The financial system and the natural real interest rate: towards a 'new benchmark theory model'

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Abstract: The 2008 financial crisis revealed serious flaws in the models that macroeconomists use to research, inform policy, and teach graduate students. In this paper we seek to find simple additions to the existing benchmark model that might let us answer three questions. What caused the boom and crisis? Why has the recovery been slow? And, how should policy respond to that slow recovery? We argue that it is necessary to add financial frictions to the benchmark model. This allows us to study the effects of leveraged financial institutions, and of a yield curve based on preferred habitats. Such features will cause endogenous changes in the natural real interest rate and the spread between that interest rate and the rate which influences expenditure decisions. They are likely to radically change the way in which the model responds to shocks. We point to some promising models that incorporate these features.
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I. Introduction

Seismologists say that their profession proceeds in two ways: with better models, and more earthquakes. In 2008 there was an economic earthquake, and our models are still catching up. During an earlier earthquake in the 1930s Keynes found that the classical model did not address his policy concerns. In the 2000s we have found that the New Keynesian dynamic stochastic general equilibrium (DSGE) model does not address our concerns. Like the other contributions to this issue, our paper offers a perspective on how to fix the benchmark model.

This paper is written from the vantage point of the graduate-school classroom. One of us was teaching the existing benchmark model during the crisis, and the other was a graduate student at that time. Both were frustrated at the gap between the models being taught in class and the issues being discussed in practice. In this paper we aim to address that gap.

We seek to find an addition, or additions, to the New Keynesian DSGE model that will help us provide answers to three questions. First, what caused the mid-2000s boom and subsequent global financial crisis? Second, why has the recovery since then been so slow? Third, how should policy respond to this slow recovery? We want to find answers of a simple, teachable kind.

We argue that the most pressing change to the New Keynesian DSGE model needed to answer our questions, although there are many possible answers, is to incorporate financial frictions.

The existing benchmark New Keynesian DSGE model relegates credit to the background (see section II of the paper). The two particular examples of such a benchmark model which we focus on in this paper are those created by Clarida, Galí, and Gertler (CGG, 1999) and the more detailed Smets and Wouters model (SW, 2007), which includes capital accumulation.[1] Both of these models assume that credit markets work without frictions. Households and firms have unlimited access to credit markets which instantly clear, and insurance is fully available against idiosyncratic risks such as losing a job. Monetary policy influences only the price of credit, rather than its availability, and the resulting change in this price is costlessly transmitted to the rest of the economy.

In reality the nature of financial frictions appears to have undergone significant changes since the crisis of 2008. There has been considerable deleveraging by banks, coming from an increase in bank capital ratios (see section III). This deleveraging appears to have caused large and persistent increases in the spread between retail and policy rates, and policies have been adopted to respond to this spread. Furthermore, there have been significant changes in the yield curve, apparently caused by changes in the willingness of banks to undertake liquidity transformation. The policies now being used to manage the recovery from the crisis, like

[1] For additional presentations of the CGG model, see also Woodford (2003) and Galí (2015). It is the latter model which we take as *the* benchmark DSGE model in our Assessment paper at the beginning of this double issue of the *Oxford Review of Economic Policy.*

macro-prudential regulation and quantitative easing (QE), appear designed to manipulate the yield curve, a possibility which is not captured in the benchmark model.

We believe that it is necessary to add a microfounded model of credit, and of financial frictions, to the New Keynesian DSGE model, in order to properly respond to these real-world developments.[2] Three methods of incorporating credit frictions into the model appear useful.

Liquidity constraints, as in Ravn and Sterk (2016), lead to counter-cyclical risk premia (that is, the premium is high when aggregate demand and output are low). This leads unemployment-fearing households to engage in precautionary savings. That, in turn, lowers aggregate demand and the natural rate of interest. However, such a framework does not allow households to borrow at all and so is not suitable for studying macroprudential policy levers that have been important since the crisis (see section IV(i)).

Leverage, as modelled by Curdia and Woodford (2016), can endogenously increase the probability of financial crisis. This can also lead to counter-cyclical risk premia—i.e. to risk premia rising when there is a downturn—to compensate banks for the cost of default. Such a framework also allows credit markets to affect aggregate demand and the natural interest rate, and is well-suited to studying unconventional policies like macro-prudential regulation and QE. However, it does not allow for effects of credit conditions on the shape of the yield curve (see section IV(ii)).

A yield curve, driven by a preferred habitat model along the lines of Vayanos and Villa (2009), would address some shortcomings of the other frameworks. Incorporating these features would help us to shed light on the ability of QE to twist the yield curve (see section IV(iii)). It would also remedy a historic omission: the absence of James Tobin's work on portfolio balance from the two other models which are considered in this paper.

As we noted at the beginning of this paper, and in our Assessment article (Vines and Wills, 2018) at the beginning of this issue of the *Oxford Review of Economic Policy*, there is an analogy here with the developments which occurred in the 1930s. Keynes inherited Alfred Marshall's classical model. He found, in his discussions at the Macmillan Committee in 1930,

[2] See Reinhart and Rogoff (2011) for an extended discussion of the effects of changes in credit conditions.

that this model could not help him to understand the unemployment which had afflicted Britain ever since the country had returned to the Gold Standard in 1925 at an overvalued exchange rate. He needed to amend the classical model. By the time he had written the *General Theory*, he had added sticky wages in the labour market. This new feature completely changed how the whole model worked. It meant that a fall in animal spirits that lowered investment might mean that unemployment could emerge as an equilibrium outcome.[3] Keynes had to invent the consumption function, the multiplier, the IS curve, and liquidity preference in order to understand the full implications of what he was saying. But now, many years later, we understand these details and can explain Keynes's 'new' system to our students in a straightforward way.

