Measuring the impact of prudential policy on the macroeconomy: A practical application to Basel III and other responses to the financial crisis

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A practical application to Basel III and other responses to the financial crisis

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Abstract

When financial regulators require banks to hold a higher ratio of equity capital to debt funding, banks incur short-term costs as they adjust their balance sheets and lose some of the advantages associated with their existing funding mix. They then seek to maintain post-tax income by, for example, raising lending margins. Higher lending margins tend to lower the volumes of borrowing. This creates a trade-off between the greater stability associated with a higher ratio of equity capital to debt funding and the level of economic activity in the short to medium term. While the benefits of greater stability are obviously very large, and the reduction in economic activity is very unlikely to be on a comparable scale, exploring the trade-off is not straightforward. Past work on this did not solve all of the modelling problems, nor does this paper. We do, however, report some useful developments, which may assist in calibrating policy or monitoring the impacts of judgements already made.

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1 Introduction

The choice and calibration of prudential standards historically has been largely an international process of political economy informed by judgement (e.g. Basel Committee on Banking Supervision (BCBS) (2006)). Before the Turner Review (FSA (2009a) and FSA (2009b)), only limited effort had been made to provide empirical support for these judgements although theoretical approaches to analyse the effects of adjusting capital requirements have been posited (e.g. Repullo and Suarez (2004); Van den Heuvel (2008)). Specifically, financial regulators did not use research findings about how banks react to changes in prudential standards to explore any trade-offs between stability and the provision of finance to the real economy. Nor did they examine the links between the calibration of prudential standards and the probability of financial crises occurring.

We and others at the FSA have taken the lead in seeking to fill the evidential gaps described above. This resulted in Occasional Papers 22 (Alfon et al (2006)), 31 (Francis and Osborne (2009a)) and 36 (OP36) (Francis and Osborne (2009b)), which sought to give a clear understanding of how banks have reacted to changes in prudential standards. OP36 confirmed that banks react to changes in regulatory capital requirements by dynamically adjusting both their level of capital and their level of risk-weighted assets to reach a desired capital ratio. This approach to estimating the additional capital that banks would need to hold in response to higher capital requirements is far more realistic than approaches that use banks' existing balance sheet assets to calculate new capital requirements, or that are not empirically based at all.

The evidence in OP36 that the specific reaction of individual banks to changes in prudential standards depends on their individual balance sheet composition when the standards are announced was used to develop a model that aggregates firm-specific data about the condition and reactions of the UK's largest banks to changes in prudential policy. The model then aggregates these individual responses to show a sector-wide response. This model currently covers about 75% of UK banks' assets.

We also worked with the National Institute of Economic and Social Research (NIESR) to help produce Occasional Paper 38 (OP38) in this series (Barrell, Davis, Fic et al (2009)). This includes a new methodology for determining the costs and benefits of bank capital and liquidity requirements for the economy as a whole.

Exploring the trade-offs between stability and the provision of finance to the real economy, and identifying the factors that influence the probability of financial crises occurring, is not at all straightforward. Numerous modelling challenges are involved, and we have been careful to make clear that we are far from having the answers to all of these. Even so, it should be possible to improve future policy judgements, and the monitoring of the impacts of judgements already made, by improving the evidence base. We therefore sought to address some of the weaknesses in previous modelling – these efforts, together with the new results generated, are reported in this paper.

There have now been important international efforts to generate research into the impacts of higher prudential standards on the global economy (see BCBS (2010a), BCBS (2010b) and BCBS (2010c)). The BCBS findings are consistent with those generated for the UK from the work mentioned above.

1.1 Principal improvements to our model

It is obvious that the kind of modelling described above can give only approximate answers to the difficult questions that policy makers must address. Empirical research on how banks react to changes in prudential standards is unavoidably based mostly on data generated during the 'great moderation' (around 1990 to 2007). It remains to be seen just how similar post-crises reactions will be. The prudential changes driving these reactions were less material and pervasive than Basel III and the other post-crisis measures. Moreover, assessment of the economic impacts of banks' reactions depends on the outputs of macroeconomic models, which themselves are unavoidably the result of the interaction of a large number of equations representing imperfectly understood (or estimated) relationships.

This does not mean that the modelling fails to achieve some clear and important results. A bank that is obliged to move from its present ratio of capital to risk-weighted assets to a higher ratio must choose one or more of the following three options: (i) raising fresh, qualifying capital; (ii) reducing the outright value of its assets; and (iii) lowering the average risk-weighting of its assets. The final option means that meeting higher liquidity standards that involve holding incremental highly liquid paper also contributes to meeting higher capital standards. We see that, in reality, banks use all three options for increasing their ratios of capital to risk-weighted assets. Historically, in the UK, about half of the required adjustment has come through increases in capital and about half through reductions in risk-weighted assets (relative to the level of capital and assets that would have pertained in the absence of the policy change).

We also see that banks pass at least some of the cost of the adjustment to their customers in the form of an increased interest rate margin or 'wedge' between lending and deposit rates. Customers, especially corporate customers, react to the increase in the lending wedge by reducing their borrowing from banks. Indeed, it appears that the increase in the wedge faced by corporate borrowers in the short term is typically greater than the increase faced by household customers. This may be because the greater demand elasticity on the part of corporate borrowers helps banks to reduce their risk-weighted assets most efficiently. Some but not all of the reduction in borrowing from banks is offset by borrowing from other sources, such as shadow banks or in debt markets by firms issuing their own paper.

By including the relationship between bank capital/liquidity and the lending wedge in NIESR's macroeconomic model NiGEM, the impact of higher regulatory requirements on overall UK economic output can be estimated using a general, rather than partial, equilibrium approach. While reduced borrowing from banks is associated with a reduction in the level of investment and consumption, the effect is not as large as one might expect from the reduction in banks' assets. The impact on GDP is small, presumably because of sufficient availability of substitutes for bank lending.

Another clear finding is that allowing banks a lengthy transition period to higher prudential standards lowers the macroeconomic costs (BCBS (2010b) and BCBS (2010c)). This is intuitive. Banks are somewhat constrained by long-term lending contracts. If they are obliged to move rapidly to higher prudential standards, they will have to achieve a higher proportion of the adjustment through raising fresh capital. This might have to be done at a time when capital is expensive, or the fact that many banks are raising fresh capital at the same time may itself make bank capital expensive. Our preliminary research on the FSA's tighter supervisory prudential regime introduced in the immediate wake of the financial crisis tentatively supports this observation. We find that banks' response to the new measures has been somewhat different from the historical experience: rather than about half of the required adjustment coming through increases in banks' capital and about half through reductions in risk-weighted assets, about 60% of the adjustment was made through capital and 40% through assets, although the evidence is far from conclusive.

An important development since the publication of OP38 is an improved model of financial crisis. The modelling of benefits in OP38 depends on a Logit model of the probability of a financial crisis occurring, with capital and liquidity ratios as key determinants of the likelihood. The benefits of higher prudential standards are obtained by multiplying the cost of a crisis, measured in terms of GDP losses in past crises, by the change in the probability of crisis that results from changes in capital and liquidity requirements. We take the net present value of the expected costs and benefits over a long time frame to obtain our measure of the net impact on GDP. By applying this approach to a range of changes in requirements, one can identify what level of higher standards would cease to provide net benefits for the economy overall, aside from welfare effects.

The two main improvements to the crisis model reported in OP38 are as follows. First, the probabilities of crisis are updated annually in Bayesian fashion to ensure different states of the world are appropriately taken into account. Second, another significant variable has been added to the crisis model. As reported in OP38, the model included the capital and liquidity ratios of banks and the rate of change in house prices, a variable which is strongly associated with the incidence of past crises. The model now also includes the balance on the UK's current account. Since house prices and the current account deficit are not solely the product of financial regulation, the crisis model suggests that financial regulators by themselves do not hold all of the levers that influence the probability of financial crisis. It appears that monetary and even fiscal policy may also be relevant (see, for example, Cecchetti, Genberg et al (2000), Acharya et al (2009), Reinhart et al (2009)). This tends to validate the role of the Financial Policy Committee as set out in HM Treasury's recent paper (HM Treasury (2011)).

A specific result of the improved modelling presented here is that our central estimate of the impacts of the (realistic) package of policy measures that we analyse is a small long-run increase in national income. In other words, any short-run reductions in GDP are more than offset in the longer term as crises become rarer. This is in addition to the increase in stability itself, which we would expect to be associated with a substantial increase in welfare (on the basis that people have a strong preference for stability).

We have also undertaken stochastic simulations to place confidence bands around our central estimate of impacts on national income. These show that the true outcome, in income terms, may be materially more or less favourable than the central estimate, although the error bands are skewed towards higher net benefits. Even an outcome of net costs in terms of national income would not, however, have any direct effect on the very large welfare benefits of stability.

1.2 What is in this paper?

The FSA's Discussion Paper 09/04 (FSA 2009b) acknowledged a number of issues with the framework of analysis deployed in OP38. Much of this paper describes the methodological improvements we have subsequently made. Our fresh estimate of the impacts of an updated package of policy measures is also included.

Specifically, the paper proceeds as follows. In section 2, we review recent literature on estimates of the costs of the recent crisis, and the costs and benefits of prudential policy. We also briefly explore other relevant research. In section 3, we describe the work we have done to model the responses of individual banks to changes in prudential standards. This is an important addition to the framework described in OP38, since it ensures that the correct inputs are used in the macroeconomic modelling, given a particular calibration of new prudential standards. In section 4, we discuss changes made to the modelling of the costs, including the calibration of the cost of increasing the capital ratio and how we have dealt with the issue of the different types of capital referenced in the recent policy proposals. In section 5, we describe the improvements we have made to the modelling of benefits by adding variables to the crisis prediction model. We also describe additional work undertaken on the depth and length of a crisis and the Bayesian calculation of expected benefits. Section 6 includes our estimate of the impacts of an updated package of policy measures on the UK economy and a general discussion of the caveats and limitations of this estimate. Finally, section 7 discusses some of the uncertainties around our results.

1.3 Would further work be useful?

The law of diminishing returns clearly applies when results are unavoidably approximate. There is, however, one big issue that might merit further consideration. So far, policy and related research have dealt almost entirely with individual banks rather than with banks as a network. This has the advantage of being *relatively* simple and the disadvantage of not dealing directly with an important reason for prudential regulation: network externalities.

Recent papers (e.g. Haldane and May, 2011) have begun to explore the characteristics that appear to make the banking network more or less stable. It is clear that the probability of financial crisis depends partly on the strength of individual nodes (i.e. banks) within the network and partly on some characteristics of the network itself. These may include the complexity of the network and the extent of similarity between the exposures of the individual nodes. For example, a high degree of complexity and major exposures by individual nodes to the same asset classes may materially reduce the stability of the network. Such features of the banking network may be influenced by prudential regulation or even conduct regulation, especially if these include elements that bear on the operation of competition, as is likely.

Our existing crisis model does implicitly take some account of network effects. For example, one of the features captured by our house price variable may be lack of diversity between nodes. Also, the observed increase in stability associated with higher capital and liquidity standards takes account of any effects these standards have on the structure of the network or diversity of exposures. However, the model does not include any direct measures of the relationship between the probability of crisis and structural features of the network. This could be a useful development, for example if policy makers are able to develop policy interventions designed to change the structure of the network (possibly while leaving the level of capital unchanged). Such empirical modelling might, in addition to providing measures of the impact of policy, reveal which firms are truly of systemic importance (what if it is not just the large ones?) and which features of the network are related most strongly to financial crisis. There would, however, be significant issues about data and feasibility to address.

2 Literature review

In this section, we discuss some recent papers that estimate the impact of prudential policy on the economy. We then discuss a number of papers outlining important uncertainties in current analysis of the impacts of prudential regulation.

2.1 Examining estimates of the impact of prudential policy

OP38 sets out a framework for estimating the costs and benefits to the UK economy of higher capital and liquidity standards, and also provides preliminary estimates of these costs and benefits. Specifically, OP38 proposes an approach to quantifying the benefits based on the 'early warning' literature on crisis prediction. This determines the historical links between the probability of a financial crisis occurring and a set of explanatory variables, using a multivariate logit model similar to that developed by Demirgüç-Kunt and Detragiache (1998). Historical macroeconomic data and levels of banking sector capitalisation and liquidity from OECD countries are used to estimate the change in the probability that a financial crisis occurs. The inclusion of banking sector specific ratios related to capital and liquidity allows the change in the probability of crisis to be attributed directly to changes in financial regulation. To calculate the benefits of tightening prudential standards, the change in probability of crisis is multiplied by an estimate of the expected cumulative loss in GDP associated with crisis. This loss is estimated from NIESR's NiGEM world economic model.

OP38 examines the costs of the regulatory changes by estimating a set of UK-specific, reduced-form equations that link higher capital and liquidity levels in the UK banking system to loan spreads in both consumer and corporate credit markets. When incorporated into NiGEM, these banking sector equations estimate the expected deviation of the path of economic output from the baseline as a result of the estimated changes in borrowing costs in the economy. The framework outlined in OP38 forms the basis of our own modelling work: our use of the model is described in greater detail later in this paper.

2.1.1 The Basel Committee on Banking Supervision Working Groups

The Financial Stability Board (FSB) and the BCBS established two working groups – the Macroeconomic Assessment Group (MAG) and the Long-term Economic Impact (LEI) Group – to coordinate international efforts to measure the likely macroeconomic impacts of stronger bank capital and liquidity requirements. The reports by these two groups focus on the macroeconomic costs of the transition to the new regulatory standards, and their long-run impact, respectively.

The report from the MAG (BCBS (2010b) and BCBS (2010c)) aggregates the outputs of macroeconomic models from 15 member countries, as well as a number of international organisations, to examine the macroeconomic effects of the transition to substantially increased capital and liquidity standards. Most submissions to the group from member countries use a two-step procedure to estimate the macroeconomic impacts on individual economies:

- First, members estimated the effects of the changes in prudential standards on lending spreads and volumes using either accounting-based estimates or estimates based on banks' dynamic balance sheet adjustments in response to shortfalls against desired capital ratios, as in the methodology developed in OP36.
- Second, the impact on lending spreads was used in members' standard macroeconomic policy analysis models to estimate the impact on GDP.

