FIRSTRUN – Fiscal Rules and Strategies under Externalities and Uncertainties.
Funded by the Horizon 2020 Framework Programme of the European Union.
Project ID 649261.

FIRSTRUN Deliverable 4.6

A description of the macroprudential policy block of the NiGEM model

Abstract:
In this paper we incorporate a macroprudential policy model within a semi-structural global macroeconomic model, NiGEM. The existing NiGEM model is expanded to include two macroprudential tools: loan-to-value ratios on mortgage lending and variable bank capital adequacy targets. The former has an effect on the economy via its impact on the housing market while the latter acts on the lending spreads of corporate and households. A systemic risk index that tracks the likelihood of the occurrence of a banking crisis is modelled to establish thresholds at which macroprudential policies should be activated by the authorities. Explicit modelling of a systemic risk index also allows for a cost-benefit analysis of macroprudential policy.

Keywords: Macroprudential policy, house prices, credit, systemic risk, macroeconomic modelling
JEL Classification: E58, G28

Authors:[1]
Oriol Carreras, NIESR
E. Philip Davis, NIESR and Brunel University
Iana Liadze, NIESR
Rebecca Piggott, NIESR
James Warren, NIESR

Delivery date: 2017-04-30

[1] Carreras, Research Fellow, NIESR, o.carreras@niesr.ac.uk. Davis, Fellow, NIESR and Professor of Banking and Finance, Brunel University, e_philip_davis@msn.com and pdavis@niesr.ac.uk. Liadze, Research Fellow, NIESR, i.liadze@niesr.ac.uk. Piggott, Research Fellow, NIESR, r.piggott@niesr.ac.uk. Warren, Research Fellow, NIESR, j.warren@niesr.ac.uk. We thank Ray Barrell and Jagjit Chadha for helpful comments.

Contents

1 Introduction

Since the global financial crisis, there has been increasing interest among authorities in both advanced and developing countries in introducing macroprudential policy. Macroprudential policy can be defined as being focused on the financial system as a whole, with a view to limiting macroeconomic costs from financial distress (Crockett 2000), and with risk taken as endogenous to the behaviour of the financial system. However, as noted by Galati and Moessner (2014), "analysis is still needed about the appropriate macroprudential tools, their transmission mechanism and their effect". Theoretical models are in their infancy and empirical evidence on the effects of macroprudential tools is still scarce, although our recent work (Carreras et al. 2016) and its references do show promising results for the effectiveness of macroprudential policies. A primary instrument for macroprudential policy has not yet emerged. Meanwhile, for authorities, targets of macroprudential policy are typically house prices, credit and the credit-GDP gap or judgemental assessments based on a range of macroprudential indicators. This leaves aside potential for use of systemic risk indicators based on early warning models for banking crises as a complementary target for macroprudential policy, on which there is a rich literature (see for example Davis and Karim (2008) and Barrell et al. (2010a)).

We contend that extant model-based work often either omits feedback from the macroeconomy to the financial sector, in particular a macroprudential reaction function, and/or would find disequilibrium hard to manage, and that both of these difficulties can be improved in our semi-structural global macroeconomic model NiGEM. Accordingly, in this paper we seek to introduce macroprudential considerations to an established global macromodel (NiGEM), initially by instruments of variable bank capital adequacy and mortgage loan-to-value ratios. The former will impact the economy by acting on the spread between borrowing and lending of corporate and households while the latter will transmit through its impact on the housing market.

A systemic risk indicator will keep track of the likelihood that a financial crisis takes place. Based on the work by Karim et al. (2013), the systemic risk index will be a function of banking sector capital adequacy and liquidity ratios, house price growth and the current account to GDP ratio. We shall enable users to trigger macroprudential policy directly or enable policy to be triggered endogenously as the systemic risk indicator reaches critical levels, which can itself vary between countries or be set by the user.

The paper is structured as follows: in Section 3 we present a brief taxonomy of macroprudential tools. In Section 4 we review some of the extant theoretical work on macroprudential in the macroeconomy. Section 5 introduces NiGEM and Section 6 looks at some earlier work on macroprudential policy in NiGEM. Section 7 outlines the specific extensions to NiGEM that we are introducing and Section 8 concludes.

2 Taxonomies

Authorities around the world are implementing a macroprudential pillar to economic policy, to complement microprudential, monetary and fiscal policy. Such a pillar is aimed to prevent financial crises by limiting systemic risk – the danger that there arises widespread disruption to provision of financial services that impact in turn on the real economy. In order to appropriately calibrate such measures, there is a clear need for a forecasting and simulation tool to assess appropriate triggers for macroprudential intervention, the effect of such interventions and their relationship to monetary and fiscal tools. Such a tool should also allow for global interactions and trends in financial and economic quantities and prices and cross border spillovers. NiGEM, extended to allow for user driven as well as endogenous macroprudential interventions, is ideally suited to such a role.

In this context, bear in mind that macroprudential policy may vary across time, where the policy seeks to limit the procyclical build-up of risk during a credit-driven upturn, or may be implemented at the cross-sectional level, whereby the aim is to maximise the resilience of the financial system to shocks arising from failure of large institutions or markets. The following table (from Bennani et al. 2014) shows how some tools are used to dampen the expansionary phase while others target the contractionary phase. Others again focus on contagion between systemic institutions and they aim to control risk via capital, assets or liquidity. Our own approach will focus largely on time series tools (marked in bold), although the cross sectional elements will also be reflected in any impact of such policy on aggregate actual or target capital adequacy.

Table 1: The time and cross-sectional dimensions

	Time dimension	**Cross-sectional dimension**
Capital	**Countercyclical capital buffer**	G-SII and O-SII buffer
	Dynamic provisioning	Systemic risk buffer (SRB)
	Sectoral capital weights	[Leverage ratio]
	[Countercyclical leverage ratio]	
Assets	**Loan-to-value (LTV) caps**	Large exposure measures
	Loan-to-income (LTI) caps	Concentration limits
	Debt-to-income (DTI) caps	
Liquidity	Limits on loan-to-deposit ratio	Systemic liquidity surcharge
	[Time varying] liquidity ratios	Liquidity coverage ratio (LCR)
	[Time varying margin requirements]	Net stable funding ratio (NSFR)
		Minimum haircuts/margin floors
		Reserve requirements

Source: Bennani et al. (2014).

