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Abstract

The failure of the ubiquitous New Keynesian "'Dynamic Stochastic General Equilibrium' (NK-DSGE) models to capture interactions of finance and the real economy is widely-recognized since the 2008-9 financial crisis. NK-DSGE models exclude money, debt and asset prices and, importantly, ignore changing credit markets. These problems stem from assuming unrealistic micro-foundations for household behaviour, and that aggregate behaviour mimics a fully-informed 'representative agent' (both assumptions are embodied in the underlying 'rational expectations permanent income' hypothesis (REPIH)). This survey critiques the NK-DSGE models and its integral REPIH model, and discusses alternative post-crisis general equilibrium models which do incorporate debt and allow crises to occur. But neither model type can be directly applied to policy-making. The survey reviews misspecifications in standard non-DSGE macro-models used by central banks (e.g. the Fed.'s FRB-US), and related co-integration literature linking consumption with household portfolios. These too omit most of the 'financial accelerator', ignoring credit shifts and crucially, aggregating liquid, illiquid assets, debt and housing into a single 'net worth' construct. The survey's second focus is to improve non-DSGE models for policy using the Latent Interactive Variable Equation System (LIVES) approach, in which aggregate consumption is jointly modelled with the main elements of household balance sheets, extracting credit conditions as a latent variable. Empirical work on aggregate data is surveyed revealing the important role of debt and financial assets and the time and context-dependent role of housing collateral. Rather than 'one-size-fits-all' monetary and macro-prudential policy, institutional differences between countries then imply major differences for monetary policy transmission and policy.

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

Keywords: DSGE, macroeconomic policy models, finance and the real economy, financial crisis, Consumption, credit constraints, Household portfolios, asset prices.

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1. Introduction

In response to the famous question from the Queen of England as to why the global financial crisis was not foreseen, a British Academy forum concluded: "the failure to foresee the timing, extent and severity of the crisis and to head it off, while it had many causes, was principally a failure of the collective imagination of many bright people, both in this country and internationally, to understand the risks to the system as a whole" (Besley and Hennessy, 2009). Most economists would acknowledge that this failure resulted in a severe reputational loss for the profession. Central banks did not foresee the crisis, but worse, such a crisis was *impossible* to see in their models, for these excluded money credit, and real estate and asset prices, in accordance with the dominant paradigm in macroeconomic thinking. The failure of the New Keynesian "Dynamic Stochastic General Equilibrium" (DSGE) model to capture the interactions of finance and the real economy has since been widely recognized.[2]

This article argues that a key to this failure lies in the unrealistic micro-foundations for the behaviour of households embodied in the 'rational expectations permanent income' model of consumption, an integral component of the New Keynesian DSGE models. Consumption is fundamental to macroeconomics, whether in the representative agent Euler equation for consumption that drives DSGE models, or the types of consumption functions in general equilibrium macro-econometric models such as the Federal Reserve's FRB-US. In the latter class of models, the data is permitted to 'speak' under less restrictive assumptions than in DSGE models. Nevertheless, the household sector equations in these models also omit many linkages with credit and asset prices central to the financial accelerator. Both types of models thus need radical improvements, though this is easier in non-DSGE models given their modular structure.

The outline of the article is as follows. Section 2 briefly reviews the Euler equation for consumption and the underlying rational expectations permanent income hypothesis. Section 3 explores the implications for consumption of idiosyncratic (household-specific) and uninsurable income uncertainty, and the interaction of uncertainty with credit or liquidity constraints (drawing on the research of Deaton, Carroll, Ayigari, and a new generation of heterogeneous agent models). These models suggest that household horizons then tend to be both heterogeneous and shorter than implied by the text-book permanent income model. In section 4 the implications for macro-econometric models using aggregate data, when there is no representative agent, are discussed. Section 5 demonstrates that structural breaks and radical uncertainty can invalidate models of the New Keynesian-DSGE variety, illustrating with the failure of the Bank of England's DSGE model both during and after the 2008-9 crisis. Section 6 describes the "credit revolutions" in the US and the UK during recent decades, major examples of structural breaks, and explains the importance of debt for understanding consumption and macroeconomic fluctuations.

Section 7 introduces a more relevant consumption function for modelling the financial accelerator: modifying the permanent income model with shorter time horizons, incorporating important shifts in

[2] See Blanchard (2016) for a brief exposition of the DSGE approach, a critique and a discussion of improvements and alternative approaches.

credit lending conditions and disaggregating household balance sheets into liquid and illiquid elements, debt and housing wealth. It is argued that mis-specifying the relationship between consumption, income and household portfolios explains the widely-cited finding of Lettau and Ludvigson (2001, 2004), that consumption growth is hardly related to wealth. Extant non-DSGE policy models at central banks and elsewhere also suffer serious mis-specification from failure to disaggregate household wealth portfolios and to include shifts in credit conditions, and this is explained in Section 8. Section 9 argues that improved models for policy should incorporate a jointly estimated sub-system of consumption, portfolio and asset price equations for the household sector. In this system, shifting credit conditions with common influences across different equations can be modelled using bank lending survey data (available in the US since 1966 for unsecured credit for households), or otherwise with "latent variable" techniques. These techniques are popular in macroeconomics to represent concepts such as potential output and the natural rate of interest, Laubach and Williams (2003). In the case of credit conditions, interaction effects previously not considered in this latent variables literature, need to be examined.

From this more evidence-based approach, important policy insights into macro-prudential and monetary policy transmission and the limits of monetary policy can be deduced, improved early warning indicators of crises developed, and data on credit growth and asset prices, and on long-run secular trends, can be interpreted. Section 10 concludes.

2. The Euler equation and the rational expectations permanent income consumption function: a brief review.

2.1 The Euler equation for consumption.

The Euler equation for consumption, popularised in the highly influential paper by Hall (1978), is the centre-piece of DSGE models. It connects the present with the future, and is essential to the iterative forward solutions of these models. It is based on the assumption of additive consumer preferences, defined over consumption both now and for each future period. A subjective discount factor puts a higher weight on the utility of near-term consumption than on consumption in the more distant future. A critical further assumption is that every consumer faces the same linear period-to-period budget constraint. The constraint requires that real wealth at the end of each period equals the previous period's wealth, plus real non-property income, plus property income (given by the real return on last period's real wealth), minus real consumption. Maximising expected utility subject to the constraint results in a marginal condition that links expected marginal utility in the different periods. Under approximate 'certainty equivalence'[3], this translates into a simple relationship between consumption at time t and planned consumption at t+1.

[3] In general, marginal utility is a non-linear function of consumption, $u'(c_t)$. But $E\ u'(c_{t+1})$ is not the same as $u'(Ec_{t+1})$ because consumption at t+1 is uncertain. If uncertainty is small or if the ratio $E\ u'(c_{t+1})/\ u'(Ec_{t+1})$ is constant, one can speak of approximate certainty equivalence in converting the relationship between marginal utilities into one between consumption levels.

The canonical 'perfect planned consumption smoothing' case is a special case where the expected real rate of return on wealth is constant and equal to the subjective discount rate. Planned consumption at t+1 and at all future periods then equals actual consumption at t. Under rational expectations, the actual consumption at t+1 differs from planned consumption, because the consumer has new information at t+1 which is, by definition, independent of the information available at t. Consumption data then follows a 'martingale' (or if the variance of consumption is constant, a random walk), so that

$$c_t = c_{t-1} + \varepsilon_t \tag{1}$$

where ε is news. Hall (1978) argued that the best forecast of next period's consumption is this period's consumption.

2.2 The rational expectations permanent income consumption function.

When planned future consumption is the same as current consumption, the intertemporal budget constraint can be used to solve for current consumption as a function of wealth and the present value of current and future expected income. This is the canonical rational expectations permanent income (REPIH) consumption function: consumption, c, is then equal to property income defined as the real rate of return, r, times last period's real wealth, A, plus permanent non-property income, y^p:

$$c_t = rA_{t-1} + {y^p}_{\mathrm{t}} \tag{2}$$

where y^p is defined as that constant level of real non-property income which, sustained over the life cycle, has the same present value as the income stream actually expected, where future incomes are discounted at the rate r. One advantage of both (1) and (2) is that the aggregate behaviour of households is the same as that of an average household, the simplest case of a 'representative agent'.[4]

To a close approximation, equation (2) underlies all representative agent DSGE models. Real wealth, A, in these models is the discounted present value of future profits, and future profits are a function of expected productivity growth which also drives income expectations. In the conventional representative agent DSGE models, credit and asset prices are a side-show, merely reflecting households' income or productivity growth expectations. They play no causal role for consumption

2.3 DSGE models entail strong underlying assumptions

The assumptions behind the consumption Euler equation, and implicitly equation (2), that underpins the representative agent DSGE models are unrealistic. As noted above, rational expectations, approximate certainty equivalence and linear budget constraints are all needed for equations (1) and (2). Assuming rational expectations implies that households have full information and an excellent computational ability to be able to optimise; but this contradicts widespread financial ignorance (see

[4] The model is often extended by assuming habit formation. Then equation (1) includes an extra term in last period's consumption change, and equation (2) becomes a partial adjustment model, in which consumption takes time to respond fully to wealth and permanent non-property income.

Lusardi (2016), Lusardi and Mitchell (2011)). Approximate certainty equivalence assumes that behaviour in an environment of uncertain income and health, and so forth, can be closely approximated by behaviour for which uncertainty does not much matter. With more realistic assumptions about preferences and income dynamics, this is highly questionable, the more so when borrowing and liquidity constraints are taken into account, see below. The single asset assumption is completely untenable, for there are both liquid and illiquid forms of wealth. Pension wealth is subject to access restrictions, equities are subject to trading costs, and both are uncertain, unlike cash. Moreover, housing is different from financial wealth, even in the absence of credit constraints, since housing is a consumer good as well as an asset, see Aron et al. (2012).

In practice, the Euler equation is strongly rejected on aggregate data, see Flavin (1981), Campbell and Mankiw (1989, 1990) and for even more powerful evidence from the UK, US and Japan, Muellbauer (2010), and micro-evidence from Shea (1995). Predictable income growth is very significantly correlated with consumption growth, violating the martingale property of equation (1). This is usually referred to as the 'excess sensitivity of consumption to income'. Since representative agent DSGE models applied to aggregate data rely on this property of the aggregate Euler equation, they fail this test.

The canonical model above used the special case of a constant real interest rate to illustrate the basic points. With a variable interest rate, or the addition of risky financial assets in the consumption capital asset pricing model, Hansen and Singleton (1983) and Campbell (1999) show how the Euler equation in log consumption will be augmented by a term in the real interest rate whose coefficient is the inter-temporal elasticity of substitution.[5] Empirical evidence on aggregate data, however, also does not support this modified model. There are unstable and usually insignificant coefficients on the interest rate term, in addition to the excess sensitivity violation noted above.