By incorporating credit frictions into our model, we seek to add three new features to the existing benchmark DSGE models. The first is a natural rate of interest that is affected by credit market conditions. The second is a spread between the natural interest rate and the interest rate faced by consumers and investors that is also caused by credit conditions. The third is a market for imperfectly substitutable risky assets that can produce a yield curve. It is our ambition to show that these three additions can change the way in which the whole system works. And we want to be able to explain what happens in a simple way. Indeed, we want to be able to do this in a way which is as simple to explain as the Keynesian multiplier.

II. The existing benchmark New Keynesian DSGE model

(i) A description of the model

We draw a distinction between theory models and policy models, following Blanchard (2018, this issue); Wren-Lewis (2018, this issue) calls the latter 'structural economic models'. As Blanchard and Wren-Lewis argue, one of the purposes of policy models is to actually fit data, so that they can be used to provide relevant policy advice. In the present paper we are only concerned with theory models, rather than the analysis of policy.

[3] We discuss the chain of reasoning in our Assessment article in this issue (Vines and Wills, 2018).

The focus of this paper is the question of how to create a theory model that is suitable for the core graduate-school course in macroeconomics. We use the term 'benchmark model' to describe the New Keynesian theory model(s) that is, or are, taught in a graduate-school course. The main ones are the three-equation CGG model, and the more detailed SW model which includes endogenous capital accumulation. Our aim is to 'fix' these benchmark models by adding a treatment of credit market frictions.

Of course, when one is trying to fix something, it is first a good idea to get clear what one is trying to fix. The letter inviting authors to contribute to this issue of the *Oxford Review of Economic Policy* explicitly put forward the SW model, rather than the CGG model, as *the* benchmark model. It is true that some graduate courses in New Keynesian macroeconomics do not present the SW model, concentrating entirely on the CGG model instead. But this can create confusion for students because, by omitting capital, the CGG model is harder to reconcile with the Ramsey model and the real business cycle (RBC) model, both of which are taught to graduate students in other modules. By contrast, the SW model has the advantage of incorporating all of the Ramsey/RBC insights in a model that also includes the effects of changes in aggregate demand and so is Keynesian in form. As a result, we argue in our Assessment that the SW model is *the* benchmark New Keynesian DSGE model (Vines and Wills, 2018). Nevertheless, to simplify our exposition in the present paper we use the smaller three-equation CGG model that abstracts from capital accumulation, and so from an endogenous natural level of output. But throughout the paper we discuss what the implications would be of allowing for capital accumulation and for the resulting endogenous natural level of output.

The SW model can be described as follows. There is an IS curve, which has two components. First, there is a forward-looking Euler equation for the consumption of a representative consumer. Second, there is a forward-looking equation for investment by the representative firm which shows that investment is driven by Tobin's q, the movements of which are determined by the size of capital adjustment costs. The natural level of output is determined by a production function employing the capital stock, labour, and the level of technology. Aggregate demand can differ from the natural level of output because of nominal rigidities, creating an output gap. That gap causes inflation, in a way described by the forward-looking Phillips curve which depends on Calvo price-setting. Monetary policy is represented by a Taylor rule, which may or may not be the product of optimization by a forward-looking central bank. This policy determines the nominal interest rate, and thus the real interest rate, which feeds into both the Euler equation for consumption and the arbitrage equation that determines Tobin's q.

Collapsing the SW model into a three-equation CGG model means abstracting from investment—consumption is the only form of private-sector demand. The CGG model therefore also abstracts from the effect of capital accumulation on the natural level of output, which will be important in some of what follows. For this reason, when we are discussing the CGG model we will keep track of the effects of any changes to the natural rate of interest rate, and to the natural level of output, in order to bear in mind the way in which this endogeneity works in the SW model.

It is useful for what follows to set out the key equations of the CGG model.[4] These are an IS curve (showing aggregate demand relative to aggregate supply, or the output gap), a Phillips Curve (showing the inflation which results from the output gap), and a Taylor rule (showing the interest rate set by monetary-policy-makers).[5] A fourth equation can be added if the natural level of output is allowed to vary, which changes the natural rate of interest.

$$\tilde{y}_t = E_t[\tilde{y}_{t+1}] - (i_t - E_t[\pi_{t+1}] - r_t^n)$$
$$\pi_t = \beta E_t[\pi_{t+1}] + \theta \tilde{y}_t$$
$$i_t = \phi_\pi \pi_t + \phi_y \tilde{y}_t + r_t^n$$
$$r_t^n = \rho + a E_t[\Delta y_{t+1}^n]$$

In this model the actual level of output is demand determined; the output gap, $\tilde{y}_t = y_t - y_t^n$, is the difference between the actual level of output and the underlying natural level of output, y_t^n, that would be attained in the absence of any nominal frictions. The IS curve comes from a forward-looking Euler equation for consumption: the difference between consumption today and what it is expected to be in the future is driven by the gap between the real interest rate and its natural level. The Calvo–Phillips curve shows an equation for π_t—the rate of inflation relative to the inflation target set by policy-makers—which is driven by expected future inflation and by the output gap. (The parameter β shows the time rate of discount.) The nominal interest rate, i_t, is controlled by the central bank and is the only interest rate in the economy. It is modelled as following a Taylor rule which depends on the deviation of inflation from its

[4] The equations of the SW model are set out in Appendix II of our Assessment article (Vines and Wills, 2018).
[5] For a full derivation see Clarida *et al*. (1999), Woodford (2003), or Galí (2015).

target, on the output gap, and on the natural real rate of interest, r_t^n, which is the real rate that would prevail in the absence of any nominal rigidities (as in Wicksell, 1898, p. 102). The natural level of output is exogenous in this CGG model, unlike in the SW model. It can be assumed to grow along a long-run balanced path due to population growth and technical progress, but that underlying growth process is ignored (again, unlike what happens in the SW model). The natural real interest rate, r_t^n, is exogenous in this model and always equal to the time rate of discount, ρ, except—as shown in equation (4)—when the natural level of output y_n is expected to change.[6] This system has the property that in the steady state the inflation rate will equal its target, output will be at its natural level, and the real interest rate will equal its natural level.