General versus specific is another taxonomy of macroprudential tools. General macroprudential instruments are notably capital or provisions held by institutions (either in time series or cross-section) not specific to sectors they lend to. An example is the countercyclical buffer of 2.5 percentage points for banks, which should be raised when times are good and lowered when they are bad. Dynamic provisioning across bank balance sheets as in Spain also fits into this category. These are tools specifically developed to mitigate systemic risk. There are additional tools that may be relevant at times such as reserve requirements, liquidity regulations, capital controls and limits on system wide currency mismatches.

There are also specific tools targeted to sectors such as housing. These were often not originally developed with systemic risk in mind, but can be modified to target systemic risk. Whereas macroprudential surveillance focused on house prices as a key indicator is common across many countries, attempts to regulate house purchase lending were historically less widespread in advanced countries, but is becoming more common in the light of the sub-prime crisis (CGFS (2010), Darbar and Wu (2014), Kuttner and Shim (2016)). Examples of such tools are the loan-to-value ratio which we shall use in our own work, debt-service to income, housing related taxes, limits on exposure to housing, risk weights on housing loans and loan loss provisioning requirements linked to housing loans. A further breakdown in specific tools is between supply side credit policies (limits on exposure to housing, risk weights on housing loans and loan loss provisioning requirements linked to housing loans), demand side credit policies (loan-to-value ratio and debt-service to income ratio) and housing related tax policies that affect house prices directly, see Kuttner and Shim (2016).

In this context, according to empirical work (as summarised and extended in Carreras et al. (2016)), effective tools of macroprudential policy include loan-to-value ratios, debt-to-income limits and bank capital requirements (which may be sectoral or general). We have scope, as discussed below, for implementing loan-to-value and capital requirements in NiGEM. We note that these tools are effective in the time series dimension and at most indirectly in the cross-sectional one.

3 Macroprudential policy in theoretical macroeconomic models

Before discussing NiGEM per se, we highlight some recent work in the field of macroprudential policy and macroeconomics as background. Galati and Moessner (2014) give a helpful breakdown of progress in macroprudential modelling, into three areas: banking/finance models, three-period banking or DSGE models, and infinite horizon general equilibrium models, which we follow in this paper.

Banking/finance models, in the tradition of Diamond and Dybvig (1983) highlight how financial contracts are affected by various incentive problems related to information asymmetry and commitment that can entail default. Then, there can be self-fulfilling equilibria generated by shocks, leading to systemic financial instability. They accordingly seek to explain the interaction of borrowers and lenders. For example, Perotti and Suarez (2011) look at price based and quantity based regulation of systemic externalities arising from banks' short term funding. Accordingly, current liquidity regulation could be justified, together with a Pigovian tax on short term funding. However, such models tend to be cross section and omit the time series dimension and thus cannot be used to address procyclicality. Furthermore, they tend to be partial equilibrium and thus omit key general equilibrium effects.

Such effects are included in three period general equilibrium models of the interaction of asset prices and non-financial and financial sector systemic risk. Such models assess risk taking by heterogeneous agents in an economy vulnerable to such systemic risks. For example there may be financial amplification during booms and busts that have external effects as in Goodhart et al. (2012) and Gersbach and Rochet (2012a and b). Individual agents take decisions without allowing for the general equilibrium effects of their actions, in particular the effects of asset sales caused by excessive borrowing on asset prices. Accordingly, they generate patterns of feedback loops entailing falling asset prices, financial constraints and fire sales. Then, macroprudential tools can be shown as helpful in preventing fire sales and credit crunches, including loan-to-value ratios, capital requirements, liquidity coverage rations, dynamic loss provisioning and margin limits on repos by shadow banks (Goodhart et al. 2013).

Further results of interest are provided by models that focus on the functions of banks in the economy such as improving liquidity insurance, risk sharing and raising funding, which as shown by Kashyap et al. (2014) can then be used to analyse weaknesses underlying the global financial crisis, notably excessive risk taking by underfunded banks relying on short term funding and exploiting the safety net. Horvath and Wagner (2013), meanwhile, show that macroprudential regulations can lead savers and banks to alter other portfolio choices. Countercyclical regulation can worsen cross sectional risk for example, although tools to reduce cross sectional risk may reduce procyclicality.

Infinite horizon DSGE models with financial frictions build on the insights of papers such as Bernanke et al. (1999) on the financial accelerator. Such models (e.g. Goodfriend and McCallum 2007) were traditionally linear, so found it hard to deal with non-linearities implicit in systemic risk and changes in regulation. They tended to assume complete markets and that defaults either do not occur or are exogenous. And furthermore they tended to ignore endogenous leverage. So a crisis is modelled as a big negative shock that gets amplified rather than a credit boom that gets out of control (Boissay et al. 2013).

More recent models have sought to overcome these problems, with multiple equilibria, non-linearity, externalities and amplification mechanisms being more sophisticated. Hence macroprudential policies can be better assessed, although the models have to remain small due to the difficulty of the solution methods (Galati and Moessner 2014). Borrowers may, for example, face occasional binding endogenous borrowing constraints in times of crisis as in Fisher's (1933) debt deflation paradigm, linked to falling asset prices and declining net worth, see for example Benigno et al. (2013). Meanwhile models such as Brunnermeier and Sannikov (2014) look at global dynamics in continuous time models with financial frictions. The financial sector does not internalise the costs associated with excessive risks, so there is high leverage and maturity mismatch. Securitisation allows risk to be offloaded by the financial sector but raises overall risk taking. The economy has low volatility and adequate growth in steady state but the steady state is unstable due to large shocks provoking endogenous leverage and risk taking with feedback loops from the financial to the real economy. The model features a pattern of rising leverage and amplification when aggregate risk declines, as in the great moderation.

Antipa and Matheron (2014) review potential tensions between monetary and macroprudential policies given overlapping impacts. They use a DSGE model calibrated to Euro Area data with a financial friction manifested in a collateral constraint. Macroprudential policy affects this constraint cyclically and the work entails investigation of the zero lower bound (ZLB). Results include the following: macroprudential policies act as a useful complement to monetary policy during crises, by attenuating the decrease in investment and, hence, output; forward guidance is very effective at the ZLB, by providing a substantial boost to demand and reducing the costs of private deleveraging at the same time; overall, countercyclical macroprudential policies do not undo the benefits of forward guidance, but rather sustain them.

