would be more able to be forward looking than the poor hand-to-mouth, so that a plausible value of α_{3t} would be 0.5. With γ_1 =0.1, γ_2 =0.02, and γ_{4t} =0.04, values implied by the estimates in equation 2 and c/y = 0.95, the MPC out of transitory income would then be 0.45 at the maximum value of mortgage credit availability and 0.49 at the post GFC value of HLI.

For doubly wealthy households, for whom Crawley and Kuchler find an MPC out of transitory income in the region of 0.25, α_{3t} would be expected to be even higher than for the wealthy hand-to-mouth, but γ_{4t} lower since the collateral role of housing wealth would be less relevant. For such households, housing wealth would be more akin to illiquid financial wealth. For example, with c/y = 0.9, α_{3t} =0.6, γ_2=0.02, and γ_{4t}=0.02, NLA/y = 0 (with debt and liquid assets cancelling each other), IFA/y = 4 and HA/y = 6, the MPC out of transitory income would be 0.18, in the range of estimates found by Crawley and Kuchler.

To conclude, the credit-augmented consumption function shown in equation 1 is consistent with the micro evidence of Crawley and Kuchler on how MPCs out of transitory income vary with household balance sheets, with the highest values for the asset poor, the lowest for the doubly asset rich, and intermediate values for wealthy hand-to-mouth households. Moreover, equation 1 suggests how the MPCs are likely to vary with changing credit conditions: more restrictive credit conditions, associated with lower average values of α_{3t} and of γ_{4t}, result in higher average MPCs, higher values of the expenditure multiplier, and more effective fiscal policy. The parameters in equations 1 and 2 can be regarded as an average of the marginal responses to common variations in each of the key elements of the budget constraints faced by households. The equation is therefore a useful quantitative bridge between what a full-blown heterogeneous model might show, taking into account all individual details, and an aggregate model that can be estimated on time-series data. As indicated above, with estimated parameters of equation 1 for micro data, microsimulations of aggregate behaviour could be carried out, modifying the implications drawn from estimates of average parameter values from aggregate time-series data. Moreover, for policy discussions on monetary policy committees, equation 1 provides a useful framework to discuss different components of policy and shock transmission and one that is amenable to quantitative evidence-based investigation.

(iii) Outlines of a household-housing model

To carry out policy simulations, the credit-augmented consumption function above, with balance sheet effects that break up the net worth restriction, needs to be embedded in a small system of equations also including the main balance sheet categories, asset pricing—especially of housing—and a residential investment equation. The latter has two functions: it captures an important part of monetary policy transmission and of the financial accelerator and, as new investment is the main element in the flow of the acquisition of housing by the household sector, it helps close the household sector model.

As explained in Hendry and Muellbauer (2018) a key contribution of such a small systems approach is to extract credit conditions as common latent variables from the system which Duca and Muellbauer (2013) termed a ‘latent interactive variable equation system’ (LIVES). Chauvin and Muellbauer (2018) estimated a six-equation LIVES for France for consumption, house prices, unsecured debt, mortgage debt, liquid assets, and ‘permanent income’—with latent variables for secured and unsecured credit. Geiger *et al*. (2016) estimated a similar system for Germany.

To provide a brief guide to the structure of these equations, let us begin with house prices. As explained in an *Oxford Review of Economic Policy* review of the role of housing in the economy (Muellbauer and Murphy, 2008), the most basic theory of what determines house prices is just a story of supply and demand, where the supply—the stock of houses—is given in the short run. Then prices are given by the inverted demand curve, that is, by the stock of housing and the factors driving demand.[35] Let the demand for the housing stock *h* be given by

$$\log h = -\alpha \log hp + \beta \log y + z \qquad (3)$$

where *hp* = real house price, *y* = real income, and *z* = other demand shifters. The own price elasticity of demand is $-\alpha$ and the income elasticity is β. Solving yields

$$\log hp = (\beta \log y - \log h + z) / \alpha \, . \qquad (4)$$

An equilibrium correction formulation embeds the long-run formulation (4) in a dynamic equation. An advantage of the inverted demand function approach (i.e. expressing price as a function of quantity and the other factors shifting demand) is that it is well-grounded theoretically, unlike many ‘*ad hoc*’ approaches. In addition, we have strong priors regarding the values of the key long-run elasticities, corresponding to the ‘central estimates’ set out in Meen (2001) and Meen and Andrew (1998), *inter alia*. For example, many estimates of the income elasticity of demand suggest that β is in the region of

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[35] Inverse demand functions have a long history, particularly in the analysis of markets for natural resources. Theil (1976) refers to a 1909 Danish study as the first empirical study of inverse demand functions.