3. Consumption, liquidity constraints and income uncertainty

In awarding the 2015 Nobel Prize in economics, the Nobel committee highlighted three areas of Angus Deaton's work[6]: empirical systems of demand equations; aggregate consumption and household saving decisions; and the study of household surveys in developing countries to measure living standards and poverty. Deaton (1991) laid the micro-foundations for examining consumption behaviour under liquidity constraints and income uncertainty. He showed that consequences included buffer stock saving and shorter time horizons than in the canonical REPIH, particularly for those facing greater income uncertainty and liquidity constraints. Confronted with income uncertainty, households hold liquid asset buffers to carry them through temporary income down-turns. Limits to the ability to insure income, credit and some liquidity constraints arise because of endemic asymmetric information, e.g. between lenders and borrowers, one of the key lessons of the information economics revolution for which Akerlof, Spence and Stiglitz were earlier awarded the Nobel prize.

[5] They apply 'constant relative risk aversion' preferences, commonly used in DSGE models, and assume log-normal distributions.
[6] http://www.nobelprize.org/nobel_prizes/economic-sciences/laureates/2015/advanced.html

Chris Carroll (1992, 2001, 2014) has taken the buffer stock theory to new levels, even without credit constraints. Studying stochastic income processes empirically, he calibrates consumption responses under plausible preference assumptions, at different liquid asset-on-hand to income ratios.

In Deaton's book (Deaton, 1992), the last ten pages brilliantly summarise the overwhelming micro- and macro-data evidence against the simple permanent income theory. He convincingly marshals theory and evidence in favour of incorporating liquidity constraints and precautionary saving in the face of uncertainty to understand consumption. Since consumers' balance sheets include illiquid assets such as pensions, stocks and bonds, and houses, he argues that, "the presence of these illiquid and sometimes high-yielding assets needs to be integrated into the model of credit-constrained consumers" (Deaton, 1992 p. 211-2).

Progress along these lines has been made by Otsuka (2004), who considers a buffer stock model in the presence of an illiquid asset with a higher return but subject to trading costs. 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. (2016) into a general equilibrium model with an otherwise conventional New Keynesian production side of the economy. Kaplan et al. (2016) then show that monetary policy conclusions are radically transformed in their 'heterogeneous agent New Keynesian' (HANK) model compared to the standard representative agent REPIH version of the NK-DSGE model. In the latter, inter-temporal 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.

As yet, these models do not incorporate housing, and hence an "ATM" type role of housing collateral in the US[7]. Together with stock-market valuation effects, the presence of housing collateral opens up a further transmission mechanism for monetary policy, which is also ignored in the NK-DSGE models. The housing transmission mechanism is explored by Hedlund et al. (2016) who have recently extended a heterogeneous agent model by introducing a housing market with plausible frictions, discussed further below.

4. Representative agents vs. heterogeneity and stochastic aggregation.

Deaton's views on the importance of uncertainty for saving and on the failure of 'representative agent' theory are echoed by Aiyagari (1994) and Carroll (2002, 2014). According to Carroll: "During the crisis, the dominant class of models, representative agent DSGE models, either had nothing useful to say about the policy questions that needed answers, or provided answers sharply at variance with both common sense and empirical evidence." One ad hoc way of improving on these models is

[7] An ATM is an automated teller machine. Klyuev and Mills (2006) likened the use of US homes to extract equity, a process that Fed chairman Alan Greenspan studied closely, Greenspan and Kennedy (2005), to a cash withdrawal from an ATM machine.

to assume two representative agents, allowing a fixed fraction of consumers[8] simply to spend current income instead of following the REPIH. This achieves a shortening, on average, of the horizon for households, thereby increasing realism. The same assumption has been widely adopted to help account for the 'excessive sensitivity' of consumption changes to (predictable) income changes, which, as noted in section 2, is one of the major empirical violations of the martingale or random walk form of the aggregate Euler equation.

However, the ad hoc model is crude and ignores precautionary and buffer stock saving behaviour. A review by Japelli and Pistaferri (2010) of the empirical literature casts doubt on the above ad hoc assumption for two representative agents: "Taken together, (the) findings are consistent with the hypothesis that precautionary savings and even perhaps insurance over and above self-insurance (achieved through government welfare programs, family labor supply, or family networks) play an important role in consumption. Here as well, households' heterogeneity is important because liquidity constraints appear to be able to account for the estimated larger marginal propensities to consume, especially in subgroups of the population that are less likely to be able to access credit markets, such as low-income or low-education households." This suggests that heterogeneity is far more pervasive than can be captured by two agents.

There are many other examples of the importance of heterogeneity. Guvenen et al. (2015) find a high degree of heterogeneity in life-cycle income risks. Moreover, as unemployment risk varies greatly by occupation and education, a representative agent model of unemployment, as in the RBC and DSGE literature with an explicit labour market, makes little sense. In the housing market, the incidence of mortgage defaults, for which negative equity and unemployment are major drivers is highly heterogeneous (see Foote et al. (2008) for the US and Aron and Muellbauer (2016a) for the UK).

Does heterogeneity mean that we must give up macro-time series analysis? Stochastic aggregation theory[9] suggests we can often still make good progress with aggregate data, including the unemployment rate, even if behaviour at the micro-level looks different from an aggregate model. An excellent example is Houthakker (1955) who showed that a Leontief production function, with no substitution, and Pareto distribution of the parameters at the micro-level, implied substitution at the macro-level as if it arose from an aggregate Cobb-Douglas technology. In the literature on lumpy adjustment costs, micro behaviour switches discretely from no adjustment to adjustment when some micro-thresholds are reached. In the aggregate however, behaviour is smooth, as explained by Bertola and Caballero (1990).

If the micro-distribution is fairly stable, so is the aggregate function. An applied example of stochastic aggregation comes from models of aggregate mortgage delinquency and foreclosure rates

[8]One could also assume that a fixed fraction of income is consumed.

[9] This contrasts with linear aggregation, where the behaviour of every single agent can be represented by a linear function with the same slope parameter across agents: then aggregate behaviour follows the same linear functional form. In stochastic aggregation, assumptions on the joint distributions of parameters and the data, allow aggregate behaviour to be represented by parameters of the distributions, such as means, variances and covariances.

(Aron and Muellbauer, 2016a). A key driver is the proportion of mortgages with negative equity: if the distribution of mortgage debt to equity is fairly stable, a shift in the ratio of average debt to average equity shifts non-linearly the fraction of borrowers with negative equity.[10] Since bad loans restrict the ability of banks to extend new credit, negative equity is an important non-linear element in the business cycle feedback loop.

5. Structural shifts, radical uncertainty and rational expectations

Structural breaks in non-stationary data are the major reason for forecast failure, as argued by Clements and Hendry (1999, 2002). Such breaks might include shifts in market structures, for example, due to globalisation, and shifts in the exchange rate regime and fiscal and monetary policy regimes. The DSGE models need stable probability distributions for their recursive optimisation. Yet Hendry and Mizon (2014, 2015) explain how structural breaks violate the 'law of iterated expectations' central to the 'rational' or model-consistent expectations of DSGE models. These types of expectations assume that the agents in the model share exactly the same knowledge about the structure of the economy as embodied in the model specified by the analyst. The 'pretence of knowledge' syndrome (e.g. Hayek (1974) and Caballero (2010)) is thus *extreme* in DSGE models. Romer (2016) is critical of the incredible identifying assumptions and 'pretence of knowledge' in both Bayesian estimation and the calibration of parameters in DSGE models.[11] A further symptom of 'pretence of knowledge' is the assumed 'knowledge' that these model parameters are constant over time.

Expectations have played a dominant role in macroeconomic theory in the last 40 years. Yet only very moderate progress has been made in systematic survey data collection of the expectations of households and firms over 3 to 5 year horizons (with the exception of inflation expectations linked to central bank targeting policies). Most surveys of households (with the notable exception of the Michigan Survey) focus on 'confidence', and the very short run. Along with the Purchasing Managers' business surveys, these are mainly useful for 'now-casting' to obtain early indicators of current data such as GDP, consumption or investment. Ironically, it is 'pretence of knowledge' as embedded in the assumption of model-consistent expectations, that helps explain this otherwise baffling failure by the profession, statistical agencies and central banks to collect the highly relevant expectations data.

There is a large literature on imperfect knowledge and learning within the framework of the New Keynesian DSGE model, see the excellent survey of Eusepi and Preston (2016). However, the

[10] A logistic function defined on a cubic in the mean debt to mean equity ratio, with slight trend adjustment, is used to generate estimates of the UK proportion of borrowers with negative equity, consistent with cross-section snapshots. Negative equity is highly significant in explaining aggregate defaults.

[11] Part of the problem of identification is that the DSGE models throw away long-run information. They do this by removing long-run trends with the Hodrick-Prescott filter, or linear time trends specific to each variable. Identification, which rests on available information, then becomes more difficult, and necessitates 'incredible assumptions'. Often, impulse response functions tracing out the dynamic behaviour of the modelled economy to shocks are highly sensitive to the way the data have been pre-filtered.

assumption of homogeneous expectations across agents and the restrictions of the New Keynesian framework discussed above cast considerable doubt on whether the insights on monetary transmission and policy issues such as the effectiveness of forward guidance translate into a more realistic world with heterogeneous uninsurable household income uncertainty, liquidity constraints and major structural breaks.

Analysis by the Bank of England shows that all their models, and particularly their DSGE model, COMPASS, performed very badly during and after the financial crisis, even relative to the wide uncertainty margins acknowledged in the blue shaded fan charts shown in Figure 1 (Fawcett et al., 2015).

[Figure 1 here]

If the Bank of England's models, with superior data access and computational power, were so wrong about the economy, it seems implausible to impute *less* ignorance and *lower* levels of uncertainty to private sector agents, as implicit in the COMPASS model. Model consistency may not always be such a bad idea, though Brayton et al (1997) allow for the possibility that households do not have model consistent expectations in the FRB-US model. However, if model consistent expectations are assumed, the economic forecast model should be robust to structural breaks, and any uncertainty attributed to the private sector around the central projections should plausibly exceed that of the central bank modellers. This macro-uncertainty adds to the idiosyncratic uncertainty at the household level. It is a further reason to impute *far* higher discount rates to household expectations of future cash flows, than only the real interest rate. By contrast with the COMPASS model, Burgess et al (2013), the Federal Reserve's FRB-US model takes far greater account of household uncertainty: it assumes that a 25 percent annual discount rate is applied by households to future income flows. This discount rate is consistent with micro-economic evidence from Hausman (1979).