The only friction in the model is that prices are adjusted infrequently and in an overlapping manner. We assume that this happens with a fixed probability for any particular firm (Calvo, 1983); this probability affects the size of the coefficient Θ. To allow prices to be set like this, there are many firms who compete monopolistically. The distortion to the natural level of output caused by monopolistic power is corrected by a simple subsidy to firms (financed by lump-sum taxes), but the distortion caused by infrequent price-adjustment and the resulting dispersion of relative prices remains present in the model; this is what makes deviations of inflation from its target costly.

In such a set-up the job of the policy-maker is relatively easy. In the face of technology or demand shocks, a policy-maker following the above Taylor rule will vary the nominal interest rate, and in turn the real interest rate, in such a way that perfectly stabilizes inflation (assuming some conditions for determinacy are observed—Sargent and Wallace (1975)). As nominal rigidities are the only friction in the model, stabilizing inflation also closes the output gap, in a result that has been described as a 'divine coincidence' (Blanchard and Galí, 2005). The result of following this Taylor rule is that, in the absence of inflation, the nominal interest rate will perfectly track the natural real interest rate, r_t^n. But cost-push shocks to inflation introduce a trade-off between stabilizing inflation and the output gap.

[6] The coefficient α depends on underlying microfounded parameters of the model, including the inter-temporal elasticity of substitution. The model can be extended to make this natural level of output a function of capital, as in the SW model.

Both this CGG framework, and the more general SW model which it simplifies, have many advantages. However, the framework which they present has important omissions. It relies on a single interest rate and so does not allow for frictions in the transmission of monetary policy. Indeed, the only role for credit in this model is through the effects of the interest rate on consumption; and since there is just one representative consumer, and no investors, everything that is produced is consumed and there are no credit flows at all. The stock of debt does not matter (in the simple model presented here, there is none), nor does it matter that banks create money, with the associated asymmetries in information, constraints on liquidity and capital, and varying risk exposures over time. Financial markets are complete, so that any idiosyncratic unemployment risk can be insured away, and individuals don't suffer from losing their jobs; they are always on their labour supply curve. Price-setting occurs in a very stylized way. Actual variables don't influence natural variables. By relying on this model for teaching we are implicitly telling our students that once inflation has been controlled, and the output gap has been closed, then our job as macroeconomists is done. These are important omissions. In particular, they clearly limit the ability of the model to deal with our three key questions: why was there a boom before the Great Financial Crisis, why has the subsequent recovery taken so long, and what can policy do about it?

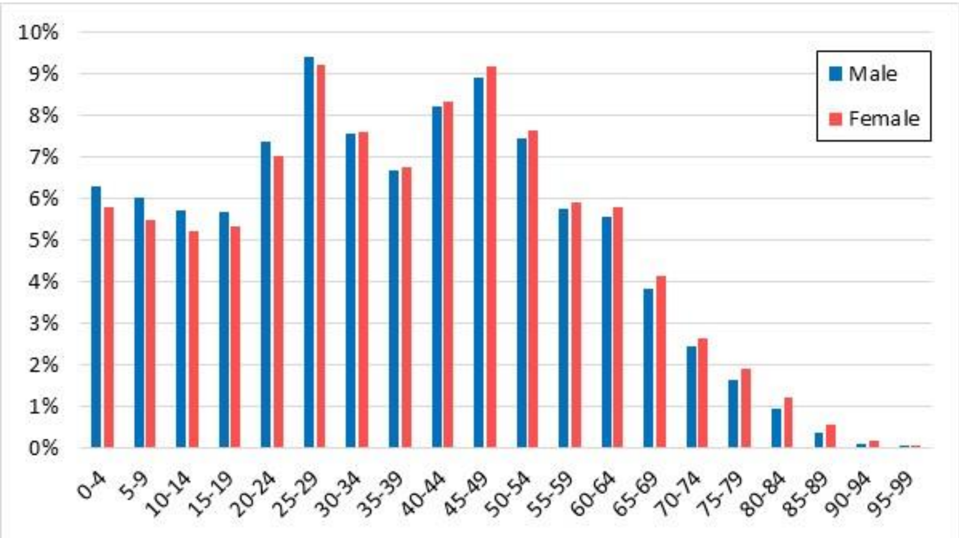
(ii) Attempting to explain secular stagnation using the existing benchmark model

One school of thought argues that our questions can be answered without radically changing the benchmark model. The 'secular stagnation' hypothesis argues that the slow recovery since the crisis may have been caused by slower population growth, a reduced rate of technological progress, and an increase in savings (Summers, 2014, 2015; Gordon, 2012; Eichengreen, 2015). This hypothesis argues that the slow recovery since 2008 can be explained without changing the SW model, but simply by changing the exogenous variables that are fed into it.