1, in which case the income and housing stock terms in the above equation simplify to log income per house, i.e. log y – log h.

The demand shifters included in z cover a range of other drivers, crucially including mortgage credit conditions (see section IV above), and nominal as well as real interest rates, represented by user cost (see section III). The user cost takes into account that durable goods deteriorate, but may appreciate in price and incur an interest cost of financing as well as tax. The usual approximation is that the real user cost is $uc = hp\left(r + \delta + t - h\dot{p}^{e}/hp\right)$, where r is the real after-tax interest rate of borrowing, possibly adjusted for risk, δ is the deterioration rate, t is the property tax rate, and $h\dot{p}^{e}/hp$ is the expected real rate of capital appreciation. Chauvin and Muellbauer (2018) find strong evidence for France of the tendency of some home-buyers to extrapolate past capital appreciation in generating expected appreciation. However, for France the nominal mortgage rate effect on house prices is even stronger than the user cost effect. This is probably because limits on debt service ratios, i.e. nominal mortgage payments relative to income, are a key criterion used by lenders to ration mortgage credit. Then reductions in nominal rates expand effective credit availability and raise house prices. This is an important element in monetary policy transmission in France, since house prices affect residential investment (see section III). The estimates for France suggest that of the rise of around 120 per cent in real house prices between the late 1990s and 2016, around 65 per cent was due to lower nominal mortgage rates, around 60 per cent to the shift in mortgage credit conditions, while the expansion of the housing stock overcame the combination of income and population growth and demography, for a small negative net effect of around 5–10 per cent.

The latent variable for mortgage credit conditions estimated in the equation system is highly negatively correlated since 1990 with the ratio for French banks of non-performing loans to total private-sector lending, suggesting a direct link between the ability of the banking sector to extend credit and house prices. Another interesting finding is that demographic effects are not confined to younger first-time home-buying age groups. This is consistent with the asset-accumulation function of home ownership for pre-retirement households.

Apart from the consumption function and the house price equation, the equation for the stock of mortgage debt relative to income also has a crucially important role for mortgage credit conditions, directly as well as indirectly by conditioning the stock of mortgage debt on the lagged house price to income ratio. As we have just seen, the latter depends on mortgage credit conditions. Other things being equal, one would expect higher house prices to result in higher mortgage debt.[36] The formulation is again in an equilibrium correction form with a basic log-linear form of the long-run solution. The French evidence is that the nominal mortgage rate effect completely dominates a direct user cost effect, given that indirect effects of both are already captured by conditioning the mortgage stock on house prices relative to income. The demographic evidence, as for house prices, is consistent with the asset-accumulation motive for home-ownership, which extends to pre-retirement households as well as to younger first-time buyers.

Equations for consumer credit and for liquid assets relative to income also have an equilibrium correction form with a basic log-linear form of the long-run solution. A key element in both is a latent variable to measure shifts in non-mortgage consumer credit availability, with a positive effect on consumer credit (and consumption) and a negative effect on liquid asset holdings, as easier access to consumer credit reduces the need to hold liquid assets as a buffer-stock. It has a quite different profile from the mortgage credit conditions indicator, with an earlier easing in the 1980s when consumer credit grew strongly from low levels. The real interest rate on consumer credit has a strong negative effect on demand for consumer credit, as does the post-retirement share of adults. The composite of wealth effects from the consumption equation captures part of the derived demand for consumer credit. In the dynamics, a positive effect from the change in the unemployment rate is consistent with a buffer-stock role of consumer credit in maintaining consumption in the face of temporary job losses.

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[36] Unless housing becomes so unaffordable that the extensive margin of potential home-buyers shrinks so much as to outweigh the higher average mortgages of successful buyers at the intensive margin.