It is a common finding too that the rational expectations assumption implies dynamic responses that too often appear implausible, large and front-loaded. One of the virtues of the FRB-US model is the modular structure which allows the model to be simulated under different expectational assumptions, see the illuminating account in Brayton et al. (1997)[12].

6. The credit revolution and the importance of debt

For most households, the major structural breaks affecting consumption and portfolio choice, given income, stem from liberalisation of credit markets. Thumb-nail sketches for the UK and the US illustrate the effects of credit shifts on the growth of debt.

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[12] They argue: "A critical factor is the speed with which the public recognizes that a change in the economic environment has occurred or will occur. The model can be simulated with several possibilities, including gradual learning about the change after it has occurred, recognition of the change at the time it occurs, and anticipation of the change before it occurs." (Op. cit., p.240). Their model can also allow financial market participants to have model-consistent expectations, while households' expectations are formed from forecasts based on the limited information in a small scale VAR model.

6.1 Shifts in credit market architecture in the UK and the US

The UK abandoned exchange controls in 1979 and the 'corset' on bank lending in 1980[13], after a decade of mainly negative real interest rates and quantitative controls on bank and mortgage lending. The High Street banks rapidly entered the mortgage market, challenging the dominant market share of the incumbent building societies (mutual savings banks). Centralised mortgage lenders gained market share in 1986-1990, by offering more generous loan terms via mortgage brokers whose incentives were driven by the fees generated. Unregulated competition promoted poor lending practices. A major credit and house price boom resulted. A large rise in interest rates in 1989-90 led to a mortgage crisis, and in turn to a credit crunch.[14] After 1996, credit was liberalised for the buy-to-let market, and also more generally via increased securitisation, increased funding from money markets and a new breed of centralised lenders operating via financial intermediaries or online. Fernandez-Corugedo and Muellbauer (2006) track an index of UK mortgage credit conditions which is consistent with this description. From 2008, with the drying up of the money markets, falling house prices and re-regulation of mortgage lenders, a severe credit contraction began. The Bank of England's Funding for Lending Scheme and other measures helped ease mortgage credit conditions somewhat after 2011.

For the US, the story is a mix of evolution and revolution. Credit card ownership and instalment credit spread between the 1960s and the 2000s. The Government Sponsored Enterprises - Fannie Mae and Freddie Mac - were recast in the 1970s to underwrite mortgages. Interest rate ceilings were lifted in the early 1980s. Falling IT costs transformed payment and credit screening systems in the 1980s and 1990s. More revolutionary was the expansion of sub-prime mortgages in the 2000s – driven by rise of private label securitization backed by credit default obligations (CDOs) and swaps. The 2000 Commodity Futures Modernization Act (CFMA) made derivatives enforceable throughout the U.S. with priority ahead of claims by others, e.g. workers, in bankruptcy. This permitted derivative enhancements for private label mortgage backed securities (PMBS) (Stout, 2011) so that they could be sold on as highly rated investment grade securities. A second regulatory change was the deregulation of banks and investment banks. In particular, the 2004 SEC decision to ease capital requirements on investment banks increased gearing to what turned out to be dangerous levels and further boosted PMBS. Similar measures to lower required capital on investment grade PMBS increased leverage at commercial banks. These changes occurred in the political context of pressure to extend credit to poor. One consequence was that loan-to-value ratios for mortgages for first-time buyers fell and Duca et al. (2011) show how these rises drove US house prices. Duca et al. (2016) model private and total first-time-buyer LTVs, jointly with house prices and rents to identify the role of the key regulatory changes. After 2007, the fall in house prices, the rise of delinquencies and

[13] The 'corset', the Supplementary Special Deposit Scheme introduced in 1973, imposed penalties on banks whose interest-bearing deposits grew faster than a pre-set limit.

[14] UK interest rates, given membership of the Exchange Rate Mechanism, were strongly affected by the rise in German interest rates due to unification, and by monetary policy tightening in response to the obvious signs of an overheated economy resulting from the credit and house price boom. Only after the UK was forced out of the ERM in 1992, could domestic monetary policy relax.

foreclosures and tighter regulation of lending practices caused a severe credit crunch in the mortgage market, eventually moderated by greater access to FHA-bank mortgages, partly taking the place of the virtual disappearance of PMBS-financed mortgages.

6.2 Why debt matters for macroeconomics

The importance of debt has long been recognised, most clearly in Irving Fisher's 1933 debt-deflation theory of depressions and his 1932 book on Booms and Depressions. Briefly summarised, his story is that when credit availability expands, it raises spending, debt and asset prices; irrational exuberance raises prices to vulnerable levels, given leverage; negative shocks can then cause falls in asset prices, increased bad debt, a credit crunch, and a rise in unemployment. In the 1980s and early 1990s, boom-busts in Norway, Finland, Sweden and the UK followed this pattern, see Steigum (2003) and Honkapohja (2009). Muellbauer and Murphy (1990) diagnosed that an unsustainable credit-driven house price boom drove the fall in the UK personal saving ratio and rise in the deficit on the balance of payments in the late 1980s. Our research suggested that extra debt of £100 had a far more negative effect on consumption than the positive effect of an extra £100 of housing or stock market wealth. Since debt is far stickier than asset prices or new credit supply, households with high debt levels at the end of a credit boom can be in a vulnerable position, and their deleveraging has negative spill-overs for the whole economy.[15]

In recent years, several empirical contributions have recognised the importance of the mechanisms described by Fisher. Mian and Sufi (2014) have provided extensive micro-economic evidence for the role of credit shifts in the US sub-prime crisis. Focusing on macro-data, Turner (2015) analyses the role of debt internationally with more general mechanisms, as well as in explaining the poor recovery from the global financial crisis. Jorda et al. (2016) have drawn attention to the increasing role of real estate collateral in bank lending in most advanced countries and in financial crises.

6.3 Macro-theory with debt and financial frictions.

Turning to the earlier (pre-2008 crisis) theoretical writings on financial frictions in credit markets, most of these were cast in a DSGE framework. For instance, Bernanke and Gertler (1989), and its dynamic general equilibrium version, Bernanke, Gertler and Gilchrist (1999), and Carlstrom and Fuerst (1997) had discussed the role of financial frictions facing firms in the amplification and persistence of shocks during business cycle episodes. These, however, abstracted from the special role of real estate. Kiyotaki and Moore (1997) introduced land, as collateral for debt in a theory model with patient and impatient agents, but no financial intermediation. In their model, the collateral requirement amplifies business cycle fluctuations: in a recession, the income from capital falls, causing the price of capital to fall, which makes capital less valuable as collateral, which limits firms' investment by forcing them to reduce their borrowing, and thereby worsens the recession. In using log-linearisation to study behaviour near a steady state, the above papers could not address the possibility of severe financial crises.

[15] The paper was written in 1989 before the bust phase manifested. The discussant, Mervyn King argued that the 1980s boom in house prices and consumption mainly reflected more positive expectations about future income growth.

Post-crisis, however, Brunnermeier and Sannikov (2014), Adrian and Boyarchenko (2012), and He and Krishnamurthy (2014), among others, have built theoretical models which incorporate financial frictions, and use non-linear methods which highlight behaviour away from the steady state. These models have far more to say about financial crises, though most exclude an explicit financial sector. For example, in Brunnermeier and Sannikov, small shocks keep the economy near the stable steady state, but large shocks put the economy in the unstable crisis regime characterized by liquidity spirals, significant inefficiencies, disinvestment, and slow recovery. Their model generates important insights: the economy is prone to instability regardless of the level of aggregate risk, because leverage and risk-taking are endogenous. Endogenous risk, self-generated by the system, dominates the volatility dynamics and affects investing firms' precautionary motive. When changes in asset prices are driven by the constraints of market participants rather than by fundamentals, incentives are to hold cash to buy assets later at fire-sale prices. As aggregate risk goes down, equilibrium leverage goes up, and amplification loops in crisis regimes become more severe - a volatility paradox. This happens because low fundamental risk leads to higher equilibrium leverage: low risk environments are conducive to a greater build-up of systemic risk, arguably relevant to the Great Moderation period from the mid-1980s to 2006. The extent and length of slumps is stochastic in their model, which significantly increases the amplification and persistence of adverse shocks.

The latter feature is shared by models of boom-bust behaviour that do incorporate an explicit banking or financial intermediary sector[16] in which bank runs, as in Boissay et al. (2016), or creditor runs, as in Paul (2016) can occur, triggered by adverse shocks following a credit boom. In such models, non-linearities are important. In Boissay et al. (2016), after an adverse shock such as a productivity slowdown, households carry on saving, increasing available funds for banks, whose increasingly risky behaviour can lead to a bank run (a breakdown of the interbank market). In Paul (2016) the maturity mismatch of intermediaries and their pro-cyclical lending resulting from an agency problem, interact. An adverse shock, reducing asset prices, can then push leverage beyond an exogenous threshold level, triggering a creditor run. Such post-crisis models, solved using global solution methods (in which non-linearities can play their full role) can give important insights into aspects of banking behaviour and for financial regulation. They are a clear advance over linearised DSGE models whose assumptions rule out financial crises. Such stylised models can be very useful for highlighting key features of how economies might operate, greatly broadening the range of possibilities beyond those permitted by the NK-DSGE model.[17] Each of these models makes a range of simplifying assumptions to achieve a tractable general equilibrium solution. However, these improved models are still far from being very useful for policy because they do not plausibly account

[16] The appendix of Brunnermeier and Sannikov (2014) discusses a version of their model with explicit financial intermediaries.

[17] In other examples, outside the present focus on finance, Schaal and Taschereau-Dumouchel (2015) develop a formal quantitative business cycle model with coordination failures and multiple equilibria, focused on business investment. Ravn and Sterk (2016) develop a heterogeneous agent model with precautionary saving and a search and match labour market in which there are also multiple equilibria. One of them is an unemployment trap, in which aggregate demand, sustained by high levels of precautionary saving, is depressed to a level at which it is no longer profitable for firms to post vacancies.

for and integrate household behaviour with real estate and credit markets, and labour markets, as well as linking with the behaviour of financial and non-financial firms.