In this argument the first two changes—slower population growth and a reduced rate of technological progress—will reduce the demand for investment in a way which can be captured within the SW framework without appealing to credit market conditions. They lower the natural rate of interest, but do not affect the gap between that interest rate and the interest rate affecting households. In more detail, what happens is the following. Investment demand is lower because less population and technology in the future will also require less capital along the Ramsey growth path. This may have a very large effect on the short-run flow of investment, since there is a need for a lower long-run stock of capital per effective worker. The short-run effect on investment might be particularly large if the adjustment costs are small.[7] All else equal, a large fall in investment demand will cause a large fall in the natural rate of interest.

In addition, global savings rates have risen. Savings have risen particularly in China, which has been attributed to marriage market competition (Wei and Zhang, 2011). It has also been attributed (by Coeurdacier *et al.*, 2015)—using an overlapping generations framework—to the shock of the one-child policy demographic policy (see Figure 1).[8] While in the SW model and CGG such increases in savings cannot be studied, an extension of the SW model in an overlapping generations manner—to make possible this study—is relatively straightforward.

Figure 1: China population profile, 2016



Note: China's one child policy created large deviations in its population profile. A large generation will soon be retiring, to be replaced by a much smaller one entering the labour force.

Source: www.populationpyramid.net, 2016.

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[7] See McKibbin and Vines (2000) for an analysis of the East Asian financial crisis of 1997–8 along these lines. This approach is less effective in explaining the rapid boom in the run-up to the global financial crisis in 2008, since there was no obvious increase in the rate of population growth or in the rate of technical change. Perhaps it sees the increase in investment in US housebuilding as resulting from an increase in the ability of sub-prime borrowers to purchase housing (i.e. an increase in sub-prime entitlements) leading to a shortage of housing, or perhaps it requires a reduction in the risk premium which takes it into the territory discussed below.

[8] See Summers (2014, 2015) and Coeurdacier *et al*. (2015) and our discussion in section III. Such an increase in savings is not something that can be explained within the SW framework as it stands. But one can add something like an overlapping generations framework to this set-up, so that one might provide this explanation without appealing to credit-market conditions.

There is also evidence that the natural rate of interest has fallen considerably since 2008. Coeurdacier *et al.* (2015) suggest that high Chinese savings led to global imbalances and to a sustained fall in the global real interest rate.[9] Barsky *et al*. (2014) find that the natural rate fell from approximately 4 per cent in 2007 to –6 per cent in 2009, where it has remained since, using an estimated variant of the SW model. Carvalho *et al*. (2016) also find that higher longevity and lower population growth has caused a long-run fall in the equilibrium real interest rate.

Nevertheless, slow population and technology growth and intergeneration savings effects do not appear to be enough to explain the low natural real interest rate since 2008.[10] Furthermore Barsky *et al*. (2014) find that the natural rate is both volatile and pro-cyclical, which the SW model cannot help us to explain.

Instead, we must turn to other explanations, which introduce countercyclical fluctuations in the natural rate of interest, and a gap between this interest rate and the interest rate which influences spending.

III. Real world changes in financial frictions

Since the 2008 crisis, credit markets have changed considerably. Figure 2 shows that during the 2008 crisis the spread between banks' borrowing and lending rates increased sharply, as did the spread of both over the bank rate. The increased spread between borrowing and lending persisted for over 2 years, and the spread over the bank rate for much longer.

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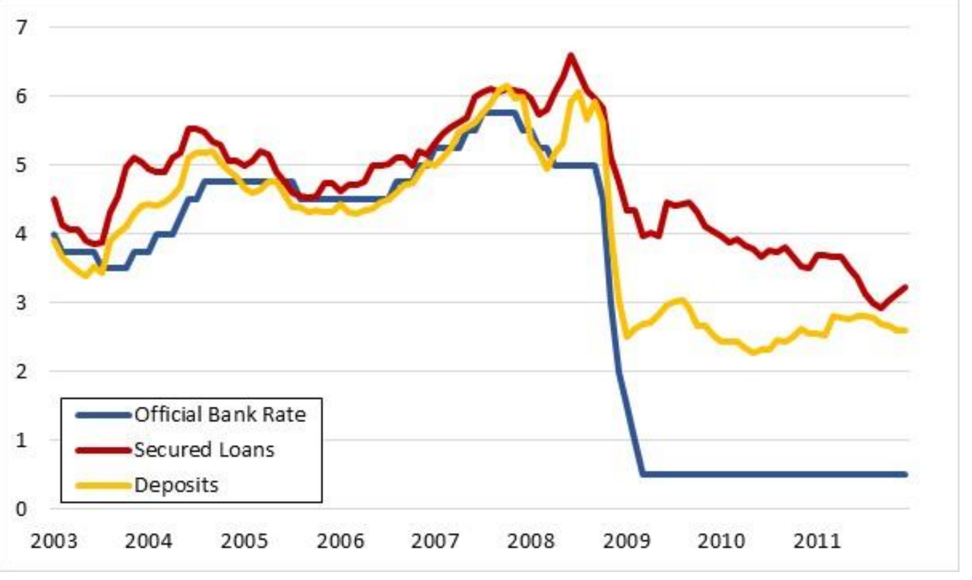
[9] If such high Chinese saving is responsible for the low natural interest rate globally, then the problem might be solved in the coming 5 years as an unusually small generation (the children of the first one-child generation) enters the workforce.

[10] Summers (2014) argues that only 10 per cent of the reduction in potential GDP can be attributed to slower technological growth.