Other simulations of the impact were carried out using dynamic stochastic general equilibrium (DSGE) models. These sought to take account of non-price adjustments, such as bank credit rationing or lending standard effects. The IMF world economic model was also used to take account of any cross-country affects not addressed in member country models.

From the median outcome of all the simulation results, the MAG estimates that a one percentage point increase in the core equity capital ratio implemented over eight years would widen lending spreads by a maximum of 15.5 basis points (on average across all affected countries) and reduce the level of GDP by a maximum of 0.15% from a baseline of no change in policy. The reduction in GDP rises to 0.17% after adjusting for additional international spillover effects, as estimated by the IMF using its world economic model.

Based on the results of the BCBS quantitative impact study (QIS) undertaken as part of the Basel III calibration exercise, the MAG calculates that banks' existing capital ratios are only 1.3 percentage points below the Basel III agreed minimum plus the capital conservation buffer. Assuming that the costs in terms of national income increase linearly with increases in banks' capital ratios, the MAG estimates that raising banks capital to this level would reduce the level of global GDP by a maximum of 0.22% from a baseline that excludes any change in banks' capital levels. This reduction would occur during the transition to new standards (estimated to be around 35 quarters). The growth rate would be only 0.03 percentage points below the baseline over the transition period before returning to earlier average long-run growth rates.

The report by the second FSB-BCBS working group, the LEI (BCBS (2010a)) focuses on estimating the steady-state costs and benefits of the stronger capital and liquidity requirements. While the LEI report observes that model uncertainty is too high to calculate the optimum calibration, it finds substantial net benefits from raising the core equity capital ratio by up to 8 percentage points and implementing the new liquidity requirements, based on Basel II definitions of capital and risk-weighted assets.

In line with OP38, the LEI calculates benefits by multiplying the expected cumulative GDP loss from a crisis by the reduction in the probability of the crisis due to tighter prudential standards. The estimates of the cumulative costs of financial crisis, however, are based on an extensive literature review that finds that the median cumulative cost of a crisis is 63% of GDP, but results vary substantially depending on the duration of the effects of a crisis on output. A critical issue here is whether the effects are permanent. The report uses a range of models to calculate the effect of prudential standards on the probability of the crisis, including empirical models of the historical links between incidence of crises and the capital and liquidity levels in the banking system (e.g. Barrell, Davis, Karim and Liadze (2010c); Kato et al (2010)), portfolio credit risk methodologies applied to the banking sector as a whole, and stress-testing models.

To estimate the costs, the LEI first uses an aggregate bank balance sheet from 13 OECD countries to estimate the increase in loan spreads required to maintain the historical return on equity in the face of increased regulatory costs. It finds that a 1 percentage point change in the capital ratio raises loan spreads by 13 basis points. The additional cost of meeting the liquidity standards is estimated to be approximately 14 basis points, after accounting for the associated fall in risk-weighted assets. These intermediate results are used in a range of members' macroeconomic models to find that a 1 percentage point increase in capital standards reduces long-run GDP by 0.09% relative to baseline, while the GDP reduction associated with the liquidity requirements is 0.08%.

More recently, Angelini et al (2011) replicated the methodology used by the LEI to calculate the impact on long-term economic performance of the Basel III proposals, producing estimates consistent with the LEI and MAG reports. The paper also extended the analysis in the LEI report by using dynamic stochastic general equilibrium (DSGE) models to assess the impact of the Basel III proposals on the volatility of economic output for various different countries. The paper reports that the volatility in economic output is reduced with the introduction of Basel III, although the impact differs widely across countries.

Two key caveats to the methodology used in this study are highlighted in the paper. First, the impact of liquidity policy is particularly uncertain due to a lack of data available for empirical analysis and other data issues. Second, the extent of uncertainty in the model outputs means that the heterogeneity of the impacts across countries cannot be derived with confidence. Consequently, the outputs represent a range of possible outcomes in which individual country impacts cannot be identified with any precision.

A criticism of the approaches discussed above lies in their reliance on models with highly simplified financial sectors that assume perfect financial markets and have few, if any, frictions. Roger and Vlcek (2012a) take stock of existing DSGE models used by central banks and highlight the need to include more heterogeneous behaviour of both financial and non-financial agents in these models. The authors identify a number of priorities for modelling going forward, including: a motivation for households and firms to manage liquidity risk; explicit links between non-financial firm default and bank losses; inclusion of a wider range of financial firms (in particular, 'shadow' banks); and, explicit incorporation of wholesale funding and interbank markets. The importance of these developments is evident as DSGE models are increasingly used for macro-financial analysis and forecasting, macroprudential analysis and the stress-testing of banks' balance sheets.

2.1.2 Other estimates and approaches

In addition to research published to support the development and calibration of Basel III, there have been a number of independent studies of the expected macroeconomic costs and benefits of prudential regulation.

Ahead of the Basel III final calibration, the Institute of International Finance (IIF) published (IIF (2010)) an assessment of the expected effects of prudential regulatory reform on macroeconomic output and employment in the US, euro area and Japan. The report estimated that the total impact of the regulatory package would be to reduce real GDP for the G3 countries by 3.1 percentage points (from a no-policy baseline). These results, however, assumed a far more rapid implementation of Basel III than was eventually proposed.

The IIF revisited this assessment (IIF, 2011) subsequent to the publication of the revised Basel III policy, and calculated a smaller, but still significant, impact on economic output. This study calculated the impact of Basel III over the period 2011 to 2015 for the G3 countries plus Switzerland and the UK. They estimate that the whole package could reduce real GDP across the G3, Switzerland and the UK by between 1½ and 3 percentage points from the no-policy baseline. The methodology is sensitive to non-empirical parameter assumptions that determine the price of bank equity in their model. In particular, the chosen parameters for the UK result in the cost of equity rising by a maximum of around 18 percentage points (from 18% in the baseline to 36%), leading to a large contraction in lending. While the two studies from the IIF are not strictly comparable, they do remind us that the speed of implementation will raise the costs of the policy package.

A recent study of the macroeconomic costs and benefits of prudential standards by Miles et al. (2011) abstracts from estimating the impact of the specific prudential policy calibrations and seeks instead to determine the optimal capital level for the banking system. To estimate the cost to banks of higher capital requirements, the authors first estimate the reduction in banks' return on equity as banks become better capitalised and balance sheet leverage (and risk) is reduced using a modified CAPM approach. This result is then used to calculate the expected change in bank's weighted average cost of capital as banks' capital ratios change.

Changes in banks' weighted average cost of capital are assumed to be passed on to non-financial firms through the cost of borrowing. A structural production function equation is used to estimate the cost of a change in banks' capital ratios on GDP. The study finds that this cost rises linearly as banks' capital ratios increase, such that the marginal cost of raising banks' capital ratios is constant, at around 1.5% of GDP. To calculate the benefits of prudential standards, the authors consider the distribution of historical shocks to GDP (and, by realistic assumption, bank assets) and estimate the levels of capital that would be required for the banking system to survive these shocks and, therefore, avoid a financial crisis. The distribution of historical shocks exhibits diminishing marginal benefits as banks' capital ratios increase, although the distribution is non-normal and somewhat skewed (towards higher negative shocks). Comparing the marginal costs to the benefits, the optimal tier 1 capital ratio is estimated to be in the 16% to 20% range.

2.2 Some uncertainties

Existing empirical approaches to modelling the effects of prudential regulation, including our own, focus on the links between higher capital and liquidity standards in the banking sector and the macroeconomy. However, the literature also highlights a number of important uncertainties in analysing the effects of prudential regulation. In this section, we highlight three issues: the extent to which new prudential policy changes the size of future crises, the interconnectedness of the banking system, and the effectiveness of competition within it.

There are several reasons to believe that changes in regulatory standards may directly affect the size of any future crisis. Hanson, Kashyap and Stein (2011) argue that, in a model with coordination failures leading to fire sales and lending constraints, banks in aggregate hold inadequate capital buffers in good times and have (private) incentives to shrink assets (including lending), rather than raise additional new capital, in the event of a system-wide crisis. These incentives to rein in lending in a downturn may be further exacerbated by: the procyclicality of risk-weighted asset measures (Goodhart et al (2004); BCBS (2011a)); and, the premium on raising external equity (relative to retained earnings) that banks may face due to equity issuance being perceived as a negative signal by outside investors (Myers and Majluf (1984)).

Higher capital buffers, time-varying regulatory buffers and contingent capital instruments may reduce the size of the banking crises and the depth of subsequent recessions by mitigating fire sale incentives and the lending bottleneck effects described above. However, the empirical literature on these effects is scarce. The LEI report (BCBS (2010a)) fails to find a statistically significant empirical relationship between prudential standards and severity of crises, possibly due to a very small number of available observations.

The effects of the new regulatory requirements on the size of the crises can also be analysed by exploring the structural stability of different banking networks and the transmission of shocks through the banking system using mathematical network models.[1] Some recent literature in this field explicitly considers the connections between prudential regulation and systemic stability using such network models. For example, Nier et al. (2008) suggests that higher capital levels in a network that has high levels of interbank connectivity (each bank is connected to a large number of other banks via interbank assets and liabilities) can increase resilience against contagious defaults. The model also suggests that a more concentrated banking sector can be more vulnerable to systemic risk as the size of interbank liabilities to any particular institution rise, even when banks are appropriately capitalised. These results are highly sensitive to the theoretical specification of the network in the model.

[1] These mathematical models have been adapted from other disciplines, such as the biological sciences examining the spread of disease through a population.

Using an alternative credit network model, Battison et al. (2009) argue for a different conclusion, namely that systemic fragility starts to rise once connectivity in the banking sector increases beyond a certain level because a shock to an individual node can feed back through that node's connections and amplify the effect to a full systemic crisis. Gai and Kapadia (2010) also find that, conditional on a single institution failing, higher concentration increases contagion in the network, potentially leading crises to be more widespread if they occur.

Despite modelling sensitivities, financial network analysis appears to be an important tool for assessing the benefits of new prudential standards, especially for policy initiatives aimed directly at reducing systemic risk, such as additional capital surcharges for systemically important banks or regulatory incentives for central counterparty clearing. For example, the recent paper by Haldane and May (2011) suggests that the stability of financial networks depends on the heterogeneity in banks' diversification choices. This implies that some consideration needs to be given to whether competitive pressures and regulatory arbitrage incentives induced by new prudential standards are likely to generate similar portfolio allocation choices by banks in the system (since these could undermine or at any rate reduce the anticipated outcomes of the standards).

A relatively unexplored area that may significantly affect the costs and benefits of the new prudential standards is interaction between regulatory changes and competition in the banking sector. For example, reduced competition has generally been associated with higher loan spreads (Ruthenberg and Landskroner (2008); BCBS (2011a)). If the current increase in capital and liquidity requirements creates additional barriers to entry or results in a more concentrated banking industry, it may amplify the macroeconomic costs of the regulatory reform as firms may be more able to pass on regulatory costs to the economy as a whole or extract additional rents through wider loan spreads. We note, however, that this effect may already be partly captured by the reduced-form empirical models of the relationship between lending spreads and capital requirements unless they explicitly control for competition.

The likelihood and the size of the financial crisis, and therefore the estimates of the benefits, are also likely to be affected if the new prudential standards materially change the nature of competition in the relevant markets. For example, Vives (2010) undertakes a detailed review of the literature on bank competition and financial fragility and concludes that there exists a trade-off between competition and stability. Vives finds that coordination problems between investors and depositors worsen with the competitive pressure, which increases the probability of a crisis and the range of fundamentals that give rise to a run on a solvent institution. Vives also identifies a range of models which suggest that an increase in competition may be associated with higher risk-taking incentives. A study of inter-state and intra-state deregulation in the US between 1976 and 1994 by Hanson, Kashyap and Stein (2011) also finds that firms tend to adopt lower and more uniform capital levels as the intensity of competition increases.

Other empirical studies provide more mixed results. Beck et al. (2006) use a panel of 69 countries over the period 1980 to 1997 and find that both high concentration in the banking sector and pro-competitive institutions, and regulatory environments are associated with a lower probability of a systemic crisis. These findings are supported by Schaek et al. (2009), who also report that, using data on 45 countries between 1980 and 2005, systemic banking crises are less likely in more competitive and more concentrated banking systems. These results may be reconcilable (highly competitive firms are very fit; firms with high market power are very strong), but the literature on competition and financial fragility suggest that the interactions between economic benefits and competitive effects of the new prudential standards merit further investigation.

2.3 Conclusion

All of the studies noted above make significant contributions to estimating the macroeconomic implications of prudential standards. They also highlight some issues that such estimates either do not or, realistically, cannot address. It is clear that there remain a number of practical obstacles to estimating the impact of Basel III on national economies. The extent to which a country is affected by the Basel III package will depend on a number of factors such as the prevalent business models of its banks, the impact of changes to capital and risk-weighted asset definitions on individual institutions, and the macroeconomic conditions in each country, an effect that is obscured by international aggregates.

We are not aware of published research that focuses on a country-specific calibration of the changes in prudential standards and that captures the behavioural responses of firms to the regulatory standards as well as the dynamic second-order effects of the changes in bank lending on the economy, including but not limited to the stabilising monetary policy responses. In the rest of this paper, we discuss the development of the models that we have used to estimate the impact of changes to prudential policy, including how we have attempted to overcome some of the practical difficulties in making estimates.

3 A model of the UK banking system

We constructed a model of individual banks' responses to changes in prudential standards, based on an analysis of historical data. The model simulates the adjustments made to elements of individual banks' balance sheets as they adjust to new capital requirements. We aggregate these individual responses across the banking sector to produce a measure of the change in the aggregate banking sector capital ratio. The aggregate capital ratio is then used in our macroeconomic model to estimate the costs and benefits of higher regulatory standards.