In future, the generation of vast amounts of micro-data from administrative sources rather than surveys subject to selection bias and large measurement errors, may allow quantitative models for the whole economy to be constructed. Ideally, such macro-models would be based on statistically-tested models of micro-behaviour, aggregated up from micro-data on millions of households and many thousands of firms. Testing should establish whether such models best assume full information optimising behaviour at the micro-level or heuristic behaviour rules adopted in agent-based modelling approaches, Geanakoplos et al. (2012). In the absence of such data, there is an important place for policy-relevant models using aggregate data, general enough to be consistent with plausible micro-behaviour and with plausible assumptions about information and market structure. Such models should be able to encompass insights from multiple stylised models, and use aggregate time series data to learn about the relevance of these insights.

7. A consumption function relevant for understanding the financial accelerator

7.1 Can models with an underlying REPIH consumption function capture financial crises?

The financial accelerator as it operated in the US sub-prime crisis is illustrated in Figure 2.[18] Channels of transmission of the initial shock operated via residential construction and consumption, both with negative effects on GDP, and via loan losses, restricting the capacity of banks to extend loans and increasing uncertainty. This raised risk-spreads in securities markets as collateral values and risk appetites fell. In business-cycle upswings, similar mechanisms operated, but in the opposite direction, and much more gradually.

[Figure 2 here]

NK-DSGE models cannot begin to represent Figure 2 – they incorporate no money, no credit and no asset prices.[19] To adequately represent interactions between the financial system and the real economy, a macro-econometric policy model of the non-DSGE variety *must* build in these mechanisms and feed-back loops. A non-DSGE model in which consumption follows the REPIH, typical of most central bank models, see section 8, is simply not adequate to the task. A more general formulation than equation (2) is needed to model the consumption channel in the financial accelerator. There are several reasons for this. First, even in the absence of credit and liquidity constraints, and precautionary behaviour in the presence of income uncertainty, the net worth formulation of household wealth in equations (2) is incorrect. This is because housing is a consumption good as well as an asset, and consumption responds differently to a rise in housing

[18] The graphic is by John Duca, see Duca and Muellbauer (2013).
[19] Charles Goodhart, member of the Bank of England's Monetary Policy Committee from June 1997 – May 2000, said of the DSGE approach: “It excludes everything I am interested in”, see Buiter (2009): http://voxeu.org/article/macroeconomics-crisis-irrelevance.

wealth than to an increase in financial wealth. There will be income and substitution effects when house prices rise (for the details, see Aron et al. (2012, p.401-2)).[20] Second, different assets have different degrees of "spendability". It is indisputable that cash is more spendable than pension or stock market wealth, subject to asset price uncertainty and access restrictions or trading costs. This suggests estimating separate marginal propensities to spend out of liquid and illiquid financial assets. Third, the marginal effect of debt on spending is unlikely just to be minus that of either illiquid financial or housing wealth (this would be entailed by employing 'net worth' as the asset[21]). The reason is that debt is not subject to price uncertainty and it has long-term servicing and default risk implications, with typically highly adverse consequences. Fourth, the two restrictions on the role of permanent non-property income in equation (2) need to be relaxed: they are the assumption that the real interest rate r is appropriate for computing the present value of future income streams, and the unit coefficient on permanent income. As argued above, income uncertainty suggests higher discounts on average. Representing aggregate behaviour for heterogeneous households by applying a single average discount rate to average income growth expectations is necessarily an approximation. Relaxing the unit coefficient and relying on empirical evidence allows for the possibility that for some households there is a substantial random walk component in non-property income[22] and also helps correct for approximation errors in the use of an average discount rate.

The fifth and final reason for a more general formulation than equation (2) to model the consumption channel is arguably one of the most compelling. Shifts in household access to credit may be hard to measure, but they strongly affect aggregate consumption. Mortgages account for most of household debt. They are affected by two types of credit constraints: a down-payment constraint on the size of a mortgage for a home buyer, in the form of loan-to-value and/or a debt-to-income or debt service ratio constraint; and limits on access to home equity loans[23]. The former constraint generally requires saving for the housing deposit. Relaxation of this constraint thus increases the consumption-to-income ratio, given existing debt. If house prices should rise relative to income, this will tend to reduce the consumption-to-income ratio for potential home buyers who have to save more (though less so for smaller down-payment constraints). It is also likely that renters, even with no plans to become owners, will spend more cautiously in anticipation of higher rents, following house price rises. Easing access to home equity loans, the second constraint, increases the (positive) effect of owning housing collateral on the consumption-to-income ratio for homeowners. Improved access to credit not secured on housing, e.g. to car loans or raised credit card limits, is also likely to positively

[20] This expands on an earlier account in Muellbauer and Lattimore (1995, p.270), and broadly similar arguments were made by Buiter (2010) and Calomiris et al. (2009).

[21] Net worth is defined as liquid assets minus mortgage and non-mortgage debt plus illiquid financial assets plus housing assets, and this assumes that the coefficients are all the same.

[22] In the extreme case where real non-property income follows a random walk, current income and permanent income are the same. log (y_t^p/y_t) is then zero. If, for other households where income does not follow a random walk, log (y_t^p/y_t) can be predicted using other data, the coefficient on log (y_t^p/y_t) in the equation for aggregate consumption will necessarily be less than one. The extreme case where all household income follows a random walk led Campbell and Deaton (1989) and Deaton (1992) to the 'excess smoothness' paradox. In the random walk case, the REPIH suggests that consumption should be as volatile as income in the absence of transitory consumption shocks and more volatile when these shocks are present. However, consumption is typically smoother than income.

[23] A home equity loan is a loan issued to an existing home owner, and secured on the home.

shift the intercept term in an equation for the consumption-to-income ratio. More generally, better credit access might be expected to *increase* the weight on permanent relative to current income since households could then better increase consumption in advance of higher expected income.

Credit liberalisation over time has a parallel in the differences across countries with varied institutional credit frameworks. Those countries with deep and liquid credit markets and easy home-equity access are likely to experience positive consumption responses to higher house prices. The opposite is likely in countries with tight down-payment requirements and limited or no access to home equity loans (see Slacalek (2009) for evidence on differences between countries and Cooper and Dynan (2016) for a review of empirical evidence on wealth and collateral effects).

7.2 A solved-out consumption model that says: "yes, we can capture financial crises"

These five possible extensions of the REPIH consumption function, lead to a more realistic consumption function meshing with the characteristics of real world asset and debt markets. An application to the UK, US and Japan incorporates these five extensions of the REPIH (Aron et al., 2012). It also includes the change in the unemployment rate as a proxy for income uncertainty and changes in nominal interest rates to capture cash-flow effects on borrowers in countries with floating rate debt. It encompasses as a special case a log-linearisation of equation (2) in which log consumption depends on the asset-to-income ratio, log income and the log of permanent relative to current income[24]:

$$\log\left(c_t / y_t\right) = \alpha_0 + \log\left(y_t^P / y_t\right) + \gamma A_{t-1} / y_t \tag{3}$$

where γ is the marginal propensity to consume (m.p.c.) out of assets. It can test empirically the restrictions embodied in the REPIH and is described in more detail below. For all three countries, the net worth restriction is rejected. For the UK and US, there are major shifts associated with credit market liberalisation in the intercept and the coefficients on house price or housing collateral effects; this suggests clear, positive housing collateral effects in more recent years. In the case of Japan, there is little evidence of significant shifts in mortgage credit conditions, but higher house price-to-income ratios bring down consumption-to-income ratios, given the substantial down-payment requirements.

Once assets and debts are disaggregated into liquid and illiquid components, separating out housing, for a general equilibrium model it is necessary to endogenise assets and debt levels and the associated asset prices. Jointly modelling consumption and key portfolio and asset prices equations has major advantages. The most important of these is that one can extract the shifts for households in their access to credit markets. In Duca and Muellbauer (2013), we measure shifts in access to home equity loans, the 'housing liquidity index' HLI, as a latent variable common to four equations for the US: consumption, the mortgage stock, the mortgage refinancing rate and home equity withdrawal[25].

[24] See Muellbauer and Lattimore (1995) for the derivation, which was adopted in FRB-US.

[25] This is defined as the increase in debt collateralised on housing minus acquisition by the household sector of residential housing.

A rich set of macroeconomic controls[26] minimises the possibility that the latent variable – the otherwise unexplained 'common factor' in these four equations – is picking up an omitted variable such as demography or income growth expectations. As the latent variable enters in the form of an interaction effect with other variables (such as debt), we term the equation system a 'Latent Interactive Variable Equation System' (LIVES).[27] Credit shifts that *can* be measured the US act as additional controls. The US is unusual in that the Federal Reserve's Senior Loan Officer Survey, running since 1966, provides information of increased access to unsecured credit. This 'credit conditions index', CCI, has an important role, shifting the intercept in the equation for consumption-to-income. The model also includes income growth expectations, anchored in survey data extracted from the Michigan Survey of households. These are used in an econometric model also incorporating short-term monetary policy effects and gradual adjustment of income to shifting long-run trends.

The long-run version of the generalised equation, omitting for simplicity the changes in the unemployment and interest rates and the partial adjustment mechanism incorporated in the empirical specification, is,

$$\log (c_{t/}\, y_t) = \alpha_{0t} + \alpha_{1t} r_t + \alpha_2 \theta_t + \alpha_{3t} \log (y_t^p / y_t) + \gamma_1 NLA_{t-1}/y_t + \gamma_2 IFA_{t-1}/y_t + \gamma_{3t} HA_{t-1}/y_t \tag{4}$$

where r is a real interest rate, θ is an indicator of income uncertainty, *NLA* is liquid assets minus debt[28], *IFA* is illiquid financial assets and *HA* is gross housing wealth.

There are four time-varying parameters that are made functions of the credit conditions: *CCI* or *HLI*. The first is the intercept term, α_{0t}, because of a reduced impact of down-payment constraints and potentially a reduced precautionary motive when *CCI* increases. The real interest rate coefficient, α_{1t}, potentially varies with credit conditions because of greater ability to engage in inter-temporal substitution. The coefficient on expected income growth, α_{3t}, varies with credit access because future income should matter more when borrowing is easier. Finally, the m.p.c. out of housing wealth, γ_{3t}, should alter because of increased access to home equity loans with as *HLI* increases. These are all testable propositions.

The long-run part of the empirical consumption equation corresponding to equation (4), estimated on quarterly US data for 1971Q4 to 2011Q1, from a four-equation variant of the system is as follows:

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[26] Including income, income expectations, unemployment, interest rates, inflation, asset prices and demography.

[27] The use of latent variables in macroeconomic modelling has a long vintage. Potential output, and the "natural rate" of unemployment or of interest are often treated as latent variables, for example in the FRB-US model and in Laubach and Williams (2003). Interaction effects of latent with other variables seem not to have been considered, however. Latent variables are often modelled using state space methods, as in Laubach and Williams (2013). Flexible spline functions can achieve similar estimates.