Figure 2: UK interest rates, 2003–12, %

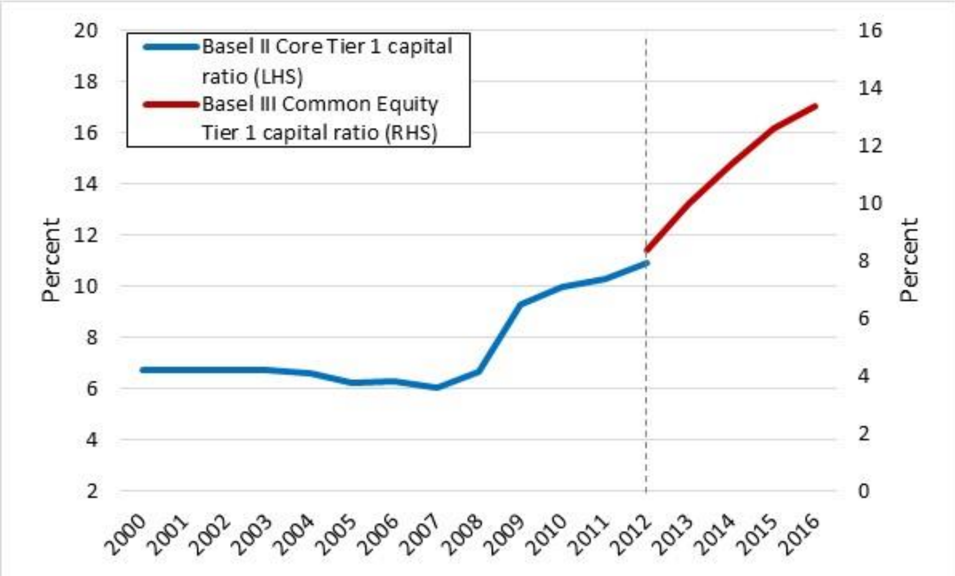


Note: Since the financial crisis the spread between borrowing and lending rates, and between both and the bank rate, has increased persistently. Secured loans are 2-year, 75% LTV, fixed-rate mortgages. Deposits are fixed-rate bond deposits

Source: Bank of England, 2012.

Since the crisis the capital ratios of banks also increased considerably (see Figure 3). Prior to the crisis, an average of 6 per cent of the risk-weighted assets of major UK banks was held in Tier 1 capital. By the time the Basel III accord was introduced in 2012 this had risen to 10 per cent. Since then the capital ratio has risen a further 6 per cent as a result of the new requirements imposed by the Basel III accord.

Figure 3: Major UK banks' capital ratios

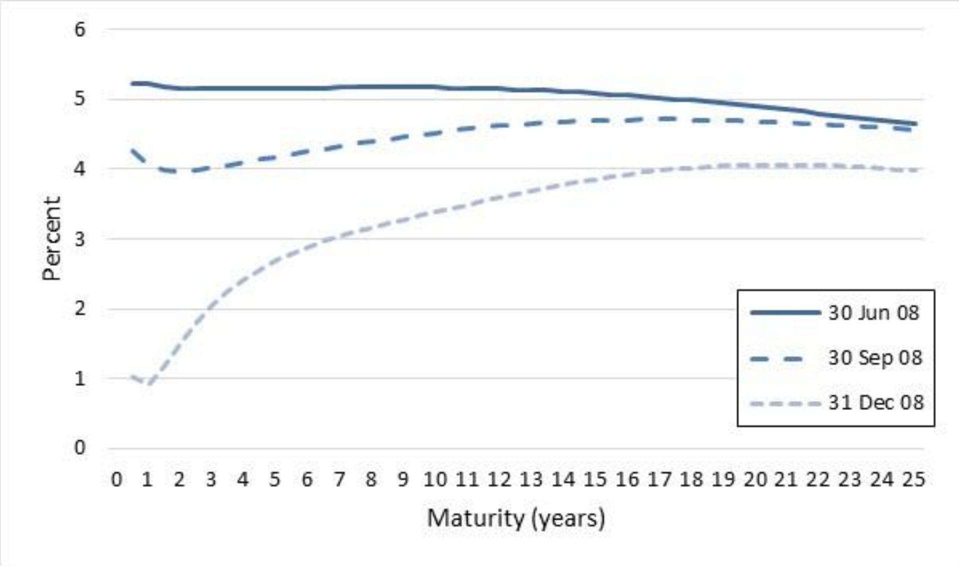


Notes: After the 2008 crisis the Tier 1 capital ratios of UK banks increased significantly, and this has continued since the introduction of the Basel III accord in 2012.

Source: PRA Financial Policy Committee core indicators, 2017.

Furthermore, during the 2008 crisis the shape of the UK yield curve changed considerably, becoming dramatically steeper as the Bank of England lowered the policy rate while longer-term yields remained largely unchanged (see Figure 4).

Figure 4: UK government liability spot yield curve



Note: During the financial crisis the UK gilt yield curve became dramatically steeper.

Source: Bank of England yield curve archive, 2017.

It is now thought that these changes in the credit markets are important in understanding both the crisis and the recovery. Summers (2015) suggests that the changes have contributed to the current climate of low investment and high savings, in addition to the demographic factors outlined in section II(ii). Investment may be low because the relative price of capital goods has declined; the process of innovation requires less capital; financial intermediation has become more costly, due to larger spreads of the type shown in Figure 2; and collateral requirements are higher. Similarly, savings may be higher because loans require more collateral *ex ante*, and costly financial intermediation is causing firms to finance investment from retained earnings. Eggertsson and Mehrotra (2014) and Hamilton *et al*. (2016) argue that a deleveraging shock has created an oversupply of savings.

If credit markets were completely independent of monetary policy, then such effects could be studied separately. However, changes in credit markets are influenced by monetary policy, which is why study of them must be embedded within a full macroeconomic model. Giavazzi and Giovannini (2010), for example, argue that inflation targeting can 'increase the likelihood of a financial crisis', and Summers (2015) notes that there are 'financial stability consequences of protracted periods of zero interest rates'.