This approach has a number of advantages. First, we can better understand the impact of a large number of complex policy propositions that overlap and interact with each. Second, the model allows us to analyse the impact on the quality of capital held on banks' balance sheets by differentiating between different tiers (core equity, tier 1 and total) of capital. Third, in addition to investigating changes to minimum capital ratios, we can investigate the impact of changes to the quality of regulatory capital or risk-weighted assets held on banks' balance sheets. In addition, this approach provides a dynamic, rather than static, analysis of any implementation profile for the policy propositions. We discuss these issues further in Section 3.2.

3.1 Banks' responses to regulatory capital requirements

In the macroeconomic impact assessment framework described in OP38, the aggregate banking sector's risk-weighted total capital ratio and aggregate ratio of liquid assets to total assets were established as policy levers that we could manipulate in the NiGEM model. This setup was useful in that it enabled us to estimate the impact on the UK economy of aggregate changes to capital and liquidity standards for the banking sector as a whole.

However, the UK banking sector is dominated by a small number of large but dissimilar institutions, and changes to prudential policy may affect these institutions in very different ways. For example, a bank with a capital to risk-weighted assets ratio very close to the regulatory minimum ratio will have no choice but to adjust capital and/or assets in response to an increase in this minimum, while a bank holding a large voluntary buffer of capital to risk-weighted assets over the minimum ratio required could in principle choose to do nothing and rely on their buffer to absorb the increase in the minimum. Treating the banking sector as a single agent making decisions based on an aggregated balance sheet, rather than as a number of heterogeneous agents making decisions based on individual balance sheet positions, will most likely fail to capture properly aggregate behaviour.

OP36 looked at the historical relationship between capital and credit supply for all banks operating in the UK over the period 1997 to 2007 and estimated a model that describes how banks adjust their balance sheets in response to shocks to their actual capital ratios. The intuition behind the model is straightforward: banks react to differences between their desired future risk-weighted capital ratio and their existing capital ratio by adjusting both their levels of capital and risk-weighted assets over time until they achieve this desired ratio. Annex 1 provides a brief technical description of the approach developed to model the relationship.

The differential rates at which banks adjust key elements of their balance sheets (the adjustment parameters) are estimated in OP36. Separate adjustment parameters are estimated for total and tier 1 capital, total assets, risk-weighted assets and total bank lending.[2] Note that the estimated adjustment parameters represent the average rate of adjustment for banks' balance sheets across the whole banking system. That is, estimates are representative of the aggregate adjustment speed for the banking sector, and not specific to each bank. The lack of individual bank adjustment parameters is a limitation of this analysis, but reflects the limitations of the data itself.

To demonstrate how different elements of a bank's balance sheet change as the bank adjusts to its desired capital ratio, we simulated the impact of a 1 percentage point increase in banks' desired capital ratio using the estimates from OP36 and given the aggregate level of capitalisation and assets in the banking system in 2009.[3] As can be seen from Table 3.1, the most significant adjustment occurs in the first year and adjustment is largely complete after four years. Importantly, the simulation shows that banks adjust by raising their total regulatory capital overall by 3.6% from the baseline. If we assumed that banks made no change to their risk-weighted assets, total regulatory capital would need to rise by 7.0% to meet the new requirement.[4]

Table 3.1: Impact over time of a 1 percentage point increase in banks' ratio of regulatory capital to risk-weighted asset ratios

	Percentage difference from baseline[1] after:				
	1 year	**2 years**	**3 years**	**4 years**	**5 years**
Change in:					
Total regulatory capital	2.1	3.0	3.4	3.5	3.6
Tier 1 capital	1.5	2.2	2.4	2.5	2.6
Assets	-1.2	-1.6	-1.8	-1.9	-1.9
Loans	-1.0	-1.3	-1.5	-1.6	-1.6
Risk-weighted assets	-1.9	-2.7	-3.0	-3.1	-3.2

[1] Reported results use aggregate balance sheet data for the UK banking sector in 2009 as a starting point. The regulatory capital to risk-weighted assets ratio for this period was approximately 0.14.

We find that the impact is much higher for total capital than for tier 1 capital, which suggests that banks flex their tier 2 capital (the difference between tier 1 and total capital) to a greater extent than the relatively expensive and inflexible tier 1 capital in order to meet capital targets. One implication of the

[2] The estimated adjustment parameters are reported in Table 3, OP36

[3] We used the average balance sheet of the four largest UK banks for this simulation although, as noted, this is unlikely to be representative of actual aggregate behaviour.

[4] Say risk-weighted assets of a bank are £100 and total regulatory capital is £14 (the regulatory ratio is therefore 0.14). If risk-weighted assets are unchanged, raising the capital ratio by 1 percentage point increases capital by £1, or 1 ÷ 14 = 7%.

model is that rules that restrict the use of tier 2 capital can have larger impacts than similar changes in total requirements would suggest.

The model also reveals the adjustments that banks make to the asset side of the balance sheet. What is interesting is that the composition of assets changes: total assets shrink by 1.4%, while risk-weighted assets shrink by 2.4% and total loans by 1.2%. This means that banks' approaches to achieving higher regulatory capital ratios typically involve proportionally greater reductions in assets with higher risk weights. For example, one might expect banks to shrink their portfolios of corporate loans, which generally attract a high risk weight, more than their portfolios of domestic mortgages, which attract a low risk weight.

Clearly, these estimation results are based on banks' behaviour in a benign economic period, and responses may differ following the recent crisis. It is difficult to assess the extent to which the estimated adjustment parameters continue to apply after the crisis due to the insufficient number of cross-time observations and the significantly different macroeconomic environment in the post-crisis period. Preliminary results we have for the post-crisis period are broadly consistent with the results in OP36, although we, unsurprisingly, observe banks adjusting to shortfalls in their capital ratios faster than in the past. However, there is insufficient data for the post-crisis period to allow us to draw any firm conclusions on whether the relationships in OP36 have changed materially. We also note that the parameters estimated in OP36 may not be wholly reliable as indicators of banks' responses to Basel III because:

- they are based on firm-specific individual capital guidance (ICG) adjustments rather than across-the-board changes in standards; and
- some of the ICG adjustments may have similar drivers to Basel III, i.e. a perception that the capital required is too low when considered against an objective assessment of bank risk positions and associated externalities, while others might have qualitatively different drivers such as concerns about strategy or management competence.

The first point suggests that, under Basel III, banks have a greater ability to raise prices and a lesser ability to raise capital than in the cases modelled in OP36 unless the findings in OP36 reflect considerable market power (which may be the case). The second point suggests that, in OP36, the observed tendency of banks to reduce balance sheets following an increase in their ICG may have a driver that is independent of the ICG. In this case, the full balance sheet shrinkage estimated in OP36 might not be expected under Basel III.

3.2 Constructing a model of the UK banking system

We populate the OP36 model above with data for each of the major UK banking groups. A change in prudential policy – in effect, a shock to banks' desired capital ratios – changes the capital ratio that each bank targets, and the surplus or deficit of the bank's actual capital ratio relative to this target. The output of the model is a prediction of how each bank's capital and risk-weighted assets adjust relative to the baseline over time. Adding together the balance sheets of all major banks with and without the policy change provides the incremental impact on, and a transition path to, future industry-wide capital ratios.

One advantage of this approach is that it allows us to simulate banks' response to a complex set of policies that overlap and interact with each other. For example, if both a leverage ratio and risk-weighted capital ratio are included in the policy package, the risk-weighted capital ratio will be binding when a bank's risk-weights are high relative to unweighted assets, and the leverage ratio is binding when a bank's risk-weights are low. We can construct a simple rule in the model that switches between these two requirements if changes to a bank's balance sheet cause these ratios to be binding at different points.

Another advantage is the ability to deal with different minimum regulatory requirements expressed in terms of core capital, tier 1 capital and total capital. For example, a large increase in the core capital to risk-weighted assets ratio might cause a bank to shrink its assets considerably, resulting in an excess of capital at the tier 1 and/or the total capital levels. The optimal response is to reduce the level of non-core capital over time. Reducing non-core capital offsets the cost of the initial increase in core capital, implying that the overall increase in cost will be the difference between the required rates of return on core and non-core capital.

We model changes in the definition of capital in a similar way. When we impose tighter conditions on the definition of core capital, for example by requiring greater deductions from tier 1 capital to calculate core capital, banks may respond by raising additional core capital. This will count towards tier 1 and total capital requirements, and will generate a surplus at those two levels if the tier 1 and total capital minima are also unchanged. In the model, all layers of capital are recalculated in each period, allowing complex dynamic responses.

A further advantage of this approach is that it enables us to express changes in banks' regulatory balance sheets in a consistent way over time. Increases in risk weights, such as those implied by proposed reform of the trading book regime, will, holding other things equal, reduce banks' risk-weighted capital ratios even though no change has been made to banks' balance sheets. Changes to the definition of capital similarly result in changes to measured regulatory capital even if the composition of capital on banks' balance sheets remains the same. This means that substantial adjustment in firms' balance sheets may be required even though official regulatory minimum capital ratios remain unchanged. Clearly, focusing solely on changes in official minimum capital ratios would underestimate the impacts of the regulatory changes as a whole. Consequently, we use the model of the banking system to convert all regulatory changes back into a definition of capital and risk-weighted assets that expresses the changes in a consistent way.

Finally, the model of the banking system addresses the issue that changes in capital requirements may affect banks differently, which could mean that the sectoral change in capital ratios is different from the change in firm-level minimum required capital ratios (i.e. a fallacy of composition). The model of the banking system allows each bank to adjust independently and then aggregates the impact across banks, so it adjusts for changes in the composition of the sector as a result of policy. For example, if one bank is required to raise substantial amounts of capital, the model predicts that this bank will shrink and come to account for a smaller proportion of the sector, so that it has a smaller weight in the calculation of the sectoral capital ratio.

One limitation of this approach is that, while the model of the banking system simulates banks' adjustments to shocks, it is not a model of the shocks themselves. If banks are adjusting to new capital standards in advance of changes to minimum requirements we need to ensure that the path to any new equilibrium takes these shocks into account.

The outputs of the model of the banking system are estimates of the incremental impact of policy changes on the capital ratio of the banking sector as a whole. These results are used in a macroeconomic model to produce estimates of social costs and benefits, as described in Chapter 6. While we cannot say that this model of the banking system provides all the answers, in its absence our confidence in whether we are using the correct inputs into our macroeconomic model would decline, while the degree of uncertainty in the macroeconomic estimates would increase. The model can also be used to produce simple predictions of the transition paths implied by different changes to regulatory standards, in terms of the likely combination of new capital raising and reductions in risk-weighted assets that will arise.

3.3 A practical example of the model of the UK banking system

To illustrate how the model of the banking system is used in practice, we present a worked example of a step-by-step impact assessment of a hypothetical policy package comprising the following elements:

- a 2 percentage point increase in regulatory minimum ratios for core tier 1, tier 1 and total capital from existing levels;
- a further tightening in prudential standards due to revision of risk weights on assets and a narrower definition of capital at all tiers; and
- a minimum total capital leverage ratio requirement of 4%.

Because the model requires regulatory data relating to individual banks that is not publicly available, we have for present purposes constructed a stylised banking sector composed of three heterogeneous banks[5].

3.3.1 Change in regulatory minima

The first part of the hypothetical policy package we present in this example is an increase in the regulatory minimum capital ratio of 2 percentage points at all tiers of capital from 1 January 2011. The change in the ratios is set out in Table 3.2 below. This increase in minima can reflect two possible changes in policy that are equivalent in our framework – a change in actual minimum capital ratios or the introduction of new regulatory capital buffers which banks

[5] The balance sheets we have constructed for these three banks do not purport to represent actual banks.

effectively treat as new minima, possibly to avoid the restrictions imposed on banks when their capital ratios fall within the buffer.

Table 3.2: Changes to Regulatory capital minima implemented in 2011

	Baseline	New ratios
Total capital ratio	8%	10%
Tier 1 capital ratio	4%	6%
Core tier 1 capital ratio	2%	4%

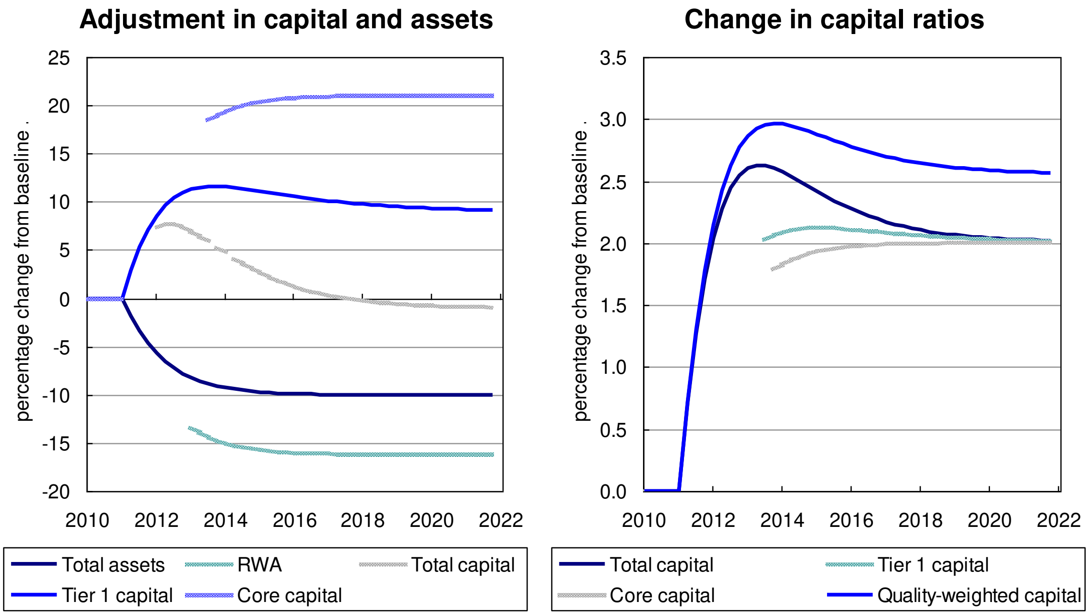
The effects of a change in regulatory minima are symmetrical for the three hypothetical firms in our modelled banking sector. Under the assumption that banks choose to maintain their voluntary capital buffers over minima at a current levels, an increase in minimum regulatory ratios translates one-for-one into a change in the target capital position for each bank.