[28] It is possible to disaggregate net worth into four 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, assuming that the coefficient on debt is minus that on liquid assets tends to be better supported by the data.

$$\log(c_t / y_t) \approx 0.131 + 0.089CCI_{t-1} - 0.0047r_t + (0.49 + 0.35HLI_t)E_t \log(y^p / y)_t$$
$$\quad (6.2) \qquad (7.7) \qquad (-6.4) \qquad (6.7) \quad (1.3)$$
$$+0.101NLA_{t-1} / y_t + 0.017IFA_{t-1} / y_t + 0.055(HLI_{t-1})HA_{t-1} / y_t$$
$$\quad (7.6) \qquad (8.6) \qquad (5.4)$$
$$(t - ratios)$$

(5)

with t-ratios in parenthesis. The main contributions of the credit-related variables to long- and short-run fluctuations in the consumption-to-income ratio are depicted in Figure 3, while Figure 4 shows the contributions of the real interest rate, illiquid financial assets (mainly the stock market) and the ratio of permanent to current income. The liquidity-weighted housing collateral effect, $(HLI_{t-1})HA_{t-1}/y_t$, accounts for much of the rise of the consumption-to-income ratio from the early 1990s to 2007 and its subsequent collapse. Note that *HLI* rose strongly from the early 1990s to 2005. The longer run contribution of the *CCI* based on the Senior Loan Officer Survey is also evident. It is striking, however, by how much the build-up in debt, revealed in the decline in the net liquid asset-to-income ratio, *NLA/y,* depresses the consumption-to-income ratio. One might call this the 'pay-back effect' of credit market liberalisation.

[Figure 3 here]

[Figure 4 here]

There were also substantial contributions to the rise in the consumption-to-income ratio from 1993 to 2001 from ratios to income of illiquid financial (mainly stock market) wealth and permanent income. The impact of the collapse of the dotcom boom and the 9/11 terror attacks on stock market wealth explains much of the temporary decline in the consumption-to-income ratio in the early 2000s. However, financial deregulation, see section 6 above, and lower interest rates, contributing to the rise in home prices, boosted the liquidity-weighted housing collateral effect. Fears by monetary policy makers about a Japan-style lost decade after the 2001-2 stock market crash were misplaced: financial deregulation was turbo-charging monetary policy effectiveness and, for the time being, more than offsetting the negative effect on consumption of the build-up of household debt.

When *HLI* and home prices actually fell sharply, beginning in 2006, followed in 2008 by the stock market, the negative effects of higher debt on consumption were no longer being offset. This is important empirical evidence for the vulnerability of households to high debt levels. US household debt to income ratios did fall after 2007 through a mixture of default and inability to take on new debt or refinance.

Regulatory, technological and market structural developments explain most of the *expansion* in credit availability or liquidity, as measured in the US by *HLI* for example. However, *contractions* in credit availability are also typically influenced by recent changes in house prices. Both are suggested by the evidence in Duca et al. (2016), who endogenise a sensitive indicator of mortgage credit conditions, the median private loan-to-value (LTV) ratio for first-time buyers in the US mortgage market, in their house price model. They find no evidence that house prices affect the LTV in *rising* housing markets, but in *falling* markets, there is strong evidence of asymmetry in that recent falls in house prices strongly reduce private LTVs. The two key credit deregulations, discussed in section 6, the CFMA of 2000 and the lifting of leverage limits on banks in 2004, drove up private LTVs. The overall LTV, for a market made up of two components, private and Federal Housing Administration (FHA)-backed mortgages, is a major determinant of US house prices, thus linking credit conditions to house prices. The house price equation in Duca et al. (2016) also finds strong evidence of a momentum effect from past house price appreciation. As demonstrated in 2004-2007, this can result in temporary house price over-valuation relative to longer-run determinants such as income, interest rates, the housing stock and (stretched) levels of credit availability. The subsequent fall in US house prices, triggering a credit crunch, was amplified by the feedback loops shown in Figure 2, where high debt levels had made households vulnerable.

7.3 Extensions to DSGE models for a housing market

The new heterogeneous agent (DSGE) model with a frictional housing market of Hedlund et al. (2016) has a similar financial accelerator mechanism to that just described. The authors write: "If a shock hits the economy and drives down house prices, housing illiquidity will deteriorate endogenously and create longer selling delays. In turn, heightened time on the market increases foreclosures, leading banks to cut back on credit, which causes demand for housing to fall even further. In other words, endogenous housing illiquidity acts both as an amplification and propagation mechanism for economic shocks via the link between housing and mortgage market conditions." This new generation of models, with better micro-foundations and market realism, contrasts with a more conventional DSGE model with two representative households, patient and impatient, and in a fixed proportion, of Iacoviello and Neri (2010). Patient households apply a LTV constraint when offering mortgage loans to the impatient households, a kind of financial friction. In their closed economy model, without banks and foreclosures, and assuming a frictionless and efficient housing market, transmission and amplification of monetary or other shocks via housing is *extremely* limited. For example, their model implies that aggregate home equity withdrawal, the excess of households' mortgage borrowing over acquisitions of housing, is always negative. In practice, US home equity withdrawal was *strongly* positive for much of the period from 2001 to 2006, and in the peak quarters was of the order of 10 percent of that quarter's household income. However, this fact and the realised foreclosures were not in the set of salient data chosen by Iacoviello and Neri for their model calibration. Indeed, for their calibrated model, they compare the correlation between consumption growth and house price growth with and without the financial friction. Without the friction, the correlation is 0.099, the result of the common influence of the shocks[29] on house prices and consumption. With the friction, the correlation rises to 0.123. One would be tempted from this to conclude, but quite wrongly, that financial frictions have little impact on the macro-economy. This is completely the opposite of what Figure 3 above implies.

[29] The major shock driving real house prices is a 'preference' shock, which Romer (2016) ironically terms a 'caloric' shock in contrast to the 'phlogiston' of productivity shocks, the major driver of real residential investment in their model.

7.4 Co-integration in consumption functions: the Lettau and Ludvigson result

Examination of the co-integration properties of the UK, US and Japanese consumption functions in Aron et al. (2012) suggests a single co-integrating vector linking the log of the consumption-to-income and asset-to-income ratios, once shifts in credit conditions are taken into account. Moreover, the growth rate of consumption reacts strongly to the lagged equilibrium correction term implied by this long-run relationship.

Well-known papers by Lettau and Ludvigson (2001, 2004, 2013) come to the completely *opposite* conclusion regarding the relationship between assets and the rate of growth of consumption. They examine the co-integration properties of US income (*y*), consumption *(c*) and net worth (*A*) for 1952-2003, and extend the data period to 2010 in their 2013 paper. They show that the lagged equilibrium correction term ('*cay*'), the deviation between log *c* and a combination of log *y* and log *a*, explains little of *Δlog c* and more of *Δlog A*. This empirical finding inspired them to make a theoretical contribution: log-linearising a simple version of the inter-temporal budget, which treats all assets including housing and human wealth as equivalent, they suggest that there is an approximate relationship linking *cay* to future real returns on assets.[30] Focusing on stock market returns, they argue that the deviation of log consumption from a linear combination of log income and log net worth can usefully predict future stock-market returns, and provide some empirical evidence to back their claim. Their work has been highly influential, attracting 1752 and 557 citations respectively for the 2001 and 2004 papers. Their claim that net worth was nearly irrelevant for explaining consumption, chimed with the dominant existing paradigm of the NK-DSGE and RBC models that asset prices were a mere side show with no reverse linkages to consumption. That is, asset prices were driven by the real economy, but did not influence consumption.

However, this finding is seriously flawed, and arises from the restrictions assumed. The reasoning above and our evidence from the LIVES models for several countries suggests that one should *not* expect a stable relationship between consumption, income and net worth as embodied in *cay*: (i) when major shifts occur in credit market architecture; and (ii) when marginal responses of consumption to liquid assets, illiquid assets and housing wealth differ. The Lettau-Ludvigson result is an artefact of assuming away the changing credit market architecture and its interactive economic effects, and adding up all assets into a highly restrictive measure of wealth, net worth, which ignores the different spendability of liquid and illiquid components of wealth. In other words, their *cay* is grossly mis-specified for forecasting US consumption growth. In a series of papers for other economies, we find that consumption growth reacts strongly to the deviation of consumption from an appropriate long-run solution which *does* incorporate credit shifts and portfolio disaggregation. It is of interest that in Germany, with small shifts in credit market architecture, consumption function research has long suggested that consumption growth does respond strongly to the deviation of the log of consumption from a combination of the log of income and the log of net worth, though the influence of income dominates (see Geiger et al. (2016) for references). In other words, for Germany, the Lettau-Ludvigson result is rejected even for a conventional net worth formulation of the consumption function.

[30] To be precise, the linkage is with future returns *plus* future consumption growth, but the assumption is made that the former dominates.

Further, the intuition for the Lettau-Ludvigson stock market forecasting result is implausible. It suggests that households as a whole, including the many who do not own stocks, are better at forecasting the stock market than stock market professionals. This contradicts what we know about financial literacy, Lusardi op cit.. The Lettau-Ludvigson result also contrasts with the plausible intuition of a related finding by Campbell (1987): both are using household consumption behaviour to make forecasts about the future through household expectations, in the case of Campbell, about future income growth. Campbell deduces from the REPIH that when the saving rate is low, people are optimistic about their future income growth and so spend more. Although the REPIH is a poor approximation to reality, this is plausible. The reverse will hold when households are pessimistic. Then even without full rational expectations, there is some information content to consumers' expectations that helps forecast future income growth.

Finally, a further problem with the Lettau and Ludvigson result, as Brennan and Xia (2005) observe, is that the deviation of log income and log net worth from a linear trend does at least as well in forecasting stock returns as *cay*. This probably reflects the tendency of the stock market to overshoot and revert to some kind of trend. This may be all that *cay* is capturing.