A more nuanced, microfounded treatment of credit markets is thus needed for the benchmark model to shed light on policies employed since the crisis. Macroprudential policy has been introduced in a number of places to stabilize the risks of financial crisis, distinct from monetary policy's aim of stabilizing inflation, in the interests of matching the number of instruments to the number of targets (Tinbergen, 1952). To appropriately comment on macro-prudential policy, the core model must have a role for its most likely levers: reserve requirements[11] and lending standards.[12] As macro-prudential and monetary policies will not be conducted in isolation, credit frictions must be nested inside a model that describes both. Quantitative easing has also been used extensively in Japan, the UK, the US, and Europe, and understanding this again requires financial intermediation and a term structure of interest rates.

IV. Endogenizing financial frictions in the benchmark model

(i) Incorporating liquidity constraints

One way of incorporating credit frictions into the benchmark model is to restrict households' access to borrowing. Recently work has begun on a heterogeneous agent new Keynesian framework with search and matching frictions in the labour market (HANK–SAM). Kaplan *et al*. (2016) impose constraints both on household liquidity and the ability of households to own firm equity; they need to solve their model numerically. Ravn and Sterk (2016) simplify this set-up by assuming that households cannot borrow at all, and cannot insure against idiosyncratic unemployment risk. The result is a model with three types of households: asset-poor households who are employed, asset-poor households who are unemployed, and asset-rich households. The model turns out to be simple enough that closed-form solutions are possible. The set-up is able to provide important insights into the distributional effects of shocks, and the role of precautionary savings which emerge as a consequence of labour-market uncertainty.

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[11] The 2012 Basel III accord allows for countercyclical bank capital buffers to be applied by national regulators. The UK Prudential Regulation Authority (PRA) was established in the same year with that purpose in mind. The US Fed implicitly applies countercyclical bank capital ratios in the way it defines its crisis scenarios for stress-testing. A crisis is defined as unemployment rising by 4 percentage points, or reaching 10 per cent, whichever is greater. When unemployment is low these scenarios become more conservative, and by extension so, too, do capital ratios.

[12] Such as loan-to-valuation ratios, used widely, or restrictions on mortgage lending to investors, as in Australia.

The model has two important frictions: sticky prices, which appear in the typical way in the New Keynesian Phillips Curve, and incomplete financial markets, which are important because they affect aggregate demand through precautionary savings, the need for which arises as a result of uncertain labour-market conditions. A sketch of the model is provided by the following set of equations.

$$\tilde{c}_{e,t} = E_t\left[\tilde{c}_{e,t+1}\right] - (i_t - E_t[\pi_{t+1}] - r_t^n)$$
$$\pi_t = \beta E_t[\pi_{t+1}] + \delta \widetilde{mc}_t(\tilde{\theta}_t, \tilde{\theta}_{t+1}, A_t)$$
$$\tilde{\theta}_t = \gamma \tilde{c}_{e,t}$$
$$i_t = \phi_\pi \pi_t + \phi_y \tilde{\theta}_t$$
$$r_t^n = g(E_t[\tilde{\theta}_{t+1}])$$

The set-up modifies the equations presented previously in the following way. The first equation is a modified Euler equation for $\tilde{c}_{e,t}$, the consumption of those asset-poor households who are employed. (The behaviour of this variable drives the dynamics of the model, since unemployed asset-poor households are unable to borrow, and the behaviour of asset-rich households is ignored.) The last term in this equation captures the fact that the natural rate of interest is now endogenous as shown in the final equation; this captures the wedge in the natural interest rate introduced by the wish for precautionary savings due to the risk of unemployment. A less tight labour market increases the risk of unemployment, and in turn increases precautionary savings, so households must be offered a lower interest rate to be prevented from saving. This is the first key new idea in the model. The second equation shows that the incomplete-markets wedge modifies the Calvo–Phillips curve so that the level of marginal costs, $\widetilde{mc}_t$, now depends on technology, A_t, and on the current and future values of labour-market tightness, $\tilde{\theta}_t$. The second important new idea in the model is that at low levels of labour-market tightness, an increase in aggregate demand has a much smaller marginal effect on inflation. This non-linearity in the Phillips curve arises because there is little hiring taking place at low levels of demand, so that any change in demand hardly increases the inflationary pressure caused by firms bidding for workers. The third equation captures the fact that everything that is consumed must be produced using labour, which in turn affects labour-market tightness, $\tilde{\theta}_t$. The next equation shows the Taylor rule for the interest rate, which in this set-up depends on the degree of labour-market tightness, rather than on the output gap. The final equation shows the way in which the natural rate of interest r_t^n depends on labour-market tightness; a less tight labour market will lower the natural rate of interest.

This framework has several appealing features, not least its tractability. It creates the possibility of three different steady states. The first is the 'typical' steady state: in normal times when the labour market is well-utilized, the behaviour of the model around the steady state has features typical of the CGG model. The second is a liquidity trap at the zero lower bound (as in Eggertsson and Woodford, 2003; Eggertsson and Krugman, 2012). The third is a new 'unemployment trap' characterized by low hiring. In this equilibrium there is low demand, due to precautionary savings by the employed caused by the incomplete-financial-markets friction; and low inflation, due to the labour market friction of sticky prices. However, inflation is not very low (or negative) because of the non-linearity in the Phillips curve identified above. This means that the Taylor rule does not give rise to a monetary policy which is sufficiently loose to prevent the low-level equilibrium from emerging.