While our framework permits a wide range of assumptions about the transitional implementation of new requirements, for simplicity we assume that the increase in the regulatory minima is, in effect, an unanticipated shock for banks. This situation can be more intuitively interpreted as an unforeseen announcement of new standards that will come into effect following a transition period that corresponds to banks' usual adjustment period (as shown in Table 3.1 above). In response to this, forward-looking firms immediately revise their targeted capital requirements in order to ensure that their voluntary buffers are preserved once the new standards are fully implemented.

Figure 3.1 below summarises the aggregate banking sector adjustment in capital and assets until a new equilibrium is reached. The model exhibits some overshooting of the total capital ratio during the transition as it is cheaper and easier for firms to flex their tier 2 capital than higher quality tiers of capital. As a result, banks reach their target *total* capital ratio faster than they achieve their targets for other tiers. However, risk-weighted assets continue to decline as banks continue to adjust to their tier 1 and core tier 1 requirements. Consequently, banks are left with surpluses against their total capital targets and shrink their tier 2 capital accordingly.

The model framework produces separate response paths for each quality tier of regulatory capital and uses these outputs to calculate the change in composition and the cost of total regulatory capital for firms. This allows us to translate combinations of policy measures that affect both the quality and quantity of capital into a single, 'quality-weighted' capital ratio that is consistent in price and quality with the firms' current (Basel II) total capital measure. The quality-weighted increase in the capital ratio can then be used as an input in our macroeconomic model, which is currently calibrated only at the total capital level. For example, the two percentage point increase in all capital ratios is approximately equivalent to an increase in the banking sector's quality-weighted total capital ratio of 2.6 percentage points, after adjusting for the different costs of different tiers of capital. We provide a more detailed explanation of our quality-weighting approach in Section 4.3.

Figure 3.1: Behavioural response of the banking sector to changes in regulatory minima



3.3.2 Changes to definition of capital and RWAs

As discussed above, the model framework also allows us to estimate the impact of prudential measures which affect banks' capital positions but do not change minimum regulatory capital ratios, such as changes to the definition of capital or adjustment of the risk weights applied to a particular asset class. To illustrate this, we now supplement the two percentage point increase in regulatory minima with the set of changes to banks' regulatory capital and risk-weighted assets shown in Table 3.3 below.

Table 3.3: Changes to capital definitions and risk-weighted assets[1]

Source of change		**Bank A**	**Bank B**	**Bank C**
Changes to the definition of regulatory capital	Core tier 1	-40%	-20%	-60%
	Tier 1	-21%	-7%	-27%
	Total	-4%	0%	-2%
Changes to risk weights on assets		+10%	0%	+5%

[1] Table shows the percentage reductions in the value of balance sheet items for each bank in the simulation as a result of definitional changes

The changes in definitions of capital and risk-weighted assets create different shortfalls against the target capital ratios for each bank in our simulation. Following the standard adjustment procedure, banks respond by raising capital and shrinking risk-weighted assets in proportion with their identified capital deficits. The idiosyncratic impact of these regulatory measures implies different adjustment paths and increases in 'old-definition' capital ratios for each firm in the modelled banking sector (see Figure 3.2 and Figure 3.3). As with changes to regulatory minimum capital requirements, we assume that these changes to capital and risk-weighted asset definitions are unanticipated and not known to banks until the beginning of 2013. We note that imposing different implementation dates will affect the transition path for banks' balance sheets, although the equilibrium outcome in the long-run is unaffected.

In combination with the increase in regulatory capital ratios discussed in Section 3.3.1, the changes to capital definitions and risk-weighted assets increase the quality-weighted capital ratio by 5.7 percentage points for Bank A, 2.8 percentage points for Bank B and 4.6 percentage points for Bank C. Aggregating across these behavioural responses, we obtain a sector-wide change in the quality-weighted capital ratio of 4.0 percentage points. We note that this calculation raises the size of the adjustment that banks need to make that is not captured by the changes in the minimum ratios. Without this adjustment, we would considerably underestimate the impact of the entire policy package on the banking system.

3.3.3 Including a leverage ratio

We now extend further the policy package examined in Sections 3.3.1 and 3.3.2 above to include a minimum leverage ratio[6] requirement of 4%. Given that the leverage ratio has not been a binding requirement for UK banks, we do not have empirical estimates of the likely voluntary buffers firms may hold over minimum capital leverage ratios. For this analysis, we assume that all banks aim to hold a constant voluntary buffer of 1% of total assets over the minimum leverage ratio requirement.

We estimate the impact of the leverage ratio requirement by converting the amount of capital required for compliance (including any voluntary buffers) into an alternative implied target capital ratio for a firm. For example, for a bank with total assets of 100 and risk-weighted assets of 50, a 4% minimum leverage ratio (with an additional 1% voluntary buffer) implies an alternative target risk-weighted capital ratio of: $(0.05) \times 100/50 = 10\%$ of RWAs. The higher of the original target risk-based capital ratio and the alternative target ratio based on the leverage requirement will then be the binding constraint on the bank, and is therefore used to calculate the capital surplus/deficit that will drive banks' behavioural responses.

A key caveat to this approach is that it implicitly assumes that, faced with a capital deficit against their target ratio, banks change their balance sheet positions in the fixed proportions identified in OP36, regardless of the source of the shortfall. We note, however, that leverage ratio requirements are less likely to lead to the lowering of average risk weights that was observed in banks' responses to changes in risk-based capital requirements.

In our hypothetical banking sector, only Bank B's total capital target implied by the new leverage ratio requirement exceeds its risk-based target capital ratio. Banks A and C are not bound by the leverage requirement at any point, so their responses remain the same as in Section 3.3.2 above. Bank B, however,

[6] Ratio of total regulatory capital to total assets.

now faces an additional, binding constraint on its total capital due to the leverage ratio. As a result, Bank B's total capital ratio increases by more than in Step 2 and no longer exhibits the overshooting effect noted earlier (see Figure 3.4). This response significantly increases the quality-weighted capital ratio for Bank B and brings the sector-wide change in quality weighted capital ratio to 5.6 percentage points.

Table 3.4 below summarises the aggregate quality-weighted changes in capital for all three steps in the analysis of the hypothetical policy package. It is useful to note from the table that, while each additional policy change adds to our estimate of the (quality-weighted) change in the capital ratio, the increase in the minimum regulatory requirement remains unchanged after Step 1. We can use these system-wide outcomes in NiGEM as a proxy for the expected response of the banking sector as a whole, which allows us to derive the long-term macroeconomic impacts of the proposed policy.

Table 3.4: Model simulation results

Scenario	Aggregate quality-weighted change in the capital ratio (percentage points)
Step 1 (minimum ratios)	2.6
Step 2 (additional changes in definition of capital/RWAs)	4.0
Step 3 (additional leverage ratio requirement)	5.6

Figure 3.2: Impact of changes in regulatory minima and individual capital & RWA shocks adjustment in capital and assets

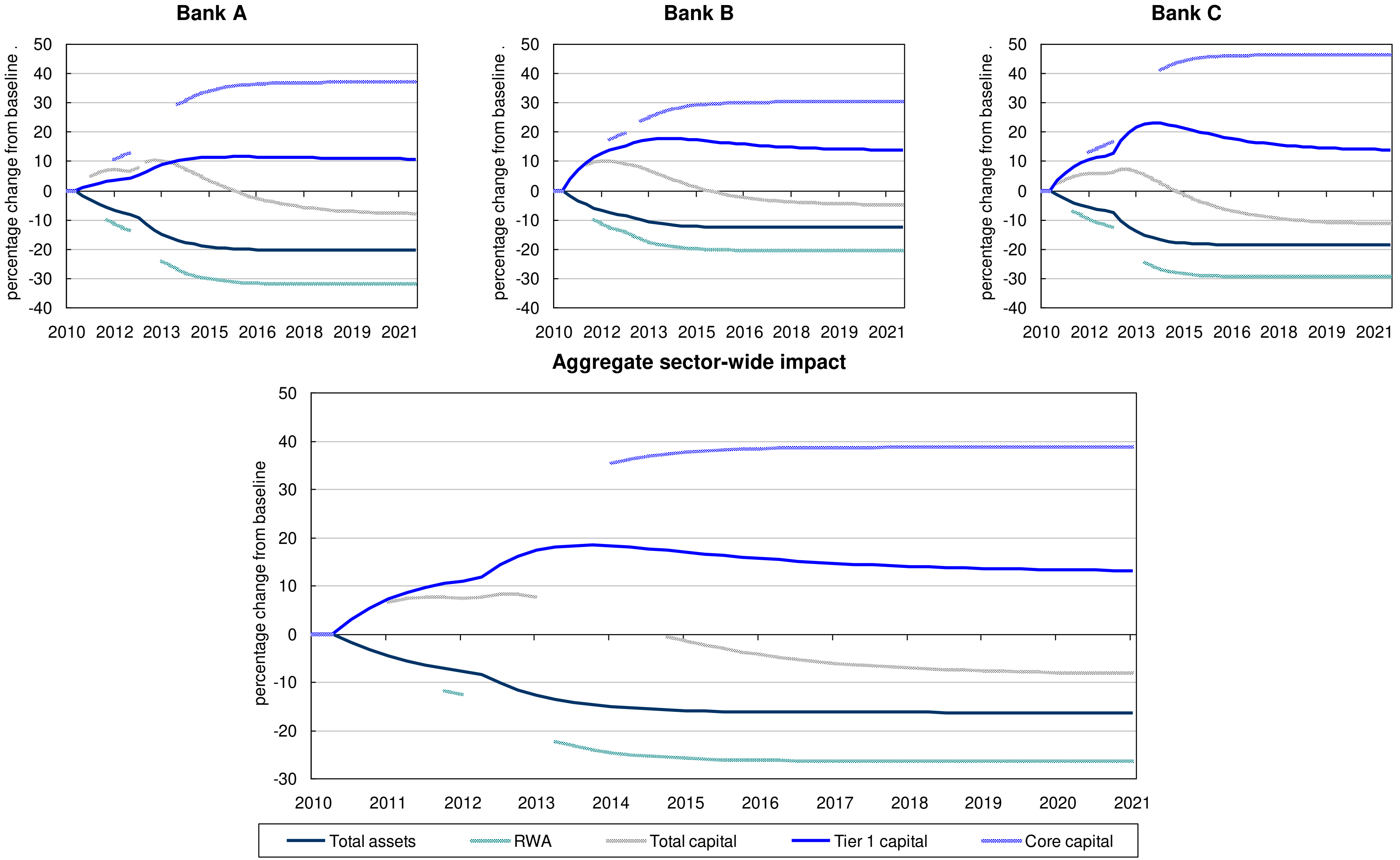


Figure 3.3: Impact of changes in regulatory minima and individual capital and RWA shocks on bank capital ratios