8. Mis-specification in non-DSGE macro-models

Many central banks or national treasuries operate or have recently introduced non-DSGE macro-models. Examples are the FRB-US model (Brayton and Tinsley, 1996), the Dutch Central Bank's DELFI model (2011), the UK Treasury's HMT-OBR model (2013), the Bank of Canada's LENS model (Gervais and Gosselin, 2014), and a model of the Deutsche Bundesbank (under construction).[31] The aggregate consumption equations in these models typically introduce wealth in a *very restrictive* form, which is incorrect, as argued above. For example, net worth is used in FRB-US, LENS, and HMT-OBR models; and net financial assets and net housing wealth in DELFI. The FRB-US and LENS models are alone in incorporating forward-looking income expectations (and with realistically high discounts applied to expected income growth). However, none of the models takes any account of shifts in credit market architecture in the consumption equation. Typical symptoms of this particular mis-specification are a low speed of adjustment in the long-run solution, and parameter instability. An example of the latter is given by the FRB-US non-durable consumption equation, which when estimated to 2009, has a speed of adjustment of 0.19, but which falls to 0.11 when estimated to 2014 (Brayton et al., 2014). Such a *slow* speed of adjustment is at odds with the 'folk-wisdom' of central bankers on how quickly policy measures affect the real economy. The varied speeds of adjustment are 0.13 in HMT-OBR, 0.15 in LENS and 0.20 in DELFI models for total consumption. These speeds are low relative to those obtained in consumption equations incorporating credit shifts and portfolio disaggregation, Aron et al (2012) for the UK and US, Muellbauer and Williams (2011) for Australia, Aron and Muellbauer (2013) for South Africa and Muellbauer et al. (2015) for Canada.

[31] Abbreviations are: FRB (Federal Reserve Board); DELFI (Dutch Economic Linkages: a Forecasting Instrument.); HMT-OBR (Her Majesty's Treasury-Office of Budget Responsibility); and LENS (Large Empirical and Semi-structural model).

Of all these models, only the DELFI model articulates equations for asset prices and the main elements of household balance sheets, including unsecured debt, mortgage debt, financial assets and housing wealth.[32] The mortgage debt equation, but that equation alone, builds in a simple proxy for credit market liberalisation through an intercept shift between the early 1990s and the mid-2000s, though none of the other equations are subject to parameter shifts. Since the house price equation is driven by mortgage debt, and housing wealth affects consumption, credit market liberalisation has wider consequences, but only indirectly and under quite restrictive assumptions.

These central bank models are substantially more realistic than NK-DSGE models. They allow empirical evidence to play some role and do incorporate money, debt and asset prices though only via net worth. The treatment of expectations in the FRB-US model is in most respects admirable, representing a major advance on the macro-econometric models that preceded it,[33] though anchoring household expectations in survey data on expectations would have been a useful further step. In the case of the US, although net worth fell sharply relative to income during the crisis, the implied restrictions and the omission of credit shifts meant that the FRB-US model substantially under-stated the magnitude of the shock transmission mechanism and the constraint of high debt levels on consumption. Yet, Figure 3 makes clear the magnitude of the 'double-whammy' on consumption from falling US house prices and the credit crunch. It also shows the effect on consumption from rising household vulnerability and escalating debt-to-income since the early 1990s.

9. Towards improved policy models

Blanchard (2016) argues that: "… different model types are needed for different tasks. Models can have different degrees of theoretical purity. At one end, maximum theoretical purity is indeed the niche of DSGEs. For those models, fitting the data closely is less important than clarity of structure. Next come models used for policy purposes, for example, models by central banks or international organizations. Those must fit the data more closely, and this is likely to require in particular more flexible, less micro-founded, lag structures (an example of such a model is the FRB/US model … which starts from micro-foundations but allows the data to determine the dynamic structure of the various relations)."[34] For central banks, there are three key requirements of a policy model: empirical congruency; accessibility, so that forecasts and policy simulations can be understood and scrutinised

[32] A systems approach to parts of the joint determination of consumption and household portfolios has also been used by Chrystal and Mizen (2001) and Cloyne et al. (2015), the latter as part of the Bank of England's 'suite of models'. However, the chosen portfolio elements are liquid assets and unsecured debt, while mortgage debt is omitted. The consumption function is driven by net financial wealth, but there is no role for housing collateral and no account whatsoever is taken of the many and major shifts in credit conditions.

[33] It is surprising that this lead was not followed more widely by other central banks. Perhaps the generalised cost of adjustment structure used throughout to guide dynamic specification was found to be too complex, or perhaps the gathering influence of the NK-DSGE crowded out this type of model development.

[34] However, his recommendation to estimate the model as a system rather than equation by equation is less persuasive. The reason is that specification error in even one equation can affect inference regarding the rest of the system. Formulation and estimation at the sub-system level, e.g. for the household sector, and if necessary using instrumental variable techniques, is likely to be more robust and adds to coherence and interpretability.

by a wide range of people; and adaptability, so that different sub-models can be quickly integrated in the core model. One advantage of the *modular* structure of the FRB-US model is that an improved set of household sector equations could be relatively easily integrated with the remaining existing structure. However, a core model with perhaps 30 or 40 behavioural equations rather than the present 60 equations, might enhance accessibility. At any rate, to include relevant variables such as money, credit and asset prices, more equations are needed than in the Bank of England's DSGE COMPASS model with its 15 variables.

The critique by Lucas and Sargent (1979) of the econometric policy models of the time had a powerful impact on the profession, see Wren-Lewis (2016). Central to the critique was that expectations were not properly dealt with in these models and that many of the restrictions imposed on individual equations were incredible, though much was also made of the initial empirical failure of these models after the oil price shocks of the 1970s. Supposedly micro-founded DSGE models with rational expectations were one result. Another was the shift to linear vector autoregressive models recommended by Sims (1980) to avoid 'incredible parameter restrictions'. However, the 'curse of dimensionality' – the rapid escalation of the number of parameters as the number of variables in a VAR system rises- forces new restrictions. These are either on the number of variables it is feasible to include and/or the application of Bayesian priors and/or exclusion restrictions common in 'structural' VARs.[35] Even more serious, DSGE and VAR approaches have major difficulties coping with structural breaks, as argued in section 4. There is much to be said for the flexible approach taken in FRB-US to the treatment of expectations, but this needs to be combined with much more careful attention to structural shifts.[36] As well as better modelling the household sector, the role of the banking sector should be articulated, linking bank balance sheets –impacted by non-performing loans- back to the ability to extend credit to the private sector. The argument of this paper has been that structural shifts in credit market architecture as well as a deeper recognition of the consequences of uncertainty and liquidity constraints would greatly improve the FRB-US model and similar policy models.

Improvements in the current set of non-DSGE policy models of central banks and national treasuries, such as the FRB-US model and the HMT-OBR model, could result in a number of gains, which are outlined below.

9.1 Deriving better early warning indicators of crises

One answer to the Queen's famous question referred to the introduction is that some economists *did* warn of dangers ahead of the 2008 global financial crisis. Danielsson et al. (2001) noted the pro-

[35] For example, certain types of shocks are assumed to have contemporaneous effects only on a sub-set of variables.

[36] See Castle et al (2015) for new methods for detecting structural breaks, and Hendry and Doornik (2014) on the use of automated methods for model selection. These methods greatly speed up the search for parsimonious data-congruent models. Hendry and Johansen (2015) discuss methodological and statistical issues underlying model selection and deal with the 'data mining' critique sometimes applied to evidence-based model selection.

cyclicality of the Basel II accords that tends to relax restrictions on banks during booms and tighten them in recessions. Rajan (2005), and his discussant Shin (2005), famously warned, and against the conventional wisdom, that the spread of financial derivatives into the global economy was likely to amplify, rather than diversify, risk to the system as a whole. William White at the Bank for International Settlements (BIS) became increasingly concerned from 2003 onwards about burgeoning risks in the financial system. Alongside this was an incipient empirical literature on early warning indicators of financial crises, such as credit-to-GDP ratios and debt service ratios. Since the financial crisis, the "early warning" empirical literature has developed[37], with greater focus on real-estate connected credit booms as indicators and the recognition that institutional differences between countries matter. Nevertheless, common to these studies, which focus on a small set of variables, is parameter instability or fairly weak results in forecasting performance.

Forecasting financial crises and judging when housing is so overvalued as to pose a risk for financial stability remains a difficult task. Two sources of house price over-valuation are temporary euphoria arising from extrapolative dynamics in house price expectations and weak fundamentals (Muellbauer, 2012). The former is relatively easily detectable from house price models. The latter needs a more comprehensive approach as negative shocks to fundamentals can arrive in multiple ways. For example, they may arise through a collapse of export markets, a terms-of-trade shock for a commodity exporting country, a rise in foreign interest rates for a small open economy with an open capital account, a collapse of financial asset prices, or a "credit crunch". Vulnerability to such shocks is typically far greater when debt levels and current account deficits are high, and when adjustment mechanisms via fiscal policy, interest rates and the exchange rate are constrained. Vulnerability is also greater when debt leverage and debt duration mismatch in the banking system is high, and when recent lending quality has been low.

Risk assessment and guidance on when macro-prudential policy is needed would be considerably enhanced if macroeconomic policy models *themselves* incorporated such feedbacks and non-linearities of the financial accelerator mechanisms. In this respect, the latent variable approach in the non-DSGE consumption-portfolio-asset price sub-systems, discussed in this paper, should be very useful. Joint modelling of these equations using a Latent Interactive Variable Equation system (LIVES) permits the extraction of often hard-to-measure credit conditions as latent variables. This has been exemplified for various countries[38], while Duca and Muellbauer (2013) explore more generally how to integrate evolving credit market architecture into flow of funds based macro-models, linking with earlier literature by Tobin and colleagues.

[37] For example, see Edge and Meisenzahl (2011), Claessens et al. (2012), Drehmann et al. (2012), Giese et al. (2014), Galati et al. (2015), Jorda et al. (2016) and Ruenstler and Vlekke (2016).

[38] Muellbauer and Williams (2011), for Australia, estimate a 3-equation LIVES model for consumption, mortgage debt and house prices. Aron and Muellbauer (2013), for South Africa, use a 3-equation LIVES model for consumption, household debt and permanent income. Chauvin and Muellbauer (2013), for France, estimate a 4-equation LIVES model for consumption, mortgage and unsecured debt, and house prices. Muellbauer et al. (2015), for Canada, estimate a 3-equation LIVES model for consumption, mortgage debt and house prices. Geiger et al. (2016), for Germany, estimate a 6-equation LIVES model, see below.

By extracting the common factor in supply-driven shifts in credit availability from multiple equations (rather than just from a credit-to-GDP indicator), it should be possible to identify episodes in which credit availability is high or has recently risen sharply. To illustrate, in the US by 2006, mortgage credit availability had increased sharply to unprecedented levels, implied by the data behind Figure 3. House prices had over-shot, while the economic environment had deteriorated following increases in the Federal Funds rate from June 2004 to July 2006, and higher oil prices. The subsequent fall in house prices, triggering a credit crunch, was amplified by the feedback loops shown in Figure 2, where high debt levels had made households vulnerable, as Duca (2006) noted at the time. These circumstances would have caused a significant recession, particularly given poor sub-prime lending quality, even without the failure of Lehman Bros.