The demand for liquid assets increases with the real rate of return on deposits and with the house price to income ratio, probably because of the need to accumulate a higher deposit to obtain a mortgage when house prices rise. Holdings of liquid assets relative to income fall as the lagged ratio of illiquid financial assets to income rises, suggesting an element of substitution between the two asset classes. The share of post-retirement adults has a positive effect on the demand for safe liquid assets.

The last equation in the six-equation system for France estimated by Chauvin and Muellbauer (2018) is an equation for the log of *per capita* permanent income, a reduced form for forecasting future household income. The ratio of working age population to the total population captures the fact that national output is partly constrained by the labour force. Long lags in the response to real interest rates, real oil prices, and competitiveness as represented by the real exchange rate probably capture effects on national income that operate through capital accumulation as well as profitability. However, changes in nominal interest rates also matter: their negative effect is an aspect of monetary policy transmission. The real stock market price index represents some of the predictive power of asset prices and there is also an effect from a survey measure of consumer confidence. The unemployment rate with a negative effect may capture the weaker bargaining power of workers in negotiating wages when unemployment is high.

Since the equation is a reduced form representation of collective household expectations for income growth, it was necessary to take account of the fact that the global financial crisis was not expected. This meant having to adjust an equation estimated for post-GFC data to take into account that households would only have learned gradually to take full account of the structural shift caused by the GFC (see Chauvin and Muellbauer (2018) for details). Such a single-equation multi-period forecasting model is not the only way to generate expectations of permanent income. FRB-US use a separate VAR model for the main components of household income for this purpose, but also generate an alternative, model-consistent set of income forecasts for permanent income, which fits less well.

For completeness of this household-housing sub-system it is necessary to add an equation for the acquisition by households of housing assets. This is likely to be dominated by residential investment done either by households in the form of improvements, or ends up under the ownership of households. Duca *et al.* (2020) review research on residential investment, most recently the 25-country study for the OECD by Cavalleri *et al*. (2019). The key driver in this research is the ratio of house prices to an index of building costs, which for many countries is well proxied by the price deflator for residential investment. Countries vary a great deal in the supply elasticity of residential investment. For example, their estimate for the US is that a 1 per cent increase in real house prices leads eventually to a 2.8 per cent increase in the volume of residential investment, but under 1 per cent in Belgium, France, Germany, Italy, and the UK. Cavalleri *et al*. (2019) find that more habitable land per head, greater ease of construction (proxied by the past expansion of built-up area), and less land-use restrictiveness boost the price elasticity of housing supply. This implies important differences between countries in monetary transmission via housing markets.

While the OECD study is an important contribution, its limited short-term dynamics probably do not fully capture the extrapolation of recent changes in real estate prices in the expectations of home builders and also omits interest rate effects. Since house prices are sticky, short-term demand shocks have an effect on residential investment not mediated through prices. Future research in this area also needs to take account of the major structural break caused in countries such as the US and Ireland by the GFC. A great deal of productive capacity, all the way down the supply chain, was lost and the construction industry became more concentrated, with many smaller building firms going under when their cash flows and the value of their land banks collapsed. This suggests that post-crisis, monetary transmission via the housing market also altered.

The final component of the household balance sheet is illiquid financial assets, held both directly and indirectly through life-insurance and pension funds. In principle, both flows of funds and prices need to be endogenized. Relative rates of return, changes in tax rules, in pension regulation, and the provision of state pensions, and demography should figure in models of the flow of funds. Empirical evidence suggests that portfolio adjustment is far more sluggish than textbook models of portfolio choice would imply. Financial asset prices are notoriously difficult to model, and sometimes taken just to be random walks. In the FRB-US model, prices of corporate equities are linked with long-bond yields, but the long-run relationship is calibrated rather than estimated. Financial asset prices are an important way in which shocks transmit to the household sector. Simulations of a large policy model are likely to be sensitive to how this shock-transmission is modelled, though more so in countries such as the US where illiquid financial assets are a major part of household balance sheets.