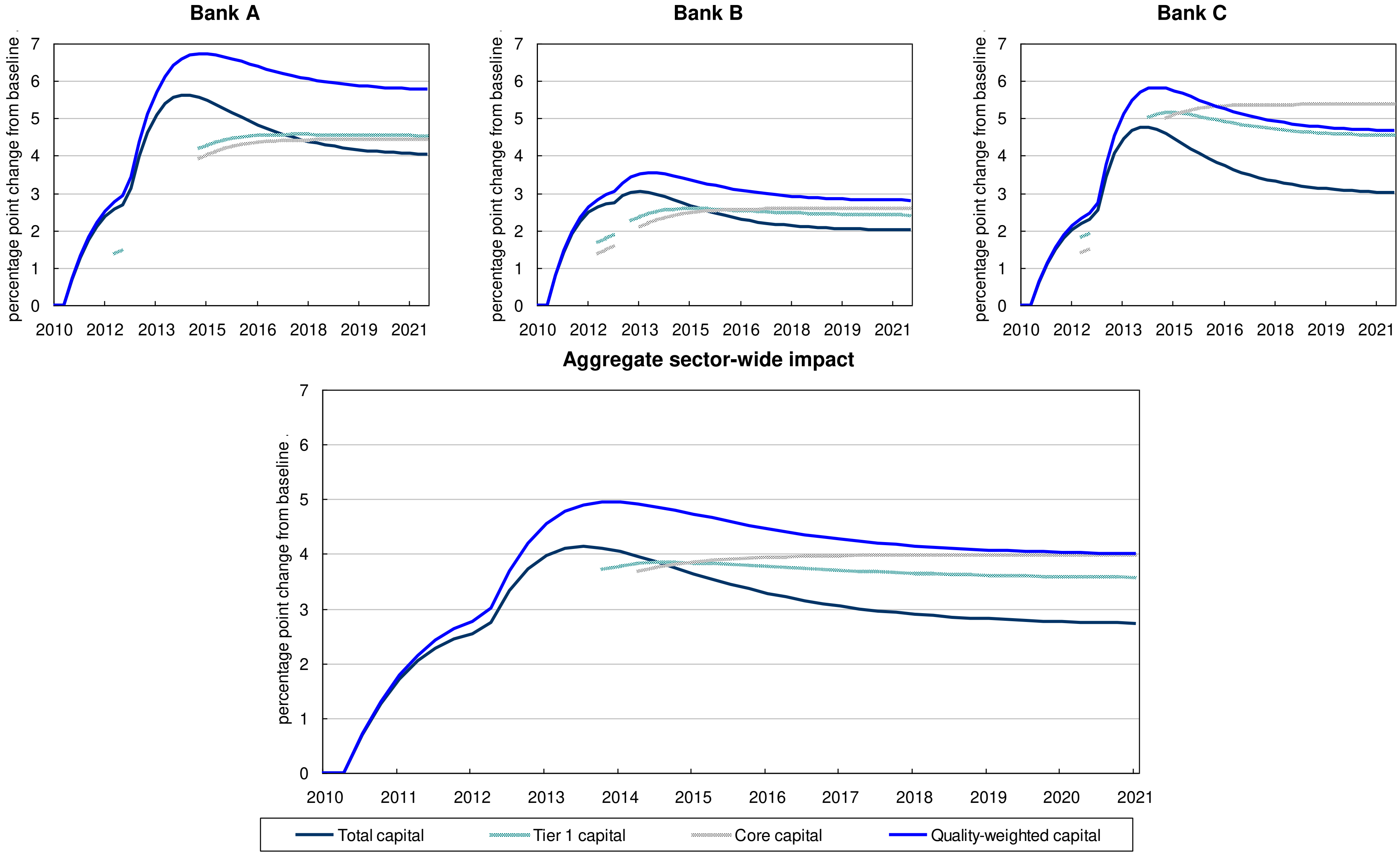
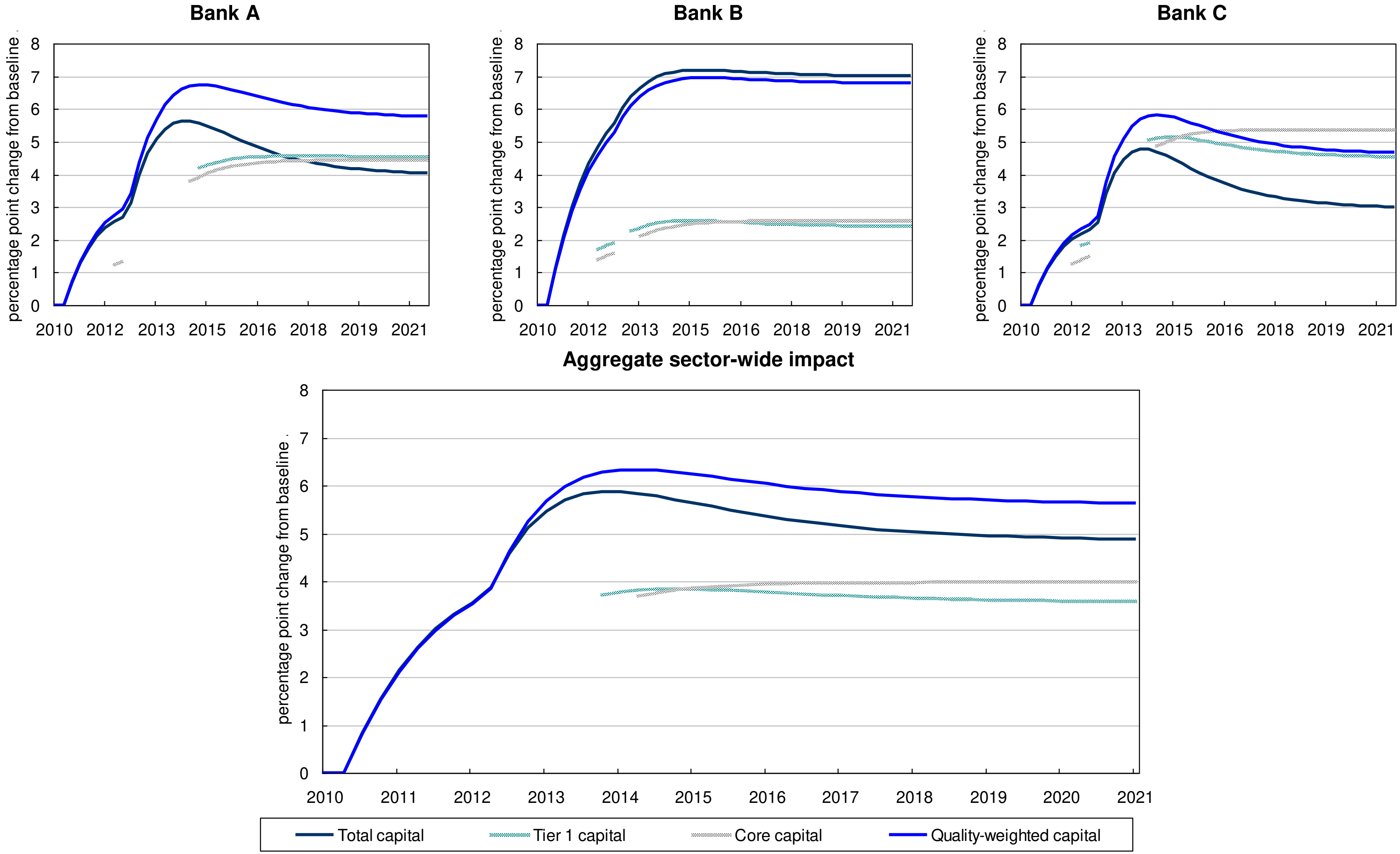


Figure 3.4: Additional impact of a leverage ratio requirement



4 Modelling the impact on the macroeconomy

We have modified the approach taken to measuring the impact of changes to prudential policy in OP38 to include both short and long-term responses to higher prudential standards. In the long-term, banks can use funding from across their balance sheets to undertake lending, so we expect banks to pass through any average rise in the cost of funding evenly across their loan portfolios. However, in the short term, our microeconomic model tells us that banks shrink their risk-weighted asset levels to achieve new capital ratios. The most efficient way for banks to adjust their risk-weighted assets (and their loan portfolios) is to reduce high-risk lending, such as corporate loans, to a greater extent than low risk lending, such as mortgage lending. If we are to properly capture the full impact of the policy package, we need to take into account the different short- and long-run costs to the economy.

The model of the banking sector described in Chapter 3 provides detailed estimates of the impacts on banks' balance sheets of detailed prudential policy proposals. However, estimates of the impact of prudential policy on the macroeconomy are usually generated from necessarily simplified models using reduced form equations. Most models of national economies are also used for the specific purpose of estimating the impact of monetary or fiscal policy and most do not explicitly model the banking sector as a target for policy change.

Our approach to analysing the impact of prudential policy on the macroeconomy proceeds by using the micro-foundations explored in our modelling of the banking system to build, where possible, relevant linkages into the NiGEM macroeconomic model described in OP38. While the consequences of calibrating and combining a range of prudential policy measures cannot be known with certainty *ex ante*, broad estimates of the consequences can be made because the results of past decisions can be observed and because there is a useful analogy between the impacts of monetary policy and the impacts of prudential policy. The impacts of past monetary policy decisions have been extensively analysed and elaborate forecasting tools, such as NiGEM, have been developed to predict the consequences of monetary policy decisions.

However, while there is an analogy based on the fact that monetary policy and prudential policy both appear to affect the cost of credit in the economy, the channels through which the various measures in the prudential policy package affect banks' costs and the broader economy are not identical to that of monetary policy. Increases in banks' costs due to changes in prudential policy both raise borrowing costs and reduce income for banks' customers by lowering deposit interest rates.

The costs of prudential standards are calculated by modelling how banks change the interest rate margins (or lending wedge) they charge their customers to offset any increase in their funding costs, and the cost of carrying additional liquid assets. The lending wedge, defined as the difference between lending and deposit interest rates, is defined separately for the corporate sector and the household sector as theoretical and empirical work shows that these sectors react differently to changes in costs, and have different consequential impacts on the macroeconomy. The household sector is further divided into secured household loans (i.e. mortgages) and unsecured household loans (i.e. credit cards). The cost of carrying liquid assets and the cost of higher capital are modelled separately in each case.

An important caveat to the results of modelling the macroeconomic changes brought about by changes to bank prudential policy is that we have to rely on banks' past responses to changes in prudential policy. However, as discussed above, past responses may not be closely representative of banks' responses to the large changes in prudential policy currently being considered. Nevertheless, we believe that the information about the likely effect on the economy that our extended macroeconomic model provides has enhanced our understanding of the impact of the full package of policy measures.

In this section, we discuss our modelling of the cost of capital and liquidity and the impact on the macroeconomy. First, we review the theoretical literature on the cost of capital. Second, we present an econometric approach to measuring the pass-through of the costs of holding incremental capital. Third, we briefly describe our estimate of the marginal cost of holding liquid assets, which reflects our discussions with the industry and inspection of individual bank data. Finally, we describe our method for modelling different types of capital, which are separated into tiers under the Basel regime and subjected to different regulatory treatment in recent reform proposals.

4.1 Equity ratios and the cost of capital

The justification for assuming a positive relationship between the capital ratio and the cost of borrowing is that a bank holding a higher capital ratio should, other things equal, be charging more to customers to offset the higher cost of funding (Saunders and Schumacher (2000)). For a bank, the choice about whether to extend credit can be represented by the following loan pricing equation, which says that credit should be extended when the (tax adjusted) return on the loan is greater than or equal to the weighted average cost of supplying the loan:

$$r_{LO}(1-t) \geq E \cdot r_E + \left[(D \cdot r_D + C + A - O) \cdot (1-t)\right] \qquad 4.1$$

where r_{LO} is the effective interest rate on the loan, t is the marginal rate of corporation tax, E and D are the proportions of equity and debt respectively backing the loan, r_E and r_D are the required rate of return on equity and debt respectively, C is the credit risk spread, equal to the expected loss, A is the cost of administering the loan, and O captures other benefits to the bank of making the loan, such as cross-selling opportunities (Elliott (2009)). The square brackets are positioned to reflect the assumption that the income and expense associated with D, C, A and O are taxable, whereas dividends payable on E are not. According to this view, then, the effect on the price of the marginal loan of raising the proportion of equity is:

$$\frac{\delta r_{LO}}{\delta E} = \frac{r_E}{1-t} - r_D \qquad 4.2$$

The marginal cost of an increase in capital requirements is therefore equal to the spread between the required return on equity and debt, adjusted for the differing tax treatment. However, this simple characterisation of the loan pricing decision assumes that the required return on equity and debt are exogenous parameters, and it therefore sets aside some of the insights of Modigliani and Miller (Modigliani and Miller (1958)). The Modigliani and Miller (M-M) theorem sets out conditions under which a firm's debt and equity prices change with a firm's choice of debt-equity mix such that the funding mix is entirely irrelevant to the value of the firm.

The assumptions required for the M-M theorem (including no information asymmetries or bankruptcy costs, perfect capital markets, no tax or other subsidy distortions) are unlikely to hold fully in practice.[7] The 'trade-off' theory represents one outcome that relaxes the 'pure' M-M assumptions. In this view, there are two countervailing influences on the cost of funding. On the one hand, the too-big-to-fail status of some banks means that debt-prices are effectively subsidised by government guarantee. In addition, the deductibility of interest payments on debt for tax purposes in many developed countries makes debt less costly and hence results in a preference for higher leverage. On the other hand, when leverage rises sufficiently so that debt-holders face a materially increased probability of default, they require a risk premium to compensate them for expected bankruptcy costs, including that the book values of assets cannot be realised in the market. Since this risk premium rises rapidly in a non-linear fashion as the equity ratio drops close to zero, the trade-off between these two factors suggests that there is a private optimal capital ratio for each bank.

The existence of a private optimal equity ratio which minimises a bank's cost of funding implies that the relationship between the equity ratio and loan pricing is ambiguous. Higher capital requirements will increase the cost of funding only when they imply a target capital ratio for the bank (including any buffer the bank wishes to hold to avoid breaching the requirement) which is higher than the private optimal capital ratio.

One implication of this is that the relationship between capital requirements and loan pricing may vary as conditions in banks and the economy in general affect the optimal capital ratio of banks. For example, Berger (1995) offers evidence that widespread bank failures and recession in the late 1980s in the US caused banks' optimal equity ratios to rise, which meant that banks which increased their equity ratios were able to improve their return on equity due to a lower risk premium on their debt repayments. If regulatory capital requirements in such circumstances are less than the banks' private optimal capital ratios, they will have little incremental impact on banks' cost of funding. That said, if banks' private optimum capital ratios vary with economic conditions, then higher capital requirements fixed through time could become binding as economic circumstances change. Moreover, the substantial

[7] We do not offer a review on these assumptions or a detailed description of possible deviations from them. A number of good summaries already exist (e.g. Berger (1995); Hillier et al (2008)). Eichberger and Harper (1997) also provides a useful discussion of the implications of the M-M theory.

increases in regulatory capital requirements envisaged in Basel III appear to set ratios in excess of banks' private optimal capital ratio.

Theoretically, negative externalities associated with bank failure suggest that regulatory capital requirements should be higher than banks' private optimal capital ratios, as society bears significant costs in the event of a bank failure that are not taken into account in firms' private decisions. This implies that society demands a lower probability of distress or default than individual investors, with limited liability, would demand for a bank.

There is in fact empirical support for the notion that regulatory capital ratios were already above banks' own private optimal capital ratios *prior to* the crisis and Basel III suggesting that, in practice, banks are on the upward-sloping section of their cost-of-funding schedule. OP36 provides empirical evidence that UK banks' actual capital ratios are strongly correlated with capital requirements and changes in requirements induce material adjustments to banks' balance sheets, strongly suggesting that changes in capital requirements are binding on banks.

In a dynamic economic environment, further issues to consider are whether banks adjust their capital ratios more quickly in the short term, and whether individual bank's adjustments have any impact at the aggregate level. Van den Heuvel (2009) discusses theoretical and empirical literature supporting the conclusion that banks adjust lending dynamically when faced with risk-based capital requirements and imperfect markets for equity. In this approach, banks reduce their lending in response to balance sheet shocks, such as increases in loan defaults and changes in monetary policy, reducing their riskier loans in response to higher funding costs (reduced profitability), especially in the short term, before allowing lending to return to previous levels over the longer term.