9.2 Explaining the long-run

These models of consumption and portfolio choice help to account for long-run trends in the data, such as the secular decline in the US household saving rate and the secular rise in the German saving rate since 2001. This contrasts with the standard practice in DSGE modelling, which is to remove *all* long-run information in the data using the Hodrick-Prescott filter, or sometimes with variable-specific time trends. Where there are major shifts in credit market architecture, there is a potential role for interaction effects between credit quality and availability with other variables, resulting in important non-linearities. This should serve as a warning against the use of a *linear* models, such as the linear VAR model and DSGE models, for parameter stability will then be a problem for the data from most countries in both these types of models.

9.3 Improved interpretation of data on credit growth and asset prices

It is of crucial significance that the LIVES models of consumption and portfolio choice will help central banks to interpret the data on the growth of credit, money and asset prices. Many observers are puzzled by the tendency of a growth in debt to be followed shortly by income growth; yet high debt levels often predict subsequent income declines, but with relatively unstable parameters. Debt growth generally reflects shifts in credit availability which expands economic activity, or else rises in house prices (which tend to be persistent). Both help to forecast subsequent economic growth, at least in the US and the UK. *With the appropriate controls* in LIVES models, there are stable and large, negative effects of debt on consumption, and hence of debt on subsequent economic growth. This resolves the apparent "paradox". Omitting the appropriate controls, which include shifts in credit supply to households and a disaggregation of the main portfolio elements, merely results in unstable and hard-to-interpret correlations.

The LIVES models, using aggregate time series data, rest on the stochastic aggregation of heterogeneity at the micro-level. Since demography and distributions of incomes and assets evolve slowly, so should the related macro-parameters. It is important to complement the macroeconomic time series evidence with micro-economic data, as from the Eurosystem's Household Finance and Consumption Survey (ECB (2013) and Arondel et al. (2016)). One reason is that this can help to calibrate the effects of demography and distributional changes at the aggregate level; but micro-evidence can also test hypotheses about behaviour in macro-models, can contribute to risk assessment[39] and the measurement of the distributional effects of policy.

The reverse is also true, evidence from micro-data in cross-sections and panels needs to be complemented with time series macro evidence. Cross-sections are snapshots at particular points in time, while most panel studies with household fixed effects and time dummies remove most of the macro information. Together with high levels of nonresponse[40], this means that conclusions for the aggregate economy from micro-data are often quite limited. Often panel data span relatively short periods, and if not, investigators all too rarely check parameter stability. Failure to detect major structural shifts with important policy implications can be the result of ignoring the macro evidence.

9.4 Gaining insights into monetary transmission for macro and macro-prudential policy

Important insights for policy and financial regulation can result from joint models of consumption and household portfolios, when taking proper account of differences in institutions and in the composition of household wealth portfolios across different countries. There is a tendency among economists to assume a 'one-size-fits-all' view of monetary transmission. However, the evidence from LIVES models suggests that with diverse lending practices, regulatory and tax regimes, monetary transmission in Germany and Japan, is very different from that of the UK and the US. One of these distinctions is between countries with mainly floating rate and mainly fixed rate mortgages. The UK's floating rate mortgages market allowed monetary policy to affect the housing market and the cash flows of debtors rapidly and effectively in the financial crisis, and is the major reason why foreclosures and house price falls were so much less severe than in the US, Aron and Muellbauer (2016b).

For Germany, Geiger et al. (2016) jointly estimate a 6-equation LIVES model for consumption, unsecured debt, mortgage debt, liquid assets, house prices and permanent income. Risk appetite and the credit conditions indices for unsecured debt and for mortgage debt (based on a mix of dummies and spreads) are the three latent variables in the model. German shifts in credit conditions have been *very small* compared with other countries.[41] A negative effect of higher house price to income ratios on German consumption is confirmed, paralleling findings for Japan.[42] The German result reflects the relatively tight down-payment constraints, very limited access to home equity loans and that fact

[39] One such hypothesis is that the *joint* distribution of household debt, assets and income affects the vulnerability of the household sector to shocks. To illustrate, the high debt-to-income levels of many Dutch households, but backed by the security of relatively high degrees of pension coverage and, for most highly indebted households, ownership of financial assets, are likely to make households *less* vulnerable than households with similarly high debt-to-income ratios in other countries. Cross-section snapshots of the joint distributions of household debt, assets and income from the Household Finance and Consumption Survey have been used by Gross and Problacion Garcia (2016) to investigate the likely effects of macro-prudential limits on default risks for households.

[40] See Panel on a Research Agenda for the Future of Social Science Data Collection (2013).

[41] Given the smaller scale of variation in consumption to income ratios, demography and pension reform play a relatively larger role in explaining these variations in Germany compared with the UK or US.

[42] See Muellbauer and Murata (2011a) and Aron et al. (2012).

that owner-occupation lies below 50 percent[43]. Thus, home-ownership in Germany and Japan does not play an "ATM" type role as it can do for households in the US and UK.

One implication is that the powerful and reinforcing feedback loop that operates via consumption in the financial accelerator, found in the US and the UK, is completely missing in Japan and Germany. Together with conservative banking regulation and practices, this makes a US-style credit and house price boom and bust far less likely. A potential financial crisis in Japan or Germany would have other causes.

There are high levels of bank and saving deposits relative to debt in Germany, and even higher in Japan. For aggregate demand, the spending of Japanese households with little or no debt far outweighs that of borrowers who benefit from higher inflation (that is, provided inflation also applied to their earnings), see Muellbauer and Murata (2011b) on lessons for monetary policy. Lowering interest rates on deposits then serves to lower aggregate consumption in Germany and Japan (given non-property income and asset prices). Moreover, if households believe that real interest rates on saving deposits will be low for a long time, they are likely to save larger fractions of their income for retirement. The Bank of Japan's attempt at forward guidance by promising higher future inflation for longer, *even* if it were credible, could only increase the pessimism of the older population by reducing the future real value of their savings balances and increasing retirement saving by much of the working age population. Other common elements of the transmission mechanism, operating via the exchange rate and via investment, currently also appear to be less effective than before, while low stock-market participation in Japan makes that wealth channel less effective than in the US or UK. Moreover, negative interest rates challenge the survival of current banking and long-term insurance structures.

There is a gathering consensus in the markets that the limits of monetary policy as practiced in recent years have been reached. Nowhere is the evidence stronger than in Japan and the core-Eurozone, suggesting policy tools need rethinking. Such a rethink should take seriously the structure of household portfolio balance sheets. Outside Germany and Japan, encouraging households to take on more debt through lower borrowing costs, and indirectly via higher house prices, can provide a short-term consumption stimulus. But adding to already high burdens of debt will result in a negative longer-term payback on consumption, and it is not a recipe for the long-term.

A further important implication of research on heterogeneous agents facing liquidity constraints and idiosyncratic uninsurable income uncertainty is that Ricardian equivalence fails. This suggests that theories about the ineffectiveness of fiscal policy and the monetary finance of fiscal expenditure[44] that rely on infinitely lived or dynastic households accurately taking into account the joint long-run budget constraint of the public sector, including the central bank, are likely to be ill founded.

[43] 43% in 2013 according to OECD data; survey data for private households excluding collective households and institutional populations from Eurostat, based on EU-SILC, suggest a figure of 52.4% in 2014.
[44] See Muellbauer (2014, 2016).

10. Conclusion

Any macro-economic model necessarily involves a degree of approximation to reality. Consistency with ‘economic theory’ is then usually put forward as a major criterion for choosing between different approaches. But which economic theory should one choose? The New Keynesian DSGE model is *not* consistent with the information revolution in economic theory of the 1970s in which asymmetric information leads to liquidity constraints and uninsurable income risks, with powerful behavioural implications. These include strongly heterogeneous, buffer stock or precautionary consumption decisions and ‘hand to mouth’ behaviour even by many wealthy households, explored by Deaton (1991), Carroll (1992, 2001), Ayagari (1994) and more recently in the heterogeneous agent literature exemplified by Kaplan et al (2016). The view taken is the present paper is that, for policy modelling purposes, approximate consistency with good theory is better than exact consistency with the wrong theory. The exact consistency of the NK-DSGE model with optimising behaviour by representative agents under a set of extreme and simplistic assumptions about information and the economic environment led to the omission of money, credit and asset prices and the neglect of structural shifts in credit market architecture. The resulting failure of the model in the run-up to, during and after the global financial crisis should have come as no surprise.

However, extant general equilibrium (but non-DSGE) policy models at central banks also have their defects: their consumption functions take no account of shifts in credit market architecture and mostly aggregate liquid assets, debt, illiquid financial assets and housing wealth into a single measure, net worth. The same defects also led Lettau and Ludvigson (2001, 2004) to draw the wrong, but highly influential, conclusions about the relationships between consumption and household portfolios and hence asset prices. The multi-country evidence cited above shows strong influences on the consumption-to-income ratio from shifts in credit conditions and from debt- and asset-to-income ratios, disaggregated into at least three components. However, institutional differences between countries imply major differences in behaviour, with profound policy implications. Better joint modelling of household consumption and portfolio decisions, in sub-systems of equations, is necessary for progress and improved policy, including macro-prudential. Fortunately the modular structure of models such as the Federal Reserve’s FRB-US should make it possible to incorporate the necessary repairs. That model’s flexible treatment of expectations meets the key objection of the Lucas and Sargent (1979) critique of the large econometric policy models of the period. With a better checks for and incorporation of structural shifts, revised macro-econometric models should be able to improve warnings of risks ahead, forecasting and policy simulations.