(iv) The rest of the system

The household-housing sector model that has just been outlined needs to be plugged into a larger econometric model with equations for capital formation and employment feeding, via production functions, into output, and equations for imports and exports, prices and wages, exchange rates, monetary policy rules, and government and financial sectors. As far as financial-real economy linkages are concerned, models such as ECB-BASE model interest rates by:

> “evaluating a risk-free term structure in line with the expectation theory. The risk-free rates are then combined with endogenously modelled risk spreads to estimate specific lending rates. The wealth components are derived by modelling the stock of financial and housing wealth as well as the flows in terms of property income from financial assets and housing.” (Angelini *et al*., 2019)

While the introduction of risk spreads is an advance on pre-GFC models, the model currently omits a bank capital channel that endogenizes bank balance sheets, including non-performing loans, and funding access of banks, with macroprudential constraints on excessive risk taking by banks. The combination of bank balance sheets and regulatory constraints should have an impact on credit supplies offered to non-financial corporations and households. Among policy models of which I am aware, the Dutch central bank’s DELFI 2.0 model comes closest to meeting these requirements, though it does not do so through explicit credit conditions indices. Ideally, the banking module should provide the link to the credit conditions indices for unsecured and mortgage loans featuring in the household-housing sub-model discussed above. In turn, the combination of high levels of debt, negative income and employment shocks, and asset price declines generated in the real economy feed back to non-performing loans. These two-way linkages need to be made explicit in a policy model suited to setting macroprudential and monetary policy and for macro stress testing.

In Chauvin and Muellbauer (2018), secured and unsecured credit conditions are treated as latent variables—functions of time dummies (or of stochastic trends in state-space estimation). The latent variable approach focuses on the supply side of household credit conditions, extracting the common information about these credit conditions from a set of related observables. As such, for monitoring the build-up of risks in credit markets, they are likely to be superior to the credit-to-GDP gap recommended by the Bank for International Settlements for setting counter-cyclical capital requirements. Endogenizing these credit conditions, as proposed above, with links to bank balance sheets and macroprudential instruments such as limits on loan-to-value and debt or debt-service-to-income, would formalize the credit channel links between the financial sector and the household and housing sectors of the economy. Since the global financial crisis, new frameworks for monitoring risks to financial stability (Adrian *et al*., 2019), and new toolkits of macroprudential instruments have been developed; see Duca *et al.* (2020) for a review of the evidence on their effectiveness. Changes in settings of macroprudential policy levers will have wider macroeconomic consequences, including on growth and inflation as well as on risks to financial stability, and these should be part of a multi-purpose policy model.

As explained in section IV, country characteristics are quite heterogeneous and the appropriate model design for each country needs to take account of this. For example, the responsiveness of consumption to higher house prices depends on access to home equity loans, ease of refinancing, and severity of down-payment constraints. Chauvin and Muellbauer (2018) and Geiger *et al*. (2016) find evidence that in France and Germany this transmission mechanism is dampening, while Aron *et al*. (2012) and Duca and Muellbauer (2013) find a powerful amplifying mechanism in the UK and the US.

The discussion around the financial accelerator illustrated in Figure 1 also explained another aspect of amplification involving housing and other real estate: the responsiveness of real estate demand to expected returns embedded in the user cost of housing depends on gearing, the tax system, and the degree to which investors *extrapolate* recent gains. With such extrapolation, a series of positive shocks, for example, easier credit conditions, lower interest rates, or higher income growth, generate capital gains in housing, which fuel expectations of further gains, raising housing demand and prices further. In turn, gearing depends on financial regulation, tax incentives, and perceived risk.

The evidence from Duca *et al*. (2011, 2016) is that, in the US, the extrapolation of past gains made a major contribution to the overshooting of US house prices up to the 2006 peak. If the risk premium perceived by housing investors and embedded in user cost rises as house prices rise relative to fundamentals, eventually the extrapolation of past gains runs out of steam and user cost rises. Once house prices begin to fall, the higher risk premium, together with the extrapolation of recent falls, can lead to overshooting on the downside. This could be an important ingredient in introducing an endogenous element in what drives the turning point from boom to bust which some theoretical models of the financial accelerator find difficult to explain. Incorporating such a variable risk premium in the house price equation of the proposed household-housing sector system is likely to enhance the usefulness of the system for assessing risks to financial stability. In countries where regulation and industry structure prevent high levels of household gearing, this housing-related source of financial instability is likely to be absent, and this should be reflected in the estimated structure of each country's policy model.