Banks with restricted access to equity markets and whose regulatory capital requirement is binding can rebuild their voluntary capital buffers by reducing profits in the future. If the regulatory capital target increases, a bank in this position needs to shrink its risk-weighted assets to achieve its desired capital ratio and restore profitability. As a result, banks with a binding capital constraint will reduce lending over time to a greater extent than banks with unrestricted access to equity.

In an aggregate, general equilibrium context, individual banks' capital choices will have a greater impact at the macroeconomic level if borrowers face switching costs[8] and where banks have imperfect access to capital markets. If switching costs are high and banks have limited access to capital markets, higher prudential standards have a larger impact on all banks' profitability, and a larger impact on aggregate lending.

[8] Switching costs can be associated with factors such as product differentiation or banks' relationships with their customers, which we observe in practice.

4.2 The econometric approach to measuring the pass-through of the costs of holding incremental capital

In this section we provide an econometric estimate of the cost pass-through using the theoretical foundations discussed above. We provide a relationship between regulatory capital requirements and the cost of credit in the UK economy with parameters estimated from historical observations.[9] Our estimate is based on regressing aggregate bank lending margins (the 'lending wedge') on the capital/liquidity ratio and other factors that may account for the variation in the lending wedge, such as asset risk. We also use an error-correction structure in the equation, which allows us to examine different short- and long-term responses. An advantage of this approach is that it uses historical data about levels of disintermediation and variations in the return on equity to reflect changes in bank risk. Hence, it can be seen as an ex-post measure of the cost of capital that takes into account market feedback.

First, we consider the long-term impact. Our estimate of the long-term cost pass-through relationship is shown in Table 4.1. We regressed the average lending wedge for all bank loans on the average bank capital ratio and other relevant economic factors (including economic activity, loan arrears and corporate insolvencies) and find that 1% increase in leverage ratio leads to a 9.4 basis points long-term increase in the average lending wedge. Annex 2 presents alternative measures of the cost pass-through based on accounting methods. The estimate in Table 4.1 is well within the range of the estimates calculated using the accounting approach.

Table 4.1: Average long-term cost pass-through equation

	Long run regression		Integration tests MacKinnon approximate p-value[1]	
	Coefficient	t-statistic	Level	Difference
Dependent variable: Lending wedge			0.761	0.000
Capital ratio	0.094	2.99	0.127	0.000
Insolvencies	0.495	5.02	0.876	0.003
Arrears	0.295	4.87	0.773	0.001
GDP gap	3.185	3.37	0.972	0.000
Net personal wealth to income ratio	0.036	1.94	0.700	0.000
Cointegration test of entire equation			0.0045[2]	
F-statistic (5, 69)	121.39			
Adjusted R-squared	0.8905			
Period	1992Q2-2010Q3			

Note(s): equation estimate over the period Q2 1992 to Q3 2010

[1] The MacKinnon approximate p-values provide a test of cointegration. The Level statistic shows the probability that the variable is integrated of degree 1, i.e. I(1). The Difference statistic shows the probability that the variable is integrated of a higher order, I(>1)

[2] The MacKinnon Level statistic for the order of integration for the entire equation.

We also take into account the difference in banks' short-term responses to changes in their costs. As discussed in Section 4.1, banks find it difficult to raise equity in the short term, reducing instead the amount of more risky

[9] This approach is based on a modified version of the model described in OP38.

lending to adjust to new capital ratios. We estimated short-term lending wedge equations for both the corporate and household sectors, which showed that banks increase the lending wedge for the corporate sector to a greater extent than for the household sector over the short term. This result should not be surprising, as corporate lending on average attracts a much higher regulatory risk weight than lending to households (which is dominated by mortgages). We also expect that demand elasticities for loans will be higher for the corporate than for the household sector, meaning that increases in the corporate lending wedge are more helpful to banks wanting to reduce the size of risk-weighted assets on their balance sheets. The lending wedge equations estimated in OP38 incorporated these effects, showing that banks increase the lending wedge for the corporate sector to a greater extent than for the household sector as capital ratios rise.

We continue to use the relationships estimated in OP38 in our simulations over the period in which banks are adjusting to the Basel III requirements. Once banks have fully adjusted to Basel III, we assume that they rebalance their portfolios such that increases in the cost of funding are applied evenly across both the corporate and household sectors. The model uses a short-term cost pass-through, ceteris paribus, of 6.7 basis points for the household sector, and 19 basis points for the corporate sector for each 1 percentage point increase the aggregate capital ratio. The long-run pass through of 9.4 basis points for both the corporate and household sectors is then applied. Intuitively this makes sense as all of a bank's lending activities face the same average funding costs once adjustment to new capital levels has been achieved (in the long run). A limitation of this approach is that we do not have integrated short- and long-run equations for the corporate and household lending wedges. We highlight linking the short and long run relationships together, possibly within a VEC framework[10], as a key area for development going forward.

4.2.1 Some caveats to our approach

The estimate of the long-term pass-through of costs shown in Table 4.1 takes into account the interaction of the supply and demand for credit in different markets within the UK economy, and is within the range of estimates derived from the accounting approach (see Annex 2). However, there are a number of alternative hypotheses that could account for an observed positive relationship between capital ratios and the margins charged by banks.

One such hypothesis is that higher margins are associated with higher asset risk (Valverde and Fernandez (2007)), and that higher asset risk causes banks to hold higher capital ratios to offset their higher default risk (OP36; Jokipii and Milne (2008)). Another hypothesis is that margins increase with market power and banks hold higher capital to protect the 'charter value' thus created (Marcus (1984); Keeley (1990); Acharya (1996)).[11] Hence, studies

[10] The relationship could be modeled in the vector error correction framework with a single long-run cointegrating equation in the average lending wedge and short-term dynamic effects in both the corporate and household sector lending wedges.

[11] A further complexity here is that regulatory capital requirements are a barrier to entry, meaning that banks' market power may increase when regulatory capital requirements increase. If this led to higher spreads, it may be worth considering whether banks would then

which include controls for these factors could find a smaller impact of exogenous changes in bank capital ratios on margins, and this is indeed the case.

While several studies based on cross-country panel data find a positive relationship between capital ratios and margin (Demirgüç-Kunt and Huizinga (2000); Saunders and Schumacher (2000); Valverde and Fernandez (2007)), in the short-run, the relationship may be negative. For example, a number of studies have found evidence for a 'weak bank effect', since banks with low capital may increase their lending rates to rebuild their capital base (Santos and Winton (2008)). It may in practice be difficult to isolate this negative short-run relationship from a related, positive long-run relationship.

The general drawbacks of observational approaches also need to be kept in mind. These have been summarised by Chater, Huck and Inderst (2010) as follows:

- any statistical model built on observational data will be correlational in character. Causal direction cannot be tested using purely observational data;
- a statistical model of observed data is likely to be sensitive to particular parametric or structural assumptions;
- any model based on observational data will be unreliable as a guide to what would happen in situations that have not yet been observed;
- relationships of interest in the data may sometimes be swamped by large-scale variation in socio-economic or financial conditions across the sample.

In assessing the impact of prudential policy, we make the important assumption that the structural parameters of the economy that we have estimated from historical data do not alter following introduction of the relevant policies. In particular, Basel III will introduce sweeping changes in banks' capital requirements and this might not be reflected in the historical data used for estimation of smaller supervisory capital changes. We also assume that our macroeconomic model as a whole remains valid for estimating impacts into the future. As a result, we are indirectly assuming that competition between banks and other intermediaries remains unchanged as a result of policy changes. In an economy where the banking sector is heavily concentrated and tends to dominate intermediation services (such as in the UK), this seems a reasonable supposition but we cannot say with any certainty that changes to the competitive landscape will not change the behaviour of banks from what we specify in our macroeconomic model. The Independent Commission on Banking recommendation (ICB (2011)) to ring-fence banks' deposit activities may also alter competition in unpredictable ways going forward.

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choose to hold still more capital, to protect the charter value created. This would have implications for expectations about banks' voluntary buffers.

4.3 Differentiating types of capital

It was necessary to develop our framework to take into account the fact that different regulatory reform proposals apply to different tiers of capital. For example, the proposals separate capital that is loss-absorbing (tier 1) from capital that is not loss-absorbing (tier 2), and also differentiate between 'core' and 'non-core' capital within the tier 1 definition (Basel 2009b). We address this by calculating a 'quality-weighted' total capital ratio which includes changes in the required quality and quantity of capital. This quality-weighted capital ratio is used in NiGEM to model the effects of proposals affecting different tiers of capital.

The capital regime that operated in the UK prior to the events of 2007 tended to focus on total capital. For example, supervisors set individual bank- and time-specific capital requirements at a total capital level based on their assessments of banks' risk profiles (see OP36 for a more detailed description). Higher quality capital was, however, captured in the tier 1 capital definition and had to account for at least half of total capital. Hence, the banking sector module presented in OP38 is parameterised to total capital. However, since the crisis of 2007-2009, proposals for regulatory reform have focused on raising additional higher quality capital, due to a widespread view that lower quality tier 2 capital failed to perform the role of insulating less subordinated debt-holders from the costs of failure (e.g. FSA (2009a), Basel Committee (2009b)). Hence, it has been necessary to adapt the FSA/NIESR framework to model the effects of changes in prudential requirements applied at different levels of capital.

Our 'quality-weighted' total capital ratio contributes to this because it is equal to the total capital ratio adjusted by the change in the weighted cost of capital that follows from changes in the quality composition of capital. For example, if the total capital ratio increases by one percentage point from 10% to 11%, and the weighted average cost of capital increases, due to changes in the quality required, by 20%, then the change in the quality-weighted capital ratio would be $(11 \times 1.2) - 10 = 3.2$ percentage points. Using the historical costs of different tiers of capital, we estimate that tier 1 capital is around 20% more expensive than total capital, in terms of the return that investors require.

Our approach implicitly assumes that the costs and benefits of altering each tier of capital are proportional to its cost relative to the average cost of total capital. On the costs side, this approach is justified since the higher return that investors require on higher quality (more loss-absorbing) capital will be reflected in higher margins charged by banks. On the benefits side, the justification is that the required return reflects investors' expected losses on their investments and hence the degree to which capital is likely to be loss-absorbing when a bank is in difficulty. In principle, increased loss absorbency is associated with a reduction in the externalities associated with bank failure and therefore with a reduction in the incidence or severity of crises, which is one intended benefit of higher prudential standards.

4.4 Reviewing our calibration of the cost of liquidity regulation

The Basel III package introduces new requirements for banks to reduce liquidity risk. Making empirical estimates of the likely cost to banks of doing this is complicated because of the lack of similar policies in the past, which means that data on banks' reactions are not available, and because the liquidity requirements will vary with the extent of maturity transformation on banks' balance sheets.

Banks can comply with liquidity standards by acquiring additional liquid assets, extending the maturity of their funding profile to reduce their 'liquidity coverage requirement' or a mixture of both. Economic theory, of course, suggests that banks will choose a response which minimises the costs of meeting the new requirement. If a bank has greater flexibility in adjusting assets than liabilities, or if the relative costs of holding additional liquid assets – the foregone higher return on the higher-yielding assets that the bank would otherwise hold – are lower than the costs of reducing the maturity mismatch, banks will choose to hold more liquid assets to meet the requirements. We lack sufficiently granular data to measure these costs, however, and they are likely to vary substantially between banks depending on their business models.

The evidence presented in OP38 suggested that banks raise the proportion of liquid assets on their balance sheet by selling some higher yielding assets and buying (lower yielding) government debt at a cost of around 150 basis points for each 1 percentage point increase in the required ratio of their liquid assets to total assets. We have used this estimate in our modelling, although clearly the impact of the new liquidity standards is an area for further research, and a considerable source of uncertainty for our estimates.

5 Improvements in the modelling of the benefits of prudential standards

In this chapter, we examine a number of issues in calculating the benefits of prudential policy. We first look at the crisis model and examine a number of variables that better predict the probability that a financial crisis occurs. We also examine a number of alternative specifications for the model. We find that the probability of crisis is dependent on the calibration of capital and liquidity policy, as well as both domestic and external economic conditions.

A further issue addressed is the calculation of benefits. Our model of the banking system shows that banks respond to changes in prudential policy over time. As our crisis model only calculates the probability that a crisis occurs within a given year, we need to consider a Bernoulli process to calculate the reduction in the probability of crisis (and hence the benefits) over a comparable period to that used to calculate the costs. Finally, we look at the losses to the economy when a financial crisis occurs, which may have either permanent or transient impacts on the economy. Financial crises that have a permanent effect on economic output impose much greater losses on the economy. If crises with permanent effects become less frequent in future as a result of tighter prudential policy, the losses avoided (and hence the measured benefits) will also be higher.

As noted in Section 2.1, our approach to the benefits of prudential standards is based on OP38, which models the probability of a banking crisis (the crisis model). The early warning literature underpins modelling of the probability of a banking crisis in OP38 and the authors discuss in detail the literature on macroeconomic early warning systems. We stress here that models derived from this literature allow us to estimate the probability of bank crises using factors likely to signal a crisis, but the models do not imply causal relationships. The chosen specification in OP38 is derived by using model selection techniques on a large set of regressors in a logit specification of a zero-one indicator of crisis occurrence. The data are for all banking crises (whether or not these crises had broader, permanent economic consequences or not) and cover a panel of OECD countries between 1980 and 2008. The banking crisis variable is consistent with the definitions set out in OP38 and Barrell et al. (2010a).[12] The model includes the capital ratio in the banking sector (LEV), the broad liquidity ratio in the banking sector (LIQ) and the lagged increase in real house prices ($RHPG$). The econometrically estimated crisis model for the probability of a crisis (p_t) is expressed as the logarithm of the odds ratio at time t[13]:

[12] The crisis variable takes the value of 1 in a year when any of the following conditions occur: the proportion of non-performing loans to total banking system assets exceeded 10%; the public bailout cost exceeded 2% of GDP; systemic crisis caused large scale bank nationalisation; extensive bank runs were visible and if not, emergency government intervention was visible.