In general, such models highlight the transmission mechanism of real and financial factors, with the combination of macroeconomic boom, credit boom and low interest rates being dangerous, with consumption smoothing and precautionary saving being key underlying factors in financial imbalances' build-up. Model calibrations can help with understanding how macroprudential regulation can reduce the risk of crisis. State contingent taxes can also play a role, as can Pigovian taxes and an optimal mix of macroprudential policy and bailouts.

4 The NiGEM model

This section provides a succinct non-technical exposition of the National Institute's Global Econometric model, NiGEM which we use in our research. Where relevant to the analysis, details of the model will be presented in the text to follow, but an in-depth discussion falls beyond the scope of this paper.[2]

NiGEM is a global econometric model, and most countries in the EU and the OECD as well as major emerging markets are modelled individually. The rest of the world is modelled through a set of regional blocks so that the model is global in scope. All country models contain the determinants of domestic demand, export and import volumes, prices, current accounts and gross foreign assets and liabilities.

[2] For further details, the reader is referred to the NiGEM website: https://nimodel.niesr.ac.uk/ .

Output is tied down in the long run by factor inputs and technical progress interacting through production functions. Economies are linked through trade, competitiveness and financial markets and are fully simultaneous.

Agents are presumed to be forward-looking, at least in some markets, but nominal rigidities slow the process of adjustment to external shocks. The model has complete demand and supply sides and there is an extensive monetary and financial sector, together with household and government sectors. As far as possible, the same theoretical structure has been adopted for each country. As a result, variations in the properties of each country model reflect genuine differences emerging from estimation, rather than different theoretical approaches.

Policy reactions are important in the determination of speeds of adjustment. Nominal short-term interest rates are set in relation to a forward looking feedback rule. Long-term interest rates are the forward convolution of future short-term interest rates with an exogenous term premium. An endogenous tax rule ensures that governments remain solvent in the long run; the deficit and debt stock return to sustainable levels after any shock, as is discussed in Blanchard and Fisher (1989). Exchange rates are forward looking and so can 'jump' in response to a shock.

Within NiGEM, labour markets in each country are described by a wage equation (see Barrell and Dury, 2003 for a detailed description) and a labour demand equation (see, for example, Barrell and Pain, 1997). The wage equations depend on productivity and unemployment, and have a degree of rational expectations embedded in them – that is to say the wage bargain is assumed to depend partly on expected future inflation and partly on current inflation. The speed of the wage adjustment is estimated for each country. Wages adjust to bring labour demand in line with labour supply. Employment depends on real producer wages, output and trend productivity, again with speeds of adjustment of employment estimated and varying for each country.

NiGEM allows the macroeconomy to be affected directly by financial regulation and financial instability. When banks increase the spread between borrowing and lending rates for individuals it changes their incomes, and can also change their decision making on the timing of consumption, with the possibility of inducing sharp short term reductions. The volumes of deposits and lending that result are demand determined. Changing the spread between borrowing and lending rates for firms may change the user cost of capital and hence investment, and the equilibrium level of output and capital in the economy in a sustained way.

5 Earlier work introducing macroprudential policy in NiGEM

To incorporate macroprudential policy in NiGEM for a project commissioned by Sveriges Riksbank, Davis et al. (2011) undertook a number of modifications of the existing Swedish model. First, housing wealth was included in the consumption function; second, household liabilities were allowed to be driven by housing wealth (previously it had been driven by income); and third, the house price equation incorporated an income, wealth and mortgage effect as well as an effect of long real rates and the household sector lending spread (the previous equation had included only the interest rate terms). Hence, the effect of banks on the economy via lending spreads is broadened from fixed investment, the stock of capital and consumption to also include house prices, which affects consumption via housing wealth.

Besides standard simulations, Davis et al. (2011) imposed three macroprudential ones. One is for a 3 percentage point rise in the bank spread for mortgages only, to show the effect of higher countercyclical capital requirements on mortgages for 2 years. Subsequently, they apply the same shock to all bank lending so it also affects the spread for the corporate sector, showing the effect of rising general capital requirements for banks. Finally a fall in regulated loan-to-value ratios was proxied by shocking the implicit user cost of housing by 3 percentage points for 2 years. The main difference between the bank spread for household lending and the user cost of capital is the effect of the household lending spread on personal income which is absent for the user cost of capital shock.

Evidence from these NiGEM simulations suggests that macroprudential policies, focused on the housing market, can have a distinctive impact on the economy which could helpfully complement monetary policy at most points in the cycle. These results are in turn broadly consistent with work assessing theoretically how macroprudential policies may affect the economy, as cited above.

Accordingly, a generalised rise in capital adequacy affecting all lending is shown to have a quite marked impact in GDP, mainly via investment rather than consumption, while a more focused capital adequacy rise for mortgage lending only or a loan-to-value ratio policy appear to have scope to reduce credit and house prices and hence consumption with less effect on the rest of the economy than other options, although the housing based policy may of course be more subject than capital adequacy based policies to disintermediation. Capital adequacy for mortgage lending affects GDP more than the loan-to-value ratio policy since it has more of an impact on personal income and hence consumption. Monetary policy does of course also affect housing market variables but also has a greater effect on the wider economy.

Catte et al. (2010) use the National Institute Global Econometric Model (NiGEM) for the US over the period 2002 to 2007. They perform a number of counterfactual simulations to investigate two central elements of the story, namely: (a) an over-expansionary US monetary policy and the absence of effective macro-prudential supervision, which permitted a prolonged expansion of debt-financed consumer spending; (b) the decision of China and other emerging countries to pursue an export-led growth strategy supported by pegging their currencies to the US dollar, resulting in a huge build-up of their official reserves, in conjunction with sluggish domestic demand in surplus advanced economies characterized by low potential output growth.

They assume in turn a policy was feasible that would influence spreads on mortgages and show that along with monetary policy tightening, this would have mitigated the housing cycle (reducing real house price rises by 1/3 over 2002-2007). However, growth would have been lower and the improvement in the current account deficit, though not trivial, would have presumably been too small to eliminate the risk of a disorderly correction. For that, a rebalancing of global demand via expansionary policies elsewhere would have been required.