VII. Conclusions

For general equilibrium, it is necessary to augment the consumption function with equations for permanent income and the immediate balance sheet drivers, and for residential investment, in a household-housing equation sub-system. This needs to embed common mortgage and unsecured credit conditions in the equations, and sub-system estimation is required to impose the cross-equation restrictions implied by these common factors. A model of this kind will track monetary transmission more accurately, can be used to update the potential build-up of risks to financial stability from credit market developments, and will be useful in incorporating the effects of macro-prudential tools. Such a sub-system needs to be incorporated in a larger econometric model with equations for other expenditure components, including non-housing investment and inventories, government expenditure and revenue, exports and imports, and prices, wages, and the exchange rate, with a production function or production functions linking output to the capital stock, employment, and the labour force. Further, some treatment of the financial sector is necessary, including an equation for equity prices and links between short and long interest rates, and ideally a small system for the banking sector, linking credit conditions, through intermediary observables such as credit spreads, with the asset and revenue base of banks, regulatory ratios, and data on non-performing loans. This should make it possible to endogenize indices of credit conditions and links with macroprudential instruments.

Macroeconomic policy models that perform well in tracking transmission from the financial sector to the real economy are needed for macroprudential stress testing of the financial system, now widely adopted by financial regulators around the world. Moreover, the debate over whether monetary policy should ever 'lean against the wind' (Borio and Lowe, 2002; Svensson, 2015, 2018, 2019), would be enhanced by policy models that capture both monetary policy and credit channels. One can argue that early in a credit cycle, when policy-makers are unsure about how the cycle could develop, a rise in interest rates for macroprudential rather than anti-inflationary reasons, could be the first step of a strategy to protect financial stability. Monetary policy is more nimble and more easily reversed than macroprudential instruments if later developments do not bear out the early caution.

A multi-purpose policy model including the household-housing sector sub-system discussed above would be useful in developing the new integrated policy framework, recommended by the IMF (Gopinath, 2019). The IMF framework includes monetary and macroprudential policy and, for small open economies, potential interventions in forex markets and in international capital flows. It does not, at present, include fiscal policy, though central banks in 2019 have called for expansionary fiscal policy in countries where monetary policy has reached its limits. The new microeconomic evidence on how the MPC out of transitory income varies with household balance sheets, consistent with the credit-augmented consumption function discussed above, should be helpful in designing fiscal policy with a high impact on demand.

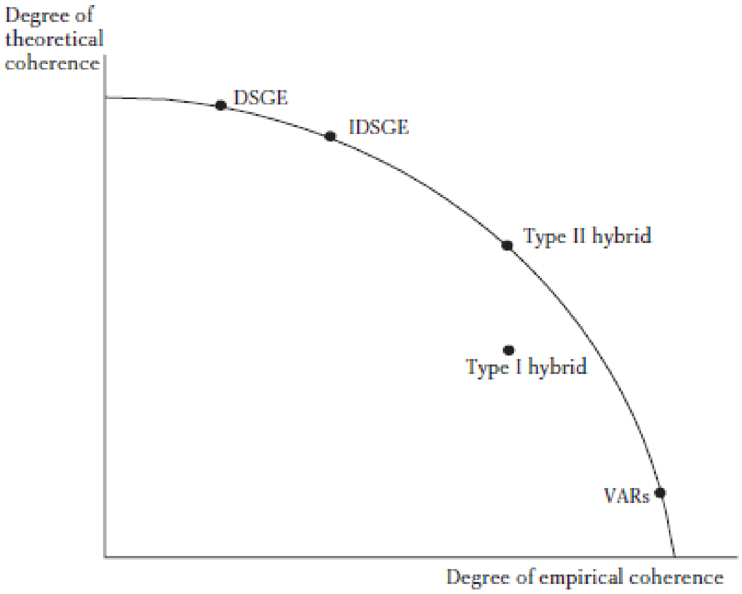
To conclude, while calibrated heterogeneous agent incomplete markets models based on individual optimizing behaviour have their place in macroeconomics, as do 'back of the envelope' calculations of monetary policy shocks for household spending, as in Auclert (2019) and Slacalek *et al*. (2020), missing dynamic general equilibrium effects limit insights from such models. This paper therefore argues in favour of improving large semi-structural macroeconometric models to take better quantitative account of *qualitative* insights from the new micro-evidence and theory and better capture these dynamic general equilibrium effects. In none of the central bank models discussed in section V, except the Dutch central bank's DELFI 2.0 model, does the banking sector feature strongly, though some models link bank lending rates, via spreads, to long-run interest rates and the central bank policy rate.