This last feature offers a useful perspective on secular stagnation, because it places precautionary savings by unemployment-fearing workers at centre stage. The model also offers a channel through which monetary policy can affect risk premia, and in turn business cycles. In the benchmark model a weak labour market will cause households to smooth consumption and save less. In this framework, a weak labour market increases precautionary savings, as workers prepare for the possibility of unemployment, which further weakens labour conditions. The additional savings lower the natural real interest rate, as seen in the equation for r_t^n. This is consistent with empirical evidence for the co-movement between labour-market tightness and the real interest rate which is observed in reality (Barsky *et al.*, 2014; Ravn and Sterk, 2016). Monetary policy can reduce the movements in risk premia described by the model by stimulating aggregate demand when it is low, and vice versa.

But the shortcoming of this approach, for the purposes of the discussion in this paper, is that it gives no role to credit and leverage. In this framework, households are restricted from borrowing completely. There is thus no scope for analysing macroprudential policies, like capital adequacy ratios and loan-to-valuation ratios, which are currently under consideration by policy-makers globally.

(ii) Incorporating leverage and risk premiums

An alternative avenue for incorporating credit frictions into the benchmark model is to introduce a stock of leverage, which affects both an interest rate spread, and the natural rate of interest.

The classic approach for incorporating credit is the 'financial accelerator' framework of Bernanke, Gertler, and Gilchrist (BGG, 1999). The financial accelerator describes how exogenous macroeconomic shocks are amplified and propagated by credit markets. In the original paper, unleveraged banks lend to leveraged firms. The lending contract is nonlinear: in good times firms keep their excess profits over the interest rate, while in bad times they go bankrupt and banks seize the residual value of their capital. Banks must charge a risk premium, or spread, over their cost of finance to cover the real cost of 'inspecting' bankrupt loans. As firms' net worth is procyclical (due to profits and asset prices), the risk premium is countercyclical, which enhances the swings in borrowing, investment, spending, and production. This type of analysis requires the full equipment of the benchmark SW model. In the absence of the bankruptcy costs, it collapses back to that model. But by including bankruptcy costs the model introduces a wedge between the interest rate received by savers and that paid by investors, in ways which are important for our purposes. Extensions to this model allow for leveraged banks to borrow from households, who also receive a bankruptcy risk premium over the risk-free rate (Luk and Vines, 2011; Ueda, 2012). Nevertheless, this kind of model is disappointing in that, with reasonable parameter values, the quantitative importance of the resulting changes in the risk premium does not seem to be large (see Luk and Vines, 2011).

More recent, and simpler, examples are provided by Curdia and Woodford (2010, 2011, 2016) and Woodford (2012), who relax the benchmark model's representative agent assumption and allow for two types of households: borrowers and lenders. Each type of agent differs by their marginal utility of consumption, which introduces a motive for financial intermediation. Borrowers face an interest rate spread over the policy rate driven by two financial frictions: a real cost of originating and monitoring loans (or a risk premium), and a mark-up in the financial sector from monopolistic competition. The model can be summarized in the following sketch,

$$\tilde{y}_t = E_t[\tilde{y}_{t+1}] - (ii(i_t, L_t) - E_t[\pi_{t+1}] - r_t^n)$$
$$\pi_t = \beta E_t[\pi_{t+1}] + \theta \tilde{y}_t + \Omega(L_t)$$
$$i_t = \phi_\pi \pi_t + \phi_y \tilde{y}_t + r_t^n$$
$$r_t^n = \rho + a E_t[\Delta y_{t+1}^n (L_{t+1})]$$
$$L_{t+1} = \rho L_t + \gamma \tilde{y}_t + \epsilon$$

where $ii(i_t, L_t)$ is the average rate of interest for borrowers and savers, which is a function of the policy rate, i_t, and a credit spread which depends on the stock of leverage, L_t. The Phillips curve now includes a real distortion from credit frictions that increases with leverage, $\Omega(L_t)$, and raises the marginal cost of supplying goods to borrowers. This in turn raises inflationary pressure for any given level of real activity. An increase in leverage allows the natural level of output to expand, but it also introduces default risk into the economy; these effects both influence the rate of interest r_t^n . Leverage evolves dynamically as a function of stock of existing leverage and the output gap in the previous period.

Incorporating credit into the model in this way has some advantages. Unlike the baseline model, it attempts to model the spread shown in Figure 2, allowing it to vary with the stock of leverage in a way which influences the natural rate of interest rate. This is in addition to the influence of capital accumulation on the natural rate of interest which is seen in the SW model. Doing this goes towards modelling a core aspect of past financial crises, as noted by Reinhart and Rogoff (2011) and by financial market participants such as Soros (1987).

Second, such a set-up breaks the 'divine coincidence' which was discussed earlier in relation to the benchmark—allowing feedback from actual variables to natural variables (see Woodford, 2012). In models with credit frictions like this, monetary policy has real effects on the flexible price equilibrium (see also De Fiore and Tristani, 2011). Curdia and Woodford (2016) show that in such a setting, the central bank's objective becomes one of stabilizing not just inflation, and thus closing the output gap, but also one of moderating the risk of future financial crisis. Thus, if the interest rate is the only policy instrument available—i.e. in the absence of macro-prudential policy—the central bank should be willing to lean against credit booms, even at the expense of disturbing its targeting of inflation and the output gap.

Third, it opens the possibility of studying other unconventional policies. Quantitative easing has already been studied in this framework by introducing a central bank that holds commercial bank reserves (Curdia and Woodford, 2011). However, the framework does not yet include a yield curve, which, as discussed below, seems important for a study of quantitative easing.