6 Macroprudential policy in NiGEM

6.1 Systemic risk index

We extend NiGEM to include a systemic risk index which will identify when the financial system and economy shows signs of needing macroprudential intervention owing to heightened risk of a financial crisis. This index drives the macroprudential policy levers (capital buffers and loan-to-value ratios) and is based on the work by Karim et al. (2013), with unweighted capital adequacy, bank liquidity ratio, real house price growth and the current balance to GDP ratio driving systemic risk. Given the prominent role that the systemic risk function plays in our modelling of macroprudential policy in NiGEM, we briefly summarize in this section the work by Karim et al. (2013).

Karim et al. (2013) utilise a multinomial logit to model the probability that a financial crisis occurs at any point in time. The dependent variable is a binary banking crisis indicator that takes the value of one at the onset of the crisis and zero elsewhere.[3] The dataset includes data on systemic and non-systemic banking crises from 14 OECD countries drawn from the IMF Financial Crisis Episode database and the World Bank database of banking crises.[4] The sample covers the period between 1980 and 2007 and the frequency of the data is annual.

Karim et al. (2013) consider up to eleven independent variables: current account balance to GDP ratio (CBR), real GDP growth (YG), inflation (INFL), real house price growth (RHPG), the M2 to foreign exchange reserves ratio (M2RES), real domestic credit growth (DCG), unweighted bank capital adequacy (LEV), bank narrow liquidity to assets ratio (NLIQ), the real interest rate (RIR) and the fiscal surplus to GDP ratio (BB). They also includes a proxy for off-balance-sheet activity of banks (OBS). The analysis starts with all of the variables included and eliminates those that are statistically insignificant one at a time. Table 2 reproduces the results reported in Karim et al. (2013) for 1980-2006.

Table 2: Nested testing of the crisis model, 1980-2006

NLIQ(-2)	-0.058 (0.242)	-0.061 (0.187)	-0.062 (0.183)	-0.064 (0.166)	-0.06 (0.181)	-0.064 (0.163)	-0.089 (0.163)	-0.082 (0.02)
CBR(-2)	-0.555 (0.004)	-0.555 (0.005)	-0.559 (0.004)	-0.568 (0.003)	-0.532 (0.003)	-0.555 (0.002)	-0.482 (0.004)	-0.454 (0.002)
RHPG(-3)	0.073 (0.124)	0.076 (0.066)	0.075 (0.066)	0.076 (0.06)	0.083 (0.028)	0.079 (0.038)	0.076 (0.038)	0.08 (0.037)
LEV(-3)	-0.804 (0.004)	-0.803 (0.004)	-0.795 (0.004)	-0.792 (0.004)	-0.726 (0.003)	-0.751 (0.002)	-0.685 (0.002)	-0.544 (0.00)
OBS(-2)	0.034 (0.278)	0.034 (0.269)	0.034 (0.257)	0.034 (0.259)	0.033 (0.25)	0.028 (0.333)	0.021 (0.333)	-
INFL(-2)	-0.115 (0.525)	-0.108 (0.537)	-0.088 (0.369)	-0.082 (0.384)	-0.081 (0.384)	-0.083 (0.385)	-	-
M2RES(-2)	0.00 (0.392)	0.00 (0.369)	0.00 (0.365)	0.00 (0.378)	0.00 (0.393)	-	-	-
YG(-2)	0.107 (0.575)	0.107 (0.573)	0.111 (0.555)	0.134 (0.42)	-	-	-	-
DCG(-2)	0.014 (0.824)	0.016 (0.802)	0.016 (0.799)	-	-	-	-	-
RIR(-2)	0.025 (0.852)	0.017 (0.89)	-	-	-	-	-	-
BB(-2)	0.016 (0.875	-	-	-	-	-	-	-

[3] An alternative approach would be to consider a binary variable that takes a value of one whenever a country is in a banking crisis. However, such an approach may bias the results as policy actions implemented during a crisis may have a direct impact on some variables of the regression model. For further discussion on this point see Demirguc-Kunt and Detragiache (1998).

[4] The countries included in the analysis are: Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Spain, Sweden, UK and the US.

Source: Karim et al. (2013).
Note: P values in parentheses.

Only four variables remain after the nested testing procedure: unweighted capital adequacy, narrow bank liquidity ratio, real house price growth and the current balance to GDP ratio. For this estimation period, OBS was considered to be proxied by house prices.

Regarding the economic intuition of the results, capital is a buffer that protects banks against losses, so a higher level of capital makes banks more robust to shocks. Lower capital not only leaves banks more vulnerable to shocks but also offers incentives for risk taking due to the moral hazard generated by the mispriced "safety net" of lender of last resort and deposit insurance. Equally, liquidity ratios show the degree to which banks are robust to sudden demands for withdrawal by depositors. House price rises permit higher borrowing at seemingly unchanged or lower levels of household leverage, but levels may be unsustainable. House prices are also correlated with commercial property prices which link closely to fragility in the banking sector (Davis and Zhu 2009). In sum, the relevance of capital and liquidity is clear as it indicates the robustness of the banking system in the face of shocks that may cause systemic risk, while house price growth is a key measure of a credit driven cycle.

A number of potential links can also be traced from current account deficits to risk of banking crises. For example, deficits may be accompanied by monetary inflows that enable banks to expand credit excessively and they may accompany an overheating economy. This may both generate and reflect a high demand for credit, as well as boosting asset prices in an unsustainable manner. These trends may be exacerbated by lower real interest rates than would otherwise be the case. Foreigners may cease to be willing to finance deficits in domestic currency if they consider their assets are vulnerable to monetisation via inflation, and such a cessation can disrupt asset markets and banks' funding. Whereas OECD countries are traditionally seen as less vulnerable than emerging market economies to such "sudden stops", it can still be argued as in McKinnon and Pill (1994) that capital inflows in a weakly regulated banking system with a safety net may lead to overlending cycles, consumption booms, rising asset prices and further increases in current account deficits. This pattern leads in turn to exchange rate appreciation and loss of competitiveness and a slowdown in growth, much as we saw in the US in the middle of the last decade. It is also commonly suggested that this may lead to a banking crisis, again much as we saw in the US toward the end of the last decade, although unlike traditional "sudden stops" the currency did not collapse.