For such models to be able to give a detailed account of potential financial instability, they will also need to be able to summarize within-financial sector transmission and amplification of shocks. As argued in section IV(ii), this arises particularly from property defaults and foreclosures. These contract the capital base and liquidity of financial institutions, increasing possible contagion between them, and affecting their ability to extend credit, as well as raising risk spreads on financial instruments. Property defaults and foreclosures represent tail risks and therefore have a highly non-linear relationship with aggregate assets prices and debt levels, as Aron and Muellbauer (2016) demonstrate in models for arrears (delinquencies) and repossessions (foreclosures) for the UK mortgage market. Models with these kinds of non-linearities will replicate low volatility growth in 'normal' times but can warn of potential crisis risks and handle crises without having to adopt a different modelling framework.

Appendix 1: On the trade-off between theoretical coherence and fitting the facts

In an influential article, Pagan (2003) argued that there was a trade-off between empirical and theoretical coherence of models, as illustrated in his Figure 1 (reproduced here as Figure A1).

Figure A1: Trade-off between theoretical and empirical coherence for models



Source: Pagan (2003, Figure 1).

He located the DSGE models of the time as being closer to the theoretical coherence end of the trade-off, and VARs as being closer to the empirical coherence end. Models of the time such as the Quarterly Projection Model for Canada, labelled 'incomplete DSGEs', were classified as being on the frontier. Macroeconometric models using equilibrium correction mechanisms with implicit long-run solutions, such as the model of the Bank of England (1999), labelled 'Type I hybrid', he classified as below the research frontier. Theoretical coherence clearly meant having strong foundations in micro-foundations under the assumption of optimizing behaviour by individual agents.

Crucial to his conception was the idea of the possibility of shifts in the frontier. When the frontier shifts, there is no longer a trade-off between models below the frontier and alternatives: models below the frontier become obsolete. Developments in thinking about household behaviour explained in section II have made the standard life-cycle permanent income hypothesis (LCPIH) obsolete. These developments are radical enough to compare with radical shifts in the history of science. Observations by Galileo of four moons orbiting around Jupiter and the phases of Venus, like Earth's moon, contradicted the widely accepted cosmology of Aristotle and Ptolemy's model of Earth as the centre of the universe, with all heavenly bodies revolving around it. Galileo's evidence supported the alternative hypothesis of Copernicus that the Earth and other planets revolved round the sun. Kepler gathered large amounts of data on the movements of the planets, contradicting the epicycles used by Ptolemy to explain observed movements of heavenly bodies. Kepler's laws of planetary motion were then explained by Newton's gravitational theory.

Analogous to the Aristotelian assumption that the Earth is the centre of the universe, is the textbook LCPIH. This is founded on the assumption of highly informed, as-if infinitively lived individuals making rational individual choices between consumption now and consumption in future periods and facing linear budget constraints, no transactions costs and efficient capital and insurance markets, making it possible to largely eliminate uncertainty. Then the intertemporal optimality condition, the consumption Euler equation, follows. It was applied in DSGE models that further assumed that aggregate behaviour was just a scaling up of the individual behaviour of a representative household. Though decisively rejected against evidence from aggregate consumption data, the tractability of the outcome and the consistency with a concept of rational action, persuaded practitioners to retain the Euler equation in calibrations, or Bayesian estimation that put a high weight on the priors as against the evidence, and applied the model to a narrow range of aggregate data. Analogously, Galileo's evidence against the Earth-centred view of the universe was widely disregarded for many years.