[13] t-stat significance level in brackets.

$$\log\left(\frac{p_t}{1-p_t}\right) = \underset{(-2.58)}{-0.333} \cdot LEV_{t-1} \underset{(-3.55)}{-0.118} \cdot LIQ_{t-1} \underset{(2.80)}{+0.113} \cdot RHPG_{t-3} \qquad 5.1$$

The results above reflect the scale of importance of each included variable (for developed banking systems).

Variables such as credit growth, inflation and terms of trade are often reported to be significant in studies that include data from less-developed countries. Many studies include these data, due to the relative scarcity of banking crises in developed economies. Thus the samples used reflect highly dissimilar economies. In OP38, these variables dropped out in the model selection process, probably because they use only data from a sample of OECD countries with developed banking systems.

OP38 finds that capital adequacy and liquidity ratios are the main factors explaining banking crisis. A probable explanation is that developed economy banking systems are more likely to be regulated in terms of these variables, and financial regulators will have a mandate to monitor these ratios and implement some corrective action when these indices deteriorate. The OP38 model also includes real house price growth as a significant factor, which is in line with research that links asset price bubbles to banking crises in OECD countries (most notably Reinhart and Rogoff (2008) and (2009)).

5.1 Crisis model improvements

To estimate the benefits of increased prudential standards, the crisis prediction model described above was updated by changing the definition of the liquid asset ratio and ensuring data consistency across the estimation sample[14], and adding a current account variable. We also introduced updated estimates of the long-term costs of a crisis.[15] We discuss each of these changes below.

5.1.1 Using narrow liquidity

OP38 estimated the impact of liquidity standards on the probability of crisis from data on broad liquid assets (defined as cash and balances with central banks and securities other than shares) for all OECD countries other than the UK, for which comparable data were not available. For the UK, a measure of ‘narrow liquidity’, which comprises cash, gold and government securities, was used. This divergence in definitions across countries results in an average liquidity ratio for the UK of 5% compared with a range between 15% for France to 24% for the US.

To address this inconsistency, Barrell et al. (2010a) used an alterative data set. This data is based on a consistent, narrow definition of liquidity (*NLIQ*) for all countries in the sample. In these data, the UK’s average liquidity ratio of 5% is closer to other OECD countries’ ratios, which for example are 11% in the Netherlands and the US. Focusing on narrow liquidity is also more

[14] This work was undertaken by NIESR and described in Barrell et al (2010a)
[15] The long term economic cost of a crisis is deviation of output from its trend.

appropriate for assessing benefits, as it is more closely aligned with the definition of liquidity used in regulatory standards.

5.1.2 Including the current account

The crisis model from OP38 was also updated to reflect NIESR research (Barrell et al (2010a)) showing that the ratio of the current account balance to GDP (CBR) plays a significant role in determining the probability of crisis. Their findings show that as the current account balance improves, the likelihood of crisis decreases. One explanation for this relationship is that inflows of external capital allow banks to engage in excessive lending. This situation, in turn, creates greater risk of the economy overheating, asset price bubbles and a reduction in lending standards, all of which increase banks' vulnerability to shocks. To capture this effect, the new crisis prediction model includes a second lag of the UK current account balance. Expressed as the logarithm of the odds ratio, the modified crisis model can now be written as[16]:

$$\log\left(\frac{p_t}{1-p_t}\right) = -\underset{(-4.10)}{0.342}\, LEV_{t-1} - \underset{(-3.30)}{0.113}\, NLIQ_{t-1} + \underset{(2.40)}{0.079}\, RHPG_{t-3} - \underset{(2.80)}{0.236}\, CBR_{t-2} \qquad 5.2$$

As can be seen from the new specification, a higher current account surplus or reduced current account deficit is estimated to reduce the probability of a crisis. Table 5.1 below demonstrates that adding the current account variable results in a significant improvement in model performance relative to the original OP38 model specification.

Table 5.1: Comparison of in-sample performance

	Current crisis model	OP38 crisis model
Failure to call a real crisis (Type I error)	25%	35%
False call rate if no crisis (Type II error)	28%	33%

Source: Barrell et al. (2010a)

The improved crisis model causes our simulations of the benefits of prudential standards in NiGEM to capture some second-order effects of capital and liquidity ratios on the probability of a crisis. As banks' costs from higher prudential standards translate into an increase in margins, internal (UK) demand is reduced, which lowers the current account deficit and results in an additional reduction in the estimated probability of future crises.

5.2 Bayesian probability calculation

As discussed above, our calculation of benefits is based on estimates of the reduction in the probability that a crisis occurs, and the subsequent loss of economic output once a crisis occurs. However, this is not a straightforward calculation between two static economic outcomes. Rather, in a dynamic economic environment, some consideration needs to be given to the impact that the evolution of economic activity has on the likelihood that a crisis

[16] t-statistic significance level are shown in parentheses.

occurs. We therefore estimate a dynamic path for both the probability of crisis and the loss of output that accompanies a crisis event. Our estimate is expressed in present value terms.

5.2.1 Calculating the probability of crisis

Two significant issues need to be addressed when analysing the impact of changes in prudential policy on the probability of a crisis. First, the probability of crisis in each period changes over the course of the economic cycle. We therefore need to calculate how prudential policy changes the probability of crisis through time. Second, the crisis model estimates the probability of one crisis occurring in a given year but we need to calculate the probability of any number of crises over the economic cycle. We discuss how we approach these issues in turn below.

On the first issue, the crisis model of Section 5.1 estimates the change in crisis probability given the economic and policy environment at a point in time. In particular, the crisis probability will vary over the economic cycle due to changes in real house price growth and the current account balance, even if prudential policy is constant over the cycle. Changes to prudential policy directly affect the crisis probability in a given period but also affect the economy over time, with the full effects not felt until some years after implementation. This generates a profile of the change in probability for each period of time.

For the second issue, we need to calculate the profile of the change in probability given that one or more crises occurs. For each year of the simulation period, the profile calculated from the crisis model provides a binary outcome, i.e. a crisis begins in that year, or it does not. The probability that a crisis occurs over a given period therefore follows a Bernoulli process, in which an exponentially increasing number of events can occur. For example, over a two year period, there are four states of the world to consider: (i) a crisis occurs in the first year, not in the second; (ii) a crisis occurs in the second year, not in the first; (iii) no crisis occurs at all; or (iv) a crisis occurs in both years. Longer time periods require much larger calculations. For example, there are 1,024 potential states of the world over a 10-year period and 32,768 potential states of the world over a 15-year period.

5.2.2 Calculating the benefits of higher prudential standards

While the number of permutations generated by the Bernoulli process is increasingly large as we lengthen the period over which we wish to calculate benefits, the number of calculations needed to make a reasonable estimate of the overall benefits can be reduced substantially. This is because the probability of more than one crisis occurring within any given period is increasingly small as the number of crises rises. We can demonstrate this through a numerical example. If the probability that a crisis occurs in any particular year is reduced from 5% per annum to 4% per annum, we calculate that the reduction in the probability that a single crisis occurs within a 10-year period is 4 percentage points using the Bernoulli process[17]. For the event that up to two crises occur within a 10-year period, the reduction in the probability is only six percentage points. The corresponding probability reduction for the event that up to three crises occur over a 10-year period is 6½ percentage points. This shows we can calculate a reasonably accurate measure of the change in the probability using a relatively small number of permutations.

Ideally, we would analyse the cost to the economy of multiple banking crises events occurring in quick succession. However, multiple banking crises within a single country have generally not been experienced, so we have no firm estimates of the permanent loss to the economy of such events. For example, Reinhart and Rogoff (2009) look at various types of economic crises (including banking crises) for over two centuries. The evidence they derive suggests that bank crises, although potentially exacerbating crises generated by other means, do not occur in quick succession. This may be because the onset of a banking crisis engenders a response from government that avoids the possibility of another crisis in quick succession.

We have restricted the calculation of benefits to include only the outcomes in which one crisis occurs each year within the period for which we make our calculations. As the probability of having more than one crisis diminishes rapidly and the additional costs to the economy of multiple crises occurring are small, we believe reducing the calculation to include only outcomes with one crisis will capture the great majority of the benefits of any prudential policy package.

5.2.3 Banking crises with permanent and non-permanent costs

As noted above, the crisis model developed in Barrell et al. (2010a) estimates the probability of a banking crisis, regardless of whether this crisis has consequences for the broader economy. If a crisis does not have consequences for the broader economy, or has 'non-permanent' costs, then the cost of such crises will be very small, or indeed zero, in terms of the loss to GDP. Only crises that impose permanent costs on the economy will therefore be pertinent for calculating the benefits of higher prudential standards. We therefore need to incorporate in the benefits calculation both an estimate of the GDP losses that are likely to occur from a banking crisis with permanent effects, and an estimate of how frequently such crisis are vis-à-vis crises with non-permanent costs.

An estimate of the loss to GDP of crises with permanent effects is based on a detailed literature survey on the depth and length of historical crises, combined with original research carried out by NIESR (Barrell et al (2010c)). Specifically, we calculate the costs of a banking crisis as the cumulative loss in GDP derived from comparing the path of GDP in the absence of a crisis

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[17] Using a Bernoulli process, the probability that a crisis occurs x times over a period of n years is given by the following formula:

$$\Pr(X = x) = \binom{n}{x} p^x (1-p)^{n-x},$$

where p is the probability that a crisis occurs and

$\binom{n}{x} = \frac{n!}{x!(n-x)!}$ is the number of combinations of x outcomes from n draws.

with a GDP path that includes post-crisis recession, subsequent recovery but a permanently lower level of GDP due to a reduction in trend productivity – the so-called 'scarring effect of a crisis' (Barrell and Kirby (2009) and Barrell (2009)). Over the long-term, our estimate shows a permanent reduction in the level of GDP of around 3 per cent compared to a scenario in which a crisis does not occur.

The LEI report (BCBS (2010a)) includes a literature review of the long-term impact of financial crises. According to this analysis, for those crises that have only temporary effects, the improvement in GDP as the economy recovers from the crisis is enough to undo most, if not all, of the losses that occur during the crisis period. Only crises that have permanent effects generate significant, cumulative losses in GDP. Because of this possible pattern of recovery in GDP, many studies find negligible or no cumulative losses. Barrell (2009) found that permanent losses are statistically significant in only one in four crises in developed countries through the period 1980 to 1995.

It seems likely that in future a greater proportion banking crises will be systemic crises, given the increased interconnectedness of the global banking system and capital mobility[18]. For our calculation of the benefits we adjust the ratio from Barrell (2009) so that one in three banking crises leads to a permanent fall in GDP. We discuss in section 7 the impact that different assumptions for this ratio have on our measure of the benefits.

5.3 Alternative formulations of the crisis model

In addition to the changes to the crisis model discussed above, we considered further changes that theoretical, empirical or practical considerations suggested might be important. However, they have not been incorporated in the final version of the model because empirical assessment using the database of 14 OECD countries over the period between 1980 and 2008 showed the effects to be statistically insignificant. Below we describe the further changes considered. Table 5.2 shows the degree to which each of these changes explained the sample data.

5.3.1 Wholesale funding intensity

The ratio of customer deposits to loans ($CDLR$) is a proxy for funding liquidity risk as a ratio below one implies each unit of loans is not fully covered by customer deposits, which are considered to be 'sticky' in most circumstances. So a higher ratio implies that banks are less likely to run out of funding for their lending, whereas a lower ratio suggests a greater reliance on short term wholesale funding, which is considered to be volatile and prone to sudden withdrawal[19]. In the run up to a crisis, rapidly expanding loan books may push banks to a higher than normal reliance on wholesale funding. The first

[18] Reinhart and Rogoff (2009) note that there is a correlation between periods of high international capital mobility and banking crises, and argue that financial innovation is a variant of the (capital) liberalisation process. There has been a sharp increase in international capital mobility in recent years, and consequently the proportion of countries involved in banking crises.

[19] There are some exceptions to this. For more details see Barrell et al (2010d).

difference in the ratio of customer deposits to loans is a variable that might reasonably be used to test this hypothesis.

Table 5.2 below shows the results of adding wholesale funding intensity to the original crisis model, through the lagged value of the yearly change in the ratio of customer deposits to loans ($\Delta CDLR$). This variable has a strong association with crisis prediction and it was a successful addition to the model, also improving its data fit over the estimation period.

We also found, however, that the association between $\Delta CDLR$ and the probability of a crisis disappears when the current account balance is included in the crisis model. This suggests that the role of $\Delta CDLR$ in signalling a fall in lending standards and increased banks' vulnerability in the run up to a crisis is better captured by the current account balance. Finally, the proxy status of $\Delta CDLR$ as a measure of short-term wholesale funding intensity led us to abandon this specification in favour of a model that includes the current account balance.

Alternative data specifications for wholesale funding intensity, such as the lagged level of $CDLR$, the first lag of interbank liabilities to the total deposit ratio and the first lag of net interbank position to assets ratio, were tried but all of them were insignificant[20]. As summarised in Table 5.2, these variables do not improve the model or show any significant association with crisis prediction.

5.3.2 International contagion

Barrell et al. (2010e) discuss the theoretical and empirical basis for banking crisis contagion. The sources of contagion stem from three possible sources: the first is contagion caused by direct inter-bank exposures. The second arises when investors recognise problems with one asset type or solvency issues with a bank in a specific country and this leads them to reduce exposures to assets or banks in other countries that are seen as having similar characteristics. The third emerges from economic fundamentals that are common to all countries in crisis.

Many early warning studies have incorporated cross border impacts of crisis through specific terms of trade variables or exchange rates. Barrell et al. develop a broader contagion measure, the weighted incidence of ongoing crisis elsewhere, using GDP as weights. Table 5.2 shows the result of adding this variable to the model. The variable is significant although it does not improve crisis prediction in all dimensions. It was therefore not included in the final version of the model.

5.3.3 Off balance sheet exposures

Barrell et al. (2010b) evaluate the role of off-balance sheet exposures in the banking system. The rationale behind this is identifying the impact of banks' exposure to off balance sheet risks, given the challenge of regulating these activities and the rapid growth of these exposures that has occurred in recent years.