Using the estimated coefficients from Karim et al. (2013), the final model of the probability of a financial crisis can be written as follows:

$$Prob(crisis_t) = \frac{1}{1 + e^{-(-0.544LEV_{t-3} - 0.082NLIQ_{t-2} + 0.08RPHG_{t-3} - 0.454CBR_{t-2})}}, \quad (1)$$

With LEV denoting bank capital to total assets ratio, NLIQ narrow liquidity to total assets ratio, RPHG real house price growth and CBR the current account balance to GDP ratio. This equation generates a probability of crisis for each country based on differing levels of these variables, whereas being based on panel estimation the coefficients are the same across countries.

Subsequently, one only needs to define a threshold value to indicate the point at which the probability of an economy suffering a financial crisis is large enough so as to warrant action from the authorities. The trigger point would lead to the authorities imposing loan-to-value ratio limits on the housing market via the mortgage demand function. There would then be an impact on house prices and in turn consumption via a wealth effect. There could also be an effect via flexible capital ratios, (countercyclical buffer) as the authorities raise required capital at the trigger point of the systemic risk function. This would impact via a rise in spreads for corporate and household lending, driven by the capital adequacy headroom in countries with banking sector models or in a more ad hoc way for other countries. Investment and consumption would both decline.

We report in Table 3 the in-sample accuracy of the logit model developed by Karim et al. (2013). As it can be seen, the model predicts the state of the economy (with or without a banking crisis) successfully in 3 out of 4 occasions.

Table 3: In-sample accuracy of early warning model (1980-2006)

	Dep = 0	Dep = 1	Total
$P(\text{Dep}=1) \leq 0.0357$	240	3	243
$P(\text{Dep}=1) > 0.0357$	84	9	93
Total	324	12	336
Correct	240	9	249
% Correct	74.07	75	74.11
% Incorrect	25.93	25	25.89

Source: Karim et al. (2013)

Notes: Using the sample proportion of crisis years (0.0357) as a cut-off.

As an alternative we have earlier estimates from Barrell et al (2010b) which used less up-to-date data but did include the subprime crisis in the estimation:

$$Prob(crisis_t) = \frac{1}{1 + e^{-(-0.34LEV_{t-1} - 0.11NLIQ_{t-1} + 0.08RPHG_{t-3} - 0.24CBR_{t-2})}}. \quad (2)$$

We did consider alternatives to a systemic risk index as outlined above, but found the index to be superior to the possible alternative triggers for macroprudential policy. For example, price based measures might be considered as an alternative trigger, and there is a literature for example on the credit quality spread of government to corporate bonds as a cyclical predictor. However in respect of financial crises, their predictive power is limited: the "efficient markets hypothesis", whereby prices convey all necessary information, may not hold. The failure of markets to internalise the cost and probability of the 2007-2009 systemic crisis is a case in point (Bennani et al., 2014). Borio and Drehmann (2009) find that real asset price gaps (between actual indices and smoothed trends), especially property price gaps, proved useful in predicting banking crises; at the same time they stress that indicators focusing exclusively on stock market prices would have failed to signal the build-up of risk as it was not correctly priced. Furthermore, most of the measures capturing banks' risk-taking that have been used in the literature, such as the expected default frequency (EDF), idiosyncratic bank volatility, the so-called Z-score, or banks' Value-at-Risk (VaR), work reasonably well for assessing risks in the cross sectional dimension but not so well in the time dimension (Dufrénot et al., 2012).

As a more viable alternative, we note the BIS work on gaps in credit volumes as a possible crisis predictor. As argued by Bennani et al. (2014), the credit-to-GDP gap as noted above is particularly relevant for calibrating the CCB as it signals the build-up of risk sufficiently early, prior to financial crises (see, e.g., Drehmann et al., 2010; Drehmann et al., 2011). However, it may not be always a robust leading indicator of costly price booms or banking crises (Borgy et al., 2014). Repullo and Saurina (2011) argue that the credit-to-GDP gap ratio could exacerbate the inherent procyclicality of the risk-sensitive bank capital regulation. In addition, as the credit-to-GDP gap ratio corresponds to the deviation from a filtered trend, its real-time use depends mostly on the reliability of the end-of-sample estimates of credit and GDP. Some authors argue that subsequent revisions of macroeconomic statistics could be as large as the gap itself (Edge and Meisenzahl, 2011), which can raise concerns about the robustness of the credit-to-GDP gap if used as the sole indicator for CCB implementation. For our own practical purposes, using the credit-to-GDP gap would require inclusion of corporate debt and non bank financial institution debt as well as household debt, which is not present in most country models in NiGEM.

Other possible triggers can include borrower leverage, lending standards, debt-to-income ratios for households and corporate and exposure of households and corporates to interest rate and currency risks. However, the systemic risk index is our preferred method of triggering macroprudential policy.

6.2 Modelling macroprudential policy in NiGEM

This section lays out the general form of the macroprudential block in NiGEM. We describe the macroprudential levers, how they interact with our systemic risk index and the effects that macroprudential tools have on the economy. Our approach will also consider the costs and benefits of macroprudential action.

A growing literature (extensively surveyed in Carreras et al., 2016) has pointed out that macroprudential tools are effective at curbing asset price and credit growth as well as ensuring minimum levels of bank capital or liquid assets to total assets. The work of Karim et al. (2013), among others, on modelling the probability of financial crisis and of costs of financial instability (Barrell et al (2009), (2010c)) indicates that the aforementioned effects of macroprudential policy may indeed limit the likelihood of a costly recession taking place. However, the implementation of such policies is likely to increase the cost of financial intermediation. Thus, we will explicitly take into account the beneficial effects of macroprudential policy on limiting the risk of a crisis taking place while incorporating the costs as captured by the impact of macroprudential tools on the borrowing and lending spread and on house prices.

Before delving into the details, we introduce in an informal manner the main ingredients and channels of the model underlying the macroprudential block. We will consider two macroprudential variables: loan-to-value ratios to housing lending and bank capital adequacy. The choice is based on work from FIRSTRUN Deliverable 4.7 (Carreras et al., 2016) that found loan-to-value ratios and bank capital adequacy to have a statistically significant impact on house price and household credit growth in advanced OECD countries. Loan-to-value ratios are specific to the housing sector and will impact the economy primarily via private consumption. By limiting the quantity of disposable credit for housing available, such a lever will have an impact on house prices which in turn will give rise to a wealth effect in the aggregate consumption equation. Bank capital adequacy will act on the spread between borrowing and lending rates of households and corporates, subsequently having an impact on private sector investment via its effect on the user cost of capital and on private consumption via an impact on house prices.