In the alternative semi-structural policy models, the solved-out consumption function followed from the same LCPIH assumptions. Here consumption is a linear function of permanent non-property income and net worth. It has been a convention in those models for decades, following Ando and Modigliani (1963), that net worth was the right concept to capture financial wealth, whether liquid or illiquid, property wealth, and debt. Models differed mainly between those with careful controls for expected as well as actual non-property income (e.g. FRB-US) and those that just focused on actual income (e.g. generations of Fair's models (Fair, 2017, 2018) and the RBA's MARTIN). The latter implicitly assumed either random walk behaviour for income (which would imply that current income *is* permanent) or that lags in the model were an adequate reduced-form representation of expectations. Asset prices, both financial and real estate, are quite cyclical and respond to many shocks including to credit supply, risk appetite, and growth expectations. Hence, for some countries such as the US, there was enough explanatory power for aggregate consumption in variations in net worth to sustain the model. In a similar way, the epicycles of Ptolemy were thought by sixteenth century observers to be an adequate explanation of the limited set of data for planetary movements on view at the time.

The information economics revolution with its emphasis on asymmetric information, and hence credit and liquidity constraints and imperfect insurance, made it clear that risks could not be fully diversified and hence brought to the fore the idiosyncratic uncertainty faced by individual households. Deaton (1991) and Carroll (1992), and in many later papers, established that, even in the simplest one-asset models, households would save to acquire a buffer stock to protect themselves against temporary fluctuations in income or consumption need. This rejects the idea that saving is just about intertemporal choice along a linear budget constraint between consumption in different periods. Deaton and Carroll's work implies that consumption is *not* a linear function of permanent income and wealth. More recent research discussed in section II has examined more realistic budget constraints with different types of assets and debt subject to transactions costs and other forms of non-linearity, e.g. Berger *et al*. (2018) and Garriga and Hedlund (2020). This body of work on optimizing behaviour of heterogeneous agents in an incomplete markets setting is the economics equivalent of the conceptual Copernican revolution. To derive aggregate quantitative implications of such behaviour requires assumptions about distributions of micro-parameters and of budget constraints. The lack of a simple analytical representation directly linking with aggregate data does not invalidate the relevance of this body of work. For given distributional assumptions, one can, in principle, simulate the effects on aggregate data of different common macroeconomic shocks. The question for builders of aggregate econometric policy models is to find adequate empirical approximations to capture the effects of macro shocks.

The overwhelming accumulation of evidence reviewed in the body of this paper, both micro and from aggregate time series data, confirms that the key precepts of the simple life-cycle permanent income model are faulty. This is the economics analogy with the evidence of Kepler against the epicycle view of planetary motion. 'Hand-to-mouth' behaviour even by asset-rich households is widespread: the marginal propensity to consume out of current income varies over households and is generally far higher than predicted by the old LCPIH model. Conversely, the response to expected future income varies over households and is generally far lower than implied by the old model. The response to housing wealth is different from that to variations in illiquid financial wealth, and in turn, different to that from liquid financial wealth. Moreover, if credit constraints are time varying, the consumption response to housing wealth is also time varying.

Aggregate empirical models based on the textbook LCPIH, whether through the consumption Euler equation, or incorporating some version of the Ando and Modigliani (1963) consumption function driven by income and net worth, are clearly not on the research frontier. Their micro-foundations are faulty and they are too strongly contradicted by empirical evidence. They are not 'adequate empirical approximations to capture the effects of macro shocks': their estimated parameters are unstable. The claim of this paper is that the better approximations set out in the paper capture far better the empirical facts summarized in the previous paragraph and have more stable parameters. Moreover, when distributional effects are thought to be important, the models set out here can be adjusted to take them into account.