It would be possible to introduce a macro-prudential policy-maker into the Curdia and Woodford (2016) model. Giving such a policy-maker a distinct objective function and a separate set of tools—like the loan-to-valuation ratio or the kind of bank capital requirements depicted in Figure 3—might make it possible for such a model to provide useful and tractable insights into the interaction between macro-prudential and monetary policy. A goal for that direction of inquiry may be to produce a macro-prudential rule akin to the Taylor rule for monetary policy.

Woodford (2012) offers a simple treatment of a model of this kind in which the strength of financial frictions switches endogenously between high and low states. Curdia and Woodford (2016) extend this set-up to that of fully microfounded setting where financial frictions evolve as a forward-looking average of all future credit spreads.

(iii) Incorporating portfolio balance, multiple maturities, and the yield curve

A third approach to credit frictions is to incorporate a yield curve. The benchmark models, and each of the models discussed above, do not include a yield curve. All the interest rates in BGG, Curdia and Woodford, and Ravn and Sterk, are rates on short-term loans. The models assume that the expectations-augmented theory of the yield curve holds; so that a long-term loan is equivalent to rolling over, period-by-period, a sequence of short-term loans charging the short-term rate. But interest rates at different maturities might well diverge from the expectations-augmented yield curve implicit in the benchmark model, because demand for, and supply of, financial assets might not be substitutable across different time periods. The resulting shape of the yield curve might come to influence investment, the natural level of output, and the natural rate of interest.

If the shape of the yield curve matters, then studying modern policies like quantitative easing in models which include only short rates (like Curdia and Woodford, 2011) will be inadequate. In fact, quantitative easing since the crisis has aimed to influence the shape of the yield curve by purchasing long-term assets in exchange for short-term ones. If the expectations-augmented yield curve theory held, then such purchases would not have affected asset prices as they did.

To properly study the yield curve, the benchmark model needs to better incorporate risk aversion. This research agenda would essentially bring James Tobin's insights on portfolio balance into modern benchmark models. In the second half of the twentieth century Tobin introduced to macroeconomics the idea that volatility—a second-order phenomenon—can have first-order effects. This gave rise to his theory on portfolio balance, which acknowledges that there exist a wide variety of assets that vary in risk and return, and established that the mixture demanded by people will depend on their risk aversion. By contrast, in the Curdia and Woodford model discussed above, the spread between the policy rate and the interest rate in the IS curve does not rely on risk-averse asset holders, but instead on leverage and the costs of financial intermediation. And in BGG the spread again depends on leverage, which increases the probability of bankruptcy losses. But banks are risk-neutral, and only charge an interest rate spread which covers only the expectation of those losses; when productivity falls this spread rises, in line with the expected costs of default.

To understand why the risk premium varies at different maturities, we must find an alternative to the expectations-augmented yield curve. One promising avenue is microfounded models that incorporate the preferred habitats hypothesis in which borrowers and lenders have different characteristics at different maturities.

The preferred habitats approach uses modern portfolio theory to analyse how investment portfolios are allocated at various maturities, incorporating varying risks and degrees of risk aversion. Such analysis is in its infancy. A relatively recent and useful contribution is that by Vayanos and Villa (2009). The model consists of households who supply bonds and possess a preference for maturity that varies over their lifetime, giving rise to habitats. Arbitrageurs bridge the gaps between habitats by buying and selling bonds of different maturities. These arbitrageurs process limited liquidity and are risk averse. For example, a household may need to borrow to buy a house, and so will issue a bond of a particular maturity, whose date of final payment depends—say—on the expected date of receipt of income in the future. An arbitrageur will need to purchase this bond, in exchange for assets at a different maturity issued by other households. Such a purchase will expose the arbitrageur to liquidity risk, for which he or she will charge a risk premium, the size of which depends on his or her degree of risk aversion. An increase in risk aversion by these arbitrageurs will lead to an increase in the natural rate of interest. In turn this will reduce investment and so the natural level of output.

The model put forward by Vayanos and Vila is so far only a partial-equilibrium model; it has not yet been nested within a full DSGE framework. Doing this would create a theory of the yield curve that is useful for macroeconomic analysis. For example, the use of such a model might shed light on how an increase in savings might increase the spread between the long-term rate of interest and the long-term rate of interest influencing investment, since those holding the savings might be unwilling to hold extra-long-term assets unless they were offered extra yield to compensate them for a loss in liquidity. A framework of this kind could also allow us to study quantitative easing, by examining its effect on the yield curve, rather than by examining its effect on central bank reserves, as is done by Curdia and Woodford (2011). One might also study how macroprudential policies affect different parts of the yield curve.

V. Conclusion

The Great Depression of the 1930s revealed serious flaws in the classical model of Alfred Marshall, which Keynes set out to remedy. The 2008 financial crisis similarly revealed flaws in the current benchmark New Keynesian DSGE models. This paper has attempted to describe simple ways to remove one of the apparent flaws—the lack of convincing financial frictions—in a way which might help us answer our three questions: what caused the boom and crisis, why has the recovery been so slow, and how should policy respond? We have described some existing models that might do this in a sufficiently parsimonious way as to be taught to first-year graduate students. While all those described hold promise, the framework in Curdia and Woodford (2016) is of particular interest because of its ability to capture the dynamics of leverage that appear to have been important during the crisis and the recovery. Properly incorporating financial frictions into the benchmark DSGE model will radically change the way it responds to shocks: by allowing for endogenous movements in the natural real interest rate and the spread between that interest rate and the rate which influences expenditure decisions. This will give an appropriately central role to leveraged financial institutions, and the policies that affect them, in the models we offer to the next generation of economists.

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