6.2.1 Macroprudential tools

The loan-to-value ratio (*ltv*) is the first macroprudential lever that we include in the model. It takes the form of a discrete function whose value depends on our systemic risk index (*sri*) as set out in equation (1). While nothing constraints the number of values that *ltv* might take, in our benchmark specification *ltv* will be a binary variable that takes the value of one, with unity representing a tightening of policy, when *sri* exceeds a certain threshold $\overline{sri}$.

$$ltv = \begin{cases} 1 & sri \geq \overline{sri} \\ 0 & otherwise \end{cases}$$

Target capital adequacy will also be triggered by the systemic risk indicator and constitutes the second macroprudential lever of the model. In this case, the modelling strategy depends on whether a particular country model within NiGEM has a fully specified banking sector or not. Countries that include a banking sector are Germany, Italy, UK and the US. For those countries where there is no banking sector, the corporate and household lending spreads are modelled as random walks. For these, we just simply introduce a wedge to the existing equations to account for the higher cost of financing imposed on credit institutions by a tightening of capital requirements.

$$iprem = f_{iprem}(sri) \tag{3}$$

$$lendw = f_{lendw}(sri) \tag{4}$$

where *iprem* denotes the corporate lending wedge and *lendw* the household counterpart.

For those countries where a banking sector exists, the household lending wedge is driven by the net wealth to household income ratio (*nwpi*), bank capital to risk-weighted total assets ratio (*levrr*), the rate of household mortgage arrears (*arr*) and the inverse *headroom* term, which as shown below captures the nonlinear effect on banks when they approach the authorities' minimum level of capital adequacy. In some cases spreads might be influenced by the short term rate (*r3m*) also, widening as the short rate approaches the lower bound as the so-called endowment effect from non interest bearing accounts diminishes.

$$lendw = f\left(nwpi, levrr, arr, \frac{1}{headroom}, r3m\right) \tag{5}$$

Headroom is the difference between banks' level of capital adequacy (*levrr*) and that required by the authorities (*levrrt*). The latter will be affected by the normal Basel level of 8% of risk adjusted capital adequacy plus any additional requirements of the authorities, as in the UK, and further additions such as the Basel III countercyclical buffer. These will all affect *levrrt* while losses, and capital building, as well as assets and their composition, will affect *levrr*.

$$headroom = 1/(levrr - levrrt) \tag{6}$$

The corporate lending wedge (*iprem*) will also be affected by inverse headroom, capital adequacy (*levrr*), the corporate insolvency rate (*insolvr*) as well as the cyclical state of the economy denoted by the actual output to potential output ratio (*y/ycap*).

$$iprem = f\left(\frac{y}{ycap}, insolvr, levrr, 1/headroom\right) \tag{7}$$

In these models, the systemic risk indicator *sri* will feed directly into the target level of capital adequacy, which in turn will feed into both *iprem* and *lendw*.

$$levrrt = f_{levrrt}(sri) \quad (8)$$

6.2.2 Transmission mechanism

Each of the two macroprudential tools we include in the model affect different sectors in the economy in a different way. Focusing first on the loan-to-value ratio, this tool primarily targets the housing market. In NiGEM, the housing market is described by a price (supply) equation, p_H, and a demand equation for household credit which includes mortgages. Loan-to-value ratios, by imposing a constraint on the quantity of mortgages supplied in the market, will potentially, through market clearing, affect house prices.

For those countries that do not have a banking sector model, the existing equation relates household credit (*liabs*) with disposable income. To accommodate the presence of macroprudential policies, we expand the equation as follows:

$$liabs = f_{liabs}(di, lendw, lrr, p_H, ltv) \quad (9)$$

Household liabilities are affected by disposable income (*di*), the household lending spread (*lendw*), the long-run risk free rate (*lrr),* house prices (p_H) and the loan to value ratio, *ltv*.

Those countries that have an explicit banking sector model split household liabilities between consumer credit and mortgages. Given that *lendw* already appears in the existing equation for mortgages, we consider a simple expansion of the existing mortgage equations to include *ltv*'s:

$$morth/ced = f_{p_H}(rpdi, lendw, lrr, rph, ltv) \quad (10)$$

where *morth/ced* denotes outstanding mortgage liabilities in real terms, *rph* denotes real house prices and the remaining variables have been defined previously. The nominal counterpart to *morth* then feeds into total household liabilities *liabs*.

House prices in the extended model will be affected indirectly by macroprudential policy in terms of the lending spread to households and by the loan-to-value ratio tool. On top of this, house prices are also determined by real personal disposable income (*rpdi*), the long-run real interest rate (*lrr*) and housing capital stock (*kh*) in order to control for supply side dynamics. Note that besides its direct impact ,the lending spread *lendw* will also impact indirectly via net interest income which affects *rpdi*.

$$p_H = f_{p_H}(rpdi, lendw, lrr, kh, ltv) \quad (11)$$

The consumption function (*c*) is affected by housing wealth (*hw*), which in turn is driven by house prices, and by net financial wealth (*nw*) which is affected by total outstanding liabilities. As a result, macroprudential policy will have an impact on private consumption via the wealth effect coming both through its impact on house prices and household liabilities. It will also impact via net interest income generated by changes in the household lending spread *lend*w which affects *rpdi*.

$$c = f_c(rpdi, nw, hw) \quad (12)$$

Turning to the capital adequacy macroprudential variable, this tool will have an impact on private investment and consumption by acting on the lending spreads of corporates and households. By affecting *lendw* (see equations (4) and (5)), *sri* will have an impact on house prices (see equation (11)) and in turn private consumption via the housing wealth variable.

Corporates will also be affected by capital adequacy as the movements in the corporate lending spread, *iprem*, triggered by *sri*, will have an impact on private sector investment via the user cost of capital.

The existing equations in NiGEM for house prices and household liabilities need to be expanded to incorporate the ingredients laid out in this Section. To this end, these equations will have to be re-estimated. In the upcoming FIRSTRUN deliverable that succeeds and complements this one, we will show the results of the estimation procedure, present counterfactual scenarios based on the macroprudential block as well as perform a cost-benefit analysis of macroprudential policies. As a result, a detailed explanation of the methods used together with an explanation of the data sources and the subsequent analysis of the time series properties of the data is carried out in the aforementioned paper.