Appendix 2: Origins of the credit augmented consumption function, equation 1

In a paper on why the UK personal-sector saving rate had collapsed, Muellbauer and Murphy (1989) proposed a consumption function incorporating many of the elements of the 'credit-augmented consumption function' set out in Aron *et al*. (2012). In an equilibrium correction framework, the long-run solution for the log of non-durable consumption was specified as a function of the log of non-property income, the log of the relative price of non-durables and durables, and ratios to income of liquid assets, debt, and illiquid assets, sometimes split into housing and financial assets. The model controlled for interest rates, including the change in the nominal rate, demography, and a proxy for income uncertainty. Crucially, tests overwhelmingly rejected the restriction that household wealth portfolios can be summarized in a single net worth statistic. Interaction effects also proved highly significant, either with illiquid assets including housing or with housing wealth, each with an ogive dummy representing financial liberalization (zero up to 1981 then rising to 0.95 in 1988). The results indicated that financial liberalization had made illiquid assets, and especially housing, far more spendable. In other words, it already emphasized the time-varying collateral channel of the linkage between housing wealth and consumption. It also suggested that debt, even in the aggregate, had far more negative consequences for spending than previously suspected.

Drawing on these findings, Muellbauer and Murphy (1990) explained how an increased ability of households to borrow against rising home equity could make consumption highly vulnerable to booms and busts in house prices, especially in an open economy where capital inflows could indirectly bolster mortgage-equity withdrawal. Relative to the full specification of equation 1, the 1989 paper omitted the log ratio of house prices to average income and the income growth expectations term—the log ratio of permanent to current income. Omission of the latter was justified on the grounds that real *per capita* non-property was close to a random walk. A random walk would justify treating current and permanent income as the same. This argument was used by Campbell and Deaton (1989) to discuss what they called the ‘excess smoothness’ of consumption—the fact that consumption is smoother than income, which would be inconsistent with the joint assumptions of the permanent income hypothesis and random walk income.

A comprehensive survey paper on consumption by Muellbauer and Lattimore (1995), summarized in Muellbauer (1994), moved beyond the (false) assumption that income is a random walk and introduced a forecast growth rate of income to proxy income growth expectations, and the change in the unemployment rate to proxy income uncertainty. The paper explained, in a two-period model, why income uncertainty tends to lead to future income being discounted more heavily than if certainty equivalence holds. This paper also set out an intertemporal choice model to explain why housing is unlike a financial asset and why, in the absence of credit constraints and illiquidity, the so-called housing wealth effect on aggregate consumption would be small and could be negative.[37] The argument was later popularized by Buiter (2010) and by Calomiris *et al*. (2009). Muellbauer and Lattimore (1995) emphasized the entirely different and potentially far more powerful role of housing wealth when there were credit and liquidity constraints. This survey paper influenced the consumption function adopted in the large Federal Reserve FRB-US model introduced in 1996, though as noted in the body of this paper, the FRB-US model adopted neither the recommended wealth disaggregation nor the controls for credit conditions.

The need to develop useful empirical forecasting models of income growth led to Muellbauer (1996) which demonstrated that US income was forecastable, in contradiction to the random walk hypothesis for income. It was also important to derive proxies for financial liberalization or a credit conditions index for use in consumption functions, house price, and other household sector equations. Muellbauer and Murphy (1997) demonstrated the relevance of shifting credit conditions for UK house prices. Aron and Muellbauer (2000), revised as Aron and Muellbauer (2013*a*), pioneered a latent variable method of estimating a credit conditions index in a two-equation model for consumption and debt using data for South Africa. The latent variable was modelled through a flexible spline function—effectively a set of time dummies—informed by institutional knowledge of regulatory and structural changes affecting credit markets. A similar technique was used by Fernandez-Corugedo and Muellbauer (2006) to measure mortgage credit conditions in the UK in a ten-equation system for proportions of first-time borrowers in the tails of loan-to-value and loan-to-income distributions, and aggregate data on mortgage and unsecured debt. This measure of credit conditions proved highly significant in a UK consumption function and an equation for home-equity withdrawal (Muellbauer, 2007), which was the basis of a real time recession forecast in Muellbauer (2008). Updated estimates of the UK consumption function with comparative equations for the US and Japan appeared in Aron *et al*. (2012). Subsequent papers, as mentioned in the text, developed the 'latent interactive variable equation system' as Duca and Muellbauer (2013) termed it, including the credit-augmented consumption function, treating credit conditions as a latent variable.

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[37] A slightly fuller explanation is in Aron *et al*. (2012).

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