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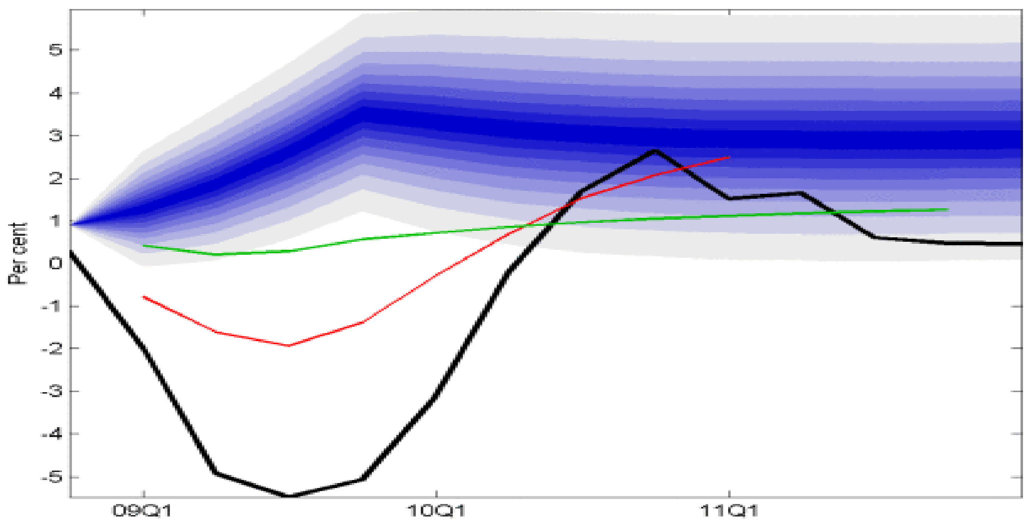
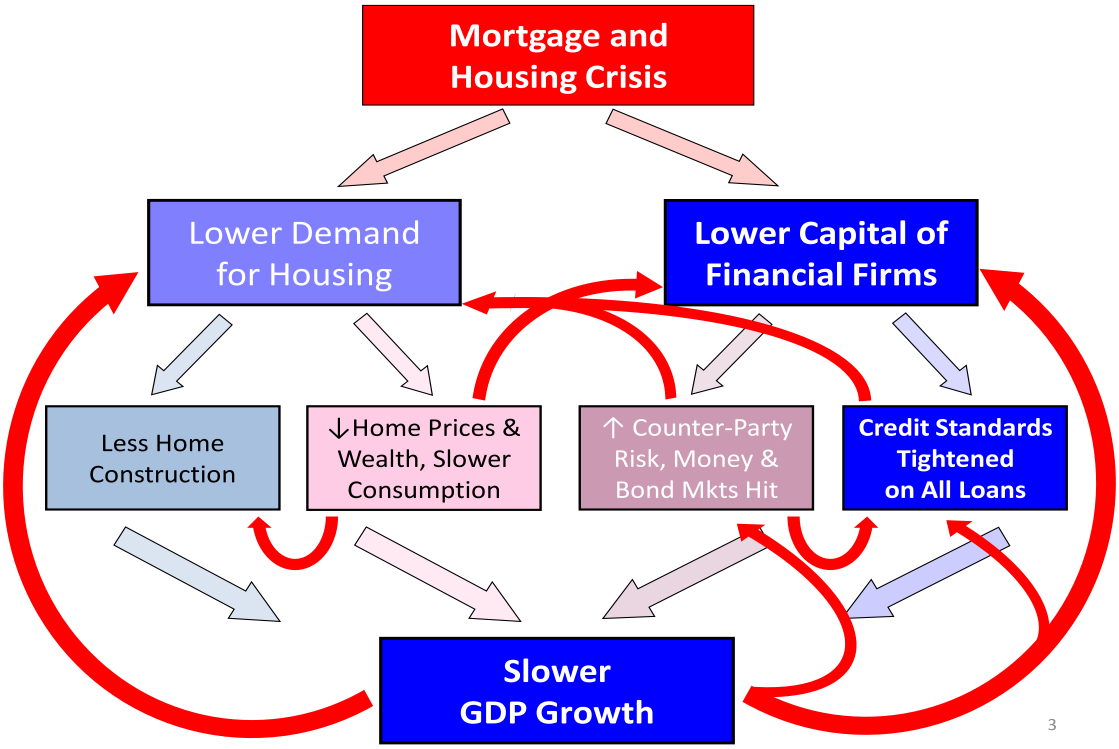
Figure 1: Real time forecasts in 2008Q4 of annual GDP growth at the Bank of England



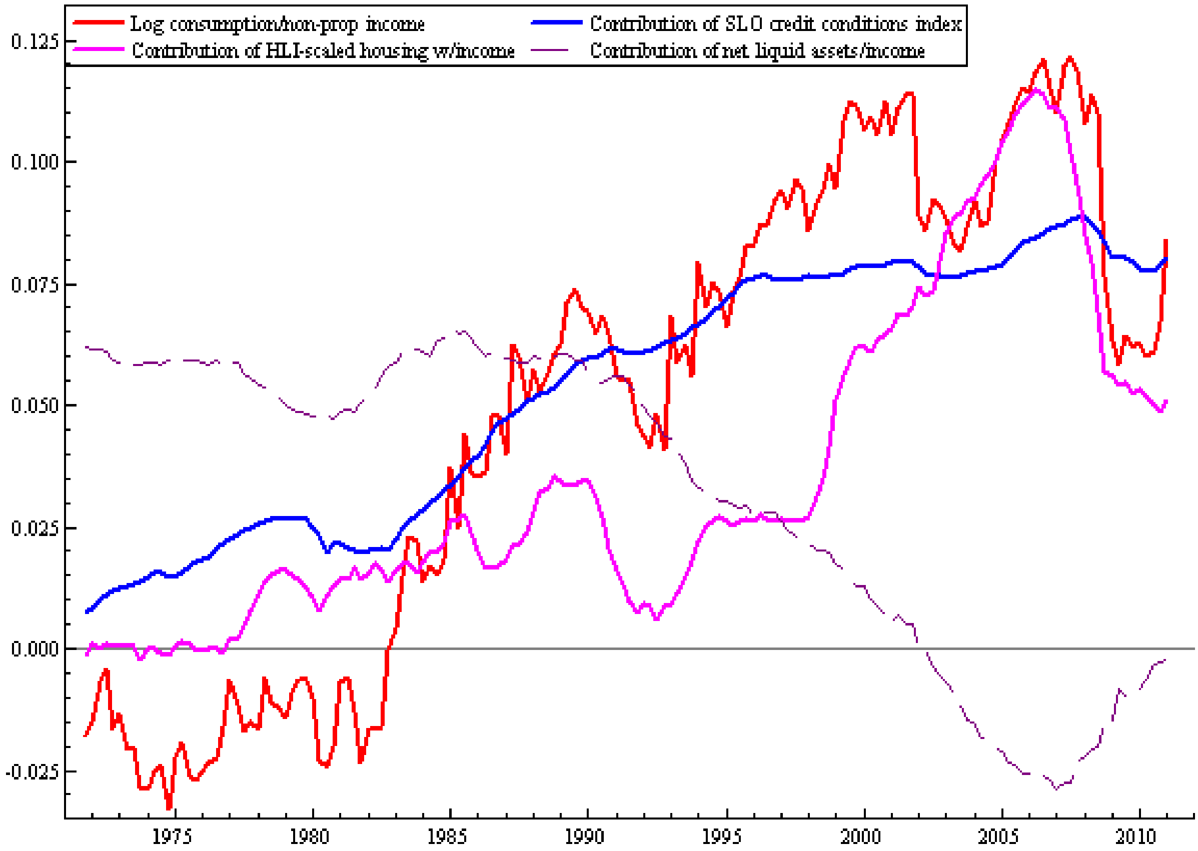
ONS data in black; *COMPASS* density forecast in shaded blues; Statistical Suite forecasts in green; *Inflation Report* forecasts in red. Source: Fawcett et al (2015)

Figure 2: The financial accelerator operating in the US subprime crisis



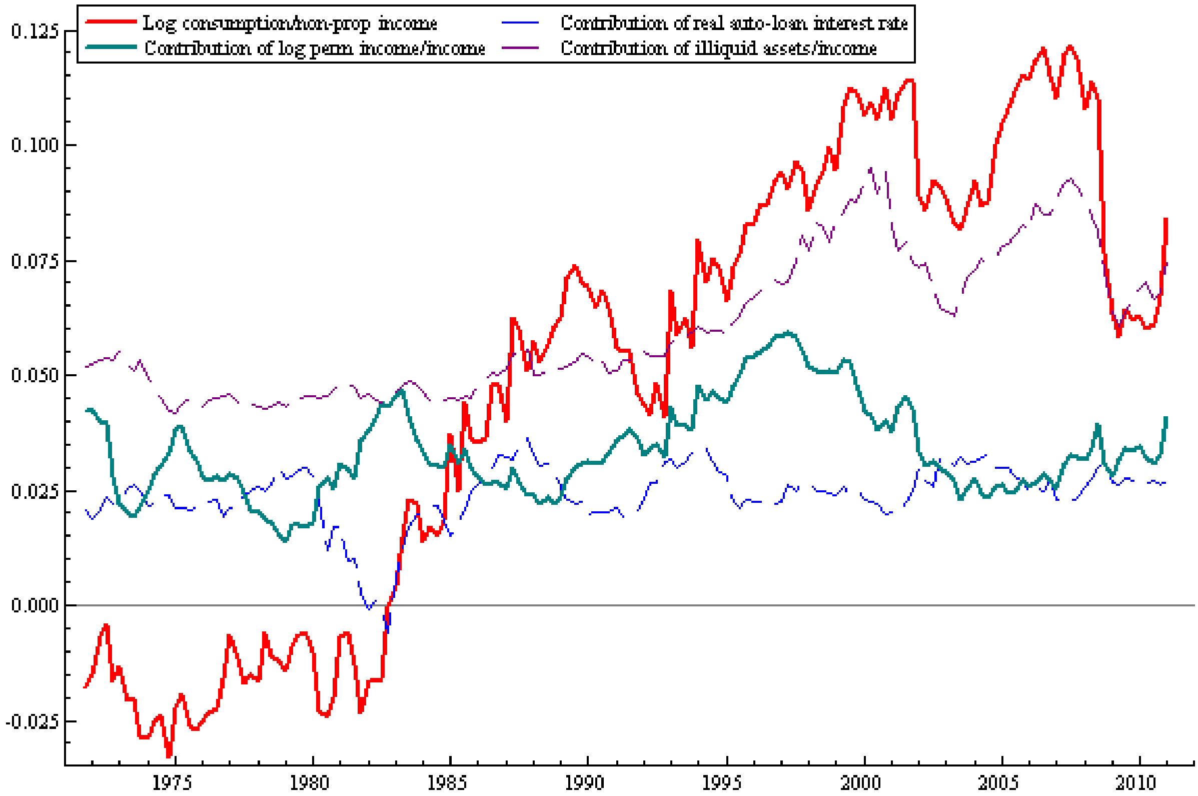
Source: Duca and Muellbauer (2013).

Figure 3: Estimated contributions of CCI, housing wealth and net liquid assets to the consumption/income ratio



Source: Duca and Muellbauer (2013). The income measure is non-property income, consumption is total consumption, including durables.

Figure 4: Estimated contributions of real interest rates, permanent income and illiquid financial assets to income to the consumption/ income ratio



Source: Duca and Muellbauer (2013). The income measure is non-property income, consumption is total consumption, including durables. Log permanent income/income is defined for non-property income and comes from a forecasting model.