Note that experience of estimation and simulation may amend the planned specification set out above to some degree.

6.3 Modelling the banking sector in selected countries in NiGEM

Further channels of macroprudential policy are available in the UK, US, German and Italian models where the banking sector is explicitly modelled. The modelling of banking sectors' influence in terms of spreads between borrowing and lending rates, in a global macromodel, was pioneered by NIESR in its work on the impact of capital adequacy regulation (Barrell et al., 2009), where other influences on spreads besides capital include measures of borrower risk. Goodhart (2010) has argued that determining spreads is precisely the way that banks should be incorporated in macro models, and not either ignored or set out in terms of the "money multiplier", see also Woodford (2010).

As described in Davis and Liadze (2012), we model banking activity as a set of supply (or price) and demand curves. Demand depends on levels of income or activity, and on relative prices, whilst supply, or price, depends upon the costs of providing assets and on the risks associated with those assets. The banking sectors in our models have four main assets, secured loans to individuals for mortgages, (morth) with a borrowing cost (rmorth) affected in part by the mark up applied to household loans by banks (lendw), unsecured loans to individuals for consumer credit (cc) with a higher borrowing cost or rate of return (ccrate) again affected by the household margin. Then there are loans to corporates (corpl) with a rate of return or cost of borrowing (lrr+corpw) where lrr is the risk free long rate and corpw is the mark up applied by banks, The whole balance sheet of assets (bbal) can then be derived by adding in liquid assets (brla) which are modelled as a fixed percentage of the balance sheet and other assets (bboa), which rise in line with total lending.

$$Bbal = corpl + morth + cc + brla + bboa \tag{13}$$

Given the balance sheet of assets we can also calculate the risk adjusted balance sheet by applying risk weights to the different assets. This is then the denominator of levrr (risk adjusted capital adequacy).

$$bbalwa = corpl + 0.5 * morth + cc + 0.2 * brla + 0.3 * bboa \tag{14}$$

Assuming then that assets equal liabilities, we can calculate the components of liabilities namely deposits (driven by M1), other liabilities (growing in line with nominal GDP), wholesale deposits (a residual, in line with the practice of banks to use this as a residual source of funds) and capital itself (driven by spreads, assets and losses as well as headroom), on-balance sheet bank activity within the UK, US, Italy and Germany (the sum of these latter variables is liabilities which is set equal to assets).

Then if regulation is tightened, for example via higher capital adequacy requirements as in Basel III, then increasing margins and reducing lending will both move banks back toward their desired capital ratio. If the capital adequacy target ratio (levrrt) rises then risk weighted capital adequacy (levrr) will increase and so will the cost of corporate and personal sector borrowing, raising the gross operating surplus that can be devoted to rebuilding capital, and reducing assets which raises levrr via a smaller denominator. In some models where arrears and bankruptcies are endogenous, there can also be a deduction from capital for losses.

In the UK, for example, there has been a normal excess above the required minimum level of capital adequacy which has averaged 3 percentage points in this sample with corresponding historic differences in the US and Germany. As the difference between the actual and this target ratio, or headroom (head), available to the banking system shrinks we might expect banks to push up their borrowing charges. As headroom goes to zero we would expect there to be significant non-linear increases in borrowing costs. In order to capture this, as noted above, we included both headroom and its inverse in all our margin equations, and we retained either variable when they are significant.

7 Conclusions

This paper lays out the general form that the macroprudential block in NiGEM will take. Our model will include two macroprudential variables; loan to value ratios for house lending and bank capital adequacy targets. The former tool is specific to the housing sector and will impact the economy primarily via private consumption. By limiting the quantity of disposable credit for housing available, such a lever will have an impact on house prices which in turn will give rise to a wealth effect in the aggregate consumption equation. The latter tool will act on the spread between borrowing and lending rates of households, subsequently having an impact on private sector investment via its effect on the user cost of capital as well as private consumption via an impact on housing wealth.

Macroprudential policies will be triggered by a systemic risk index that keeps track of the likelihood that a financial crisis occurs. We draw from the work by Karim et al. (2013) and specify an index that is a function of bank capital adequacy and liquidity ratios, real house price growth and current account balance to GDP ratio. By explicitly modelling the probability of a crisis, we allow for a cost-benefit analysis of macroprudential policies, whereby the benefit is captured by the diminished probability of a crisis and the cost by the impact of macroprudential policies on lending spreads and house prices.

References

Antipa, P. and Matheron, S. (2014), “Interactions between monetary and macroprudential policies”, Banque de France Financial Stability Review, 18, pp. 225-239.

Barrell, R., Davis, E. P., Fic, T., Holland, D., Kirby, S. and Liadze, I. (2009), “Optimal regulation of bank capital and liquidity: how to calibrate new international standards” FSA Occasional Paper no. 38, October.

Barrell, R., Davis, E. P., Karim, D., Liadze, I., (2010a), “Bank regulation, property prices and early warning systems for banking crises in OECD countries”, Journal of Banking and Finance, 34, pp. 2255–2264.

Barrell, R., Davis, E. P., Karim, D. and Liadze, I. (2010b), " The impact of global imbalances: Does the current account balance help to predict banking crises in OECD countries?", NIESR Discussion Paper No. 351.

Barrell, R., Davis, E., Liadze, I., Karim, D, (2010c), “The Effects Of Banking Crises On Potential Output In OECD Countries” NIESR Discussion Paper no. 358,

Barrell R., and Dury, K. (2003) 'Asymmetric labour markets in a converging Europe: Do differences matter?' National Institute Economic Review No. 183, January 2003

Barrell, R., and N. Pain (1997), 'Foreign Direct Investment, Technological Change, and Economic Growth Within Europe', Economic Journal, 107, pp. 1770-1776.

Benigno, G., Chen, H., Otrok, C., Rebucci, A. and Young, E. (2013), "Financial Crises and Macro-Prudential Policies", Journal of International Economics, 89(2), pp. 453-470.

Bennani, T., Després, M., Dujardin, M., Duprey, T. and Kelber, A. (2014), “Macroprudential framework: key questions applied to the French case”, Banque de France Occasional papers, No. 9

Bernanke, B., Gertler, M. and Gilchrist, S. (1999), "The financial accelerator in a quantitative business cycle framework", Handbook of Macroeconomics 1 (1999), pp. 1341-1393.

Blanchard, O.J. and Fischer, S. (1989) “Lectures on Macroeconomics”, Cambridge: MIT Press.

Boissay, F., Collard, F. and Smets, F. (2013), "Booms and systemic banking crises", ECB Working Paper No. 1514.

Borgy V, Clerc L and Renne J-P (2014), “Measuring aggregate risk: Can we robustly identify asset-price boom–bust cycles?”, Journal of Banking & Finance 46 (2014) 132–150

Borio, C. and Drehmann, M. (2009), "Towards an operational framework for financial stability: ‘fuzzy’ measurement and its consequences", BIS Working Paper No. 284.

Brunnermeier, M. and Sannikov, Y. (2014), "A Macroeconomic Model with a Financial Sector", American Economic Review, 104(2), pp. 379-421.

Carreras O, Davis E P and Piggott R (2016) “Macroprudential tools, transmission and modelling”, Firstrun Deliverable 4.7, Horizon 2020

Catte, P., Cova, P., Pagano, P. and Visco, I. (2010), "The role of macroeconomic policies in the global crisis", Bank of Italy Occasional Papers No. 69.

CGFS (2010), “Macroprudential instruments and frameworks: report published by the Committee on the Global Financial System” 21 May 2010, Basel.

Crockett, A. (2000), "Marrying the micro- and macro-prudential dimensions of financial stability", Remarks before the Eleventh International Conference of Banking Supervisors. Bank for International Settlements. Basel, 20-21 September 2000.

Darbar, S. M. and Wu, X. (2015), “Experiences with macroprudential policy, five case studies”, IMF Working Paper 15/123.

Davis, E. P., Fic, T. M. and Karim, D. (2011), “Housing Market Dynamics and Macroprudential Tools”, in “RUTH, the Riksbank’s inquiry into the risks in the Swedish housing market” pages 219-298, also Brunel Economics and Finance Working Paper 11-07.

Davis E P and Karim D (2008), “Comparing early warning systems for banking crises”, Journal of Financial Stability, 4, 89-120

Davis E P and Liadze I (2012), “Modelling and simulating the banking sectors of the US, Germany and the UK”, NIESR Discussion Paper 396

Davis E P and Zhu H (2009), “Commercial property prices and bank performance”, Quarterly Review of Economics and Finance 49, 1341–1359

Demirguc-Kunt, A. and Detragiache, E. (1998), “The Determinants of Banking Crises in Developed and Developing Countries”, IMF Staff Paper, Vol. 45, No.1.

Diamond, D. and Dybvig, P. (1983), "Bank runs, deposit insurance, and liquidity", Journal of Political Economy, 91(3), pp. 401–419.

Drehmann (M.), Borio (C.), Gambacorta (L.), Jimenez (G.) and Trucharte (C.) (2010) “Countercyclical capital buffers: Exploring options”, BIS Working Paper, No. 317.

Drehmann (M.), Borio (C.) and Tsatsaronis (K.) (2011) “Anchoring countercyclical capital buffers: The role of credit aggregates”, International Journal of Central Banking, 7(4), pp. 189-240.

Dufrénot (G.), Klaus (B.), Malik (S.) and Vardoulakis (A. P.) (2012) “Credit standards and financial institutions’ leverage”, mimeo.

Edge, R.M., Meisenzahl, R.R., (2011). The unreliability of credit-to-GDP ratio gaps in real time: implications for countercyclical capital buffers. International Journal of Central Banking 7 (4), 261–299.

Fisher I (1933) “The Debt-Deflation Theory of Great Depressions”, Econometrica, 1, 337-357

Galati, G. and Moessner. R. (2014), “What do we know about the effects of macroprudential policy?” DNB Working Paper No. 440.

Gali. J, (2009), “Monetary policy, inflation and the business cycle”, Princeton University Press.

Gersbach, H. and Rochet, J. C. (2012a), "Capital Regulation and Credit Fluctuations", CEPR Discussion Paper No. 9077.

Gersbach, H. and Rochet, J. C. (2012b), "Aggregate Investment Externalities and Macroprudential Regulation", Journal of Money, Credit and Banking, 44, pp. 73-109.

Goodfriend, M. and McCallum, B. (2007), "Banking and interest rates in monetary policy analysis: a quantitative exploration", Journal of Monetary Economics, 54, pp. 1480–1507.

Goodhart, C. A. E. (2010), “Money, credit and bank behaviour: need for a new approach” National Institute Economic Review, 214.

Goodhart, C., Kashyap, A., Tsomocos, D. and Vardoulakis, A. (2012), "Financial Regulation in General Equilibrium", NBER Working Paper No. 17909.

Goodhart, C., Kashyap, A., Tsomocos, D. and Vardoulakis, A. (2013), "An Integrated Framework for Analyzing Multiple Financial Regulations", International Journal of Central Banking, 9(1), pp. 109-143.

Horváth, B. and Wagner, W. (2013), "The Disturbing Interaction between Countercyclical Capital Requirements and Systemic Risk", Mimeo, Tilburg University.

Kashyap, A. K., Tsomocos, D.P. and Vardoulakis, A.P. (2014), "How does macroprudential regulation change bank credit supply?", NBER Working Paper No. 20165.

Karim D, Liadze I, Barrell R and Davis E P (2013), “Off balance sheet exposures and banking crises in OECD countries”, Journal of Financial Stability, 9, 673-681

Kuttner, K, N., and Shim, I. (2016), “Can non-interest rate policies stabilise housing markets? Evidence from a panel of 57 economies,” Journal of Financial Stability, 26, 31-44.

McKinnon, R. I., H. Pill, (1994), “, Credible liberalizations and international capital flows; the overborrowing syndrome”, Stanford University, Stanford.

Perotti, E. and Suarez, J. (2011), "A Pigovian Approach to Liquidity Regulation", International Journal of Central Banking, 7(4), pp. 3-41.

Repullo R. and Saurina J. (2011) “The Countercyclical Capital Buffer of Basel III: A Critical Assessment”, CEPR Discussion Papers, No. 8304.

Woodford, M. (2010), “Financial intermediation and macroeconomic analysis”, Journal of Economic Perspectives, 24(4), pp. 21–44.