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[20] See Barrell et al (2010e) for more details

Due to data availability problems the authors use non-interest income as a proxy for the return on off balance sheet assets. This approach is a rough estimate and assumes that all non-interest income is generated by securitizations and similar forms of assets that are stored off balance sheet. (We know that in reality some significant fee income is generated from on balance sheet loans.) It is further assumed that the returns on assets on and off balance sheet are equal[21]. Given the size of non-interest income, these assumptions result in an estimate that off balance sheet assets are typically around 80% of on balance sheet assets.

The authors then recalculate the leverage and liquidity ratios to capture the total of on and off balance sheet assets. In addition, they incorporate the change over time in the ratio of off balance sheet to on balance sheet assets[22]. The results shown in Table 5.2 are highly tentative, due to the problem of data, but they are supportive of further investigation in this area.

5.3.4 House prices and house affordability

According to the original specification of the crisis model house prices bubbles are an important determinant of financial crises. This has policy implications, including the importance of monitoring rapid property price growth and taking steps to curb such bubbles to mitigate future crises in OECD countries[23].

The interpretation of real house price growth in the original model is through its association with asset price bubbles. Here we consider a different aspect: the impact that high house price growth has on household budgets makes mortgage payments less affordable, increasing the risks associated with mortgage portfolios. To capture this effect, a number of alternative specifications were attempted, including various lag lengths and definitions.

We generated a proxy for the affordability effect by creating the ratio of nominal house price growth to consumer wage inflation and the ratio of nominal house price growth to per household nominal income. Given that this proxy is a possible alternative for real house price growth, we benchmarked these models against one that includes the current account balance and real house price growth. The results are displayed in Table 5.2, showing that the two proxies used have a weak association with crises. In both cases the strongest association is using three lags of the variable. However, the z-value for both indices ranks below 2. Both models have a lower data fit score than our preferred model, when fit is measured as the percentage of success at correctly predicting crisis and non-crisis periods over the sample. In addition, the models are deemed inferior to our preferred specification as each of them results in a lower overall Akaike information criteria (AIC) index. These results suggest that house affordability is not a significant factor in predicting financial crises.

[21] For more details and discussion see Barrell et al (2010b).

[22] Due to data problems the data use is highly smoothed; for details see Barrell et al (2010b).

[23] We believe that the NIESR real house price index is a valuable measure of asset price volatility. Its definition uses nominal house price data (averaged from quarterly data) from ECB, UK, US and other local sources. Nominal house prices are deflated by the average consumer expenditure deflator taken from the national accounts, making the real house price series comparable across countries. In contrast, other deflators like consumer price indices are not comparable across countries and make them unsuitable for this analysis.

5.3.5 Interaction between capital and liquidity

A linear specification of the crisis model (see equation 5.2 above) implies that capital and liquidity are perfect substitutes in preventing financial crises. The probability that a crisis occurs is left unchanged if banks raise their capital ratios and lower their liquidity ratios by fixed amounts, regardless of the starting levels of these ratios. The rationale behind including interactions of capital and liquidity ratios in the crisis model is that these policies in fact address different prudential risks and that they are, therefore, not substitutes for each other in the way that a linear specification implies.

For example, when either the capital ratio or the liquidity ratio is very low, the relationship between these two policy levers may be better thought of as that of imperfect complements. This is because at low levels of capital there is a high likelihood of crisis which may not be successfully mitigated by any level of liquidity. Likewise, a highly illiquid banking system may be very vulnerable regardless of its level of capitalisation. This complementarity would be captured by a significant negative coefficient on the interaction between capital and liquidity ratios in the crisis model. However, a negative interaction term would also imply an increasing incremental impact of capital on the probability of crisis as liquidity increases, and vice-versa. For example, increasing the capital ratio by one percentage point is more effective in reducing the probability of crisis when liquidity is high than when liquidity is at average levels.

We tried to capture this effect in our model by using three different specifications. First, we modelled the interaction by including an interaction term ($NLIQ \times LEV$) but excluding any other effects of capital or liquidity. The results from Table 5.2 show that the interaction term has a strong effect but significantly reduces (or removes) the influence of other variables in the model, which *a priori* we would expect to have an impact. The predictive power of the model overall is also substantially reduced, with this model predicting a large number of 'false positives'.

We then estimated an unrestricted model which included both capital and liquidity ratios directly as well as the interaction. From this specification, we found that capital and liquidity ratios could not be excluded from the model, suggesting that a model that includes only the interaction term may be mis-specified.[24] For the unrestricted model, we also found a positive coefficient on the interaction term, suggesting that liquidity has a lower impact in reducing the probability of a crisis as the proportion of capital on banks' balance sheets rises relative to liquid assets (and vice versa). This relationship may be explained if, for example, high levels of capital have a positive effect on market confidence, decreasing the probability of fire sales and other market panics that could render a bank insolvent and thereby reducing the influence of liquidity on reducing the probability of financial crises. However, it seems difficult to justify such an effect at low levels of capital (or liquidity) and we have excluded it from our model.

[24] As we estimate the crisis model using the logit model, standard test statistics do not generally apply. We used both the likelihood ratio and Wald statistics to test the hypothesis that the coefficients on the capital and liquidity ratio terms were zero. The tests strongly rejected excluding the linear terms.

Table 5.2: Crisis model estimation summary results

Model name	Variable added		Data Fit	
	Description	Statistical significance (z-value)	% of non-crises called correctly	% of crises called correctly
Original model (OP38)	–	–	66.6	65.0
New model	Current account balance[1]	-2.8	71.8	75.0
Wholesale funding intensity	Yearly change in customer deposits to loans ratio[1]	-3.5	71.3	75.0
	Customer deposits to loans ratio[1]	-0.6	63.3	66.7
	Interbank liabilities to total deposits ratio[1]	-1.2	66.7	66.7
	Net interbank position of the banking sector[1]	-0.7	68.2	66.7
International contagion[3]	Weighted incidence of ongoing crises elsewhere[1]	2.1	59.3	71.4
Off balance sheet[4]	On to off balance sheet asset ratio[1]	2.4	70.7	66.7
House prices and house affordability[5]	Wage deflated house price[2]	1.0	71.0	66.7
	Nominal income deflated house price[2]	1.5	67.9	58.3
Interaction capital-liquidity	Lagged leverage ratio times liquid assets[2]	1.8	73.6	75.0
	Interaction without linear terms[2]	-6.3	57.4	75.0

[1] Barrell et al. (2010b, 2010d, 2010e)
[2] Authors' own calculations
[3] Real house price growth is not significant in this model and so is excluded
[4] This model uses modified liquidity and leverage ratios
[5] These models replace real house price growth with house price affordability (a proxy for real house price growth)
Source: Own calculations

6 Measuring the impact of capital and liquidity standards

We now turn to the practical issue of estimating the costs and benefits of the Basel III policy package[25]. The form of the new capital and liquidity standards in the Basel III package introduces a number of additional modelling challenges which are discussed in the first section of this chapter. In the second section we set out our point estimates. We first use the banking system model approach outlined in Chapter 3 to calculate a system-wide behavioural response. We then use the NiGEM model to calculate the macroeconomic costs and benefits of the policies. NiGEM is a large scale, global structural model drawing on theoretical foundations and data estimated long-run relationships to model the likely path of key macroeconomic variables. The supply side in the model is affected by the user cost of capital, and investment decisions follow from the production function and the cost of capital. Demand is also driven by consumption, trade and government behaviour. Financial markets are forward looking and are affected by financial regulation. OP38 includes a full description of the model. The NiGEM model is used by both the corporate sector and policy-making communities.

6.1 Using our framework in practical policy analysis

In this section, we discuss a number of practical issues that arise from using our approach in a real policy context, including construction of the baseline, multilateral implementation of Basel III requirements, how the order in which policies are introduced in NiGEM can impact the measure of cost and benefits, what buffers firms will choose to hold over new capital requirements and the possible welfare implications of prudential policy.

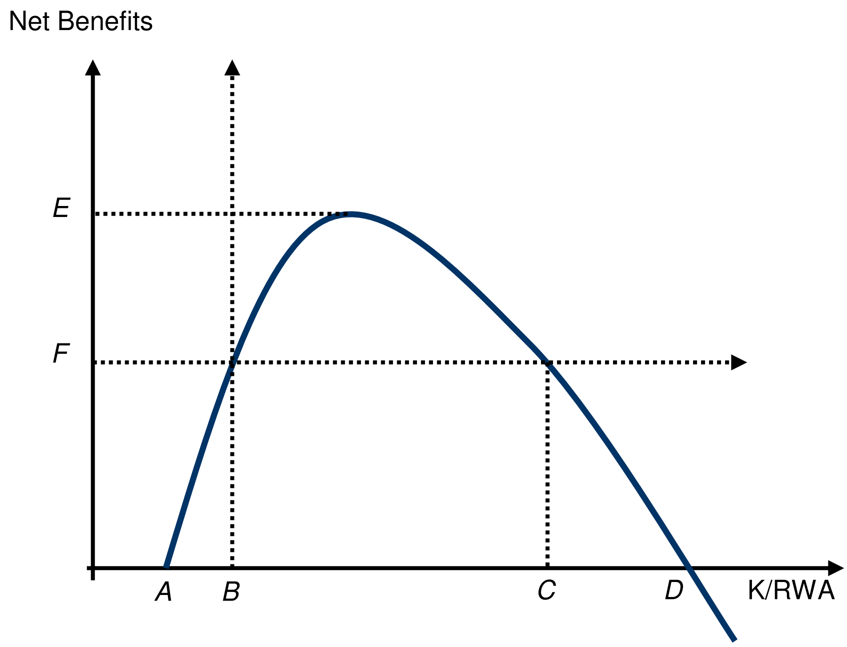
6.1.1 Identifying the baseline

To understand the impact of any policy initiative, we need to compare it with a state of the world in which the policy is not introduced. This is to ensure that the full costs and benefits of the regulations are captured. For the Basel III package of measures, calculating this hypothetical state of the world is complicated by a number of factors. First, since the onset of the financial crisis, banks have been subject to a number of regulatory actions introduced in the immediate aftermath of the crisis in anticipation of higher capital requirements to be introduced with the Basel III measures. Given that these actions have already moved banks some way towards the new standards, ignoring their impact by, say, measuring the likely increase in capital required from the latest data would likely underestimate the impact of Basel III. Second, the poorer economic conditions brought about by the financial crisis are not typical of the environment that banks face over the economic cycle, so any estimates that start from the most recent data are likely to distort any measure of the impact of Basel III. Finally, given the prolonged negotiation period for Basel III, the scale of the changes to capital ratios involved and market pressure to ensure early compliance with Basel III, banks are likely to have anticipated, to some degree, the agreed higher prudential standards.

[25] As specified in BCBS (2010d) and BCBS (2010e). The implementation of the Basel III package by the European Commission (the Capital Requirements Directive) may differ from the BCBS recommendation, which will clearly change any estimates of the impact.

The potential under-estimation of net benefits that may arise from identifying the wrong baseline is demonstrated mechanically in Figure 6.1 below, which illustrates a stylised path for net benefits as the risk-weighted capital ratio of the banking system (K/RWA) rises, *ceteris paribus*. At point A, banks are not subject to any shocks and are not anticipating changes to the existing policy regime. Policy changes that raise the capital ratio incrementally by the distance *AD* will have positive net benefits, up to a maximum of the distance from the origin to point *E*. If, however, we were to measure net benefits from a later point, say point *B,* at which banks have already raised their capital ratios in response to a shock or in anticipation of new requirements, the calculated net benefits of a change in policy will only be positive for an incremental increase in the capital ratio of distance *BC* and a maximum of the distance *EF*.

Figure 6.1: Impact of the baseline on the calculation of net benefits



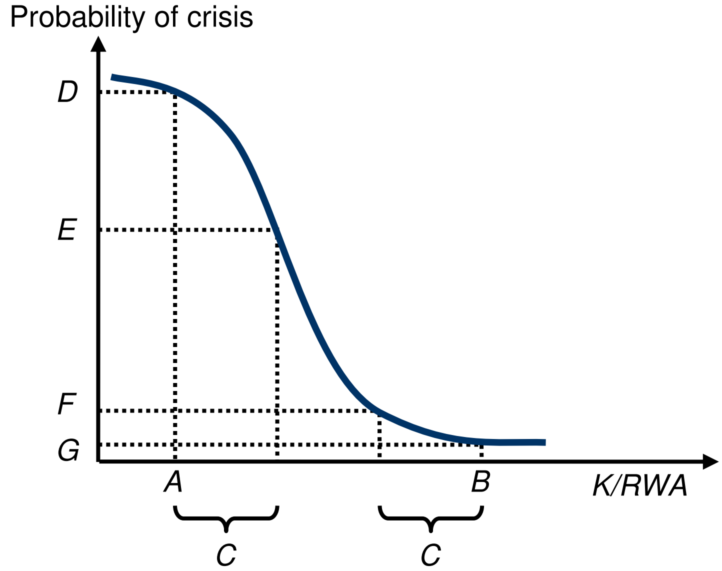
How should one interpret this chart? If banks raise their capital ratios in anticipation of new regulations, it is reasonable to attribute the associated benefits to the regulations. On the other hand, it might be argued that if banks raise their capital ratios only in response to a shock, then the benefits of their doing so should not be attributed to the subsequent regulations. We do not accept this argument since the benefits of prudential standards are estimated over the long term and banks will tend to relax their post-crisis holdings of capital as the economic cycle strengthens. For the estimates in this analysis, we therefore use a baseline that begins from the period immediately before the current financial crisis, when banks' decisions (and economic conditions) were not distorted by the immediate influence of the crisis or regulators' response to the crisis. We also point out that this analysis estimates the costs and benefits of the Basel III package, but does not attempt to estimate the optimal level for net benefits.

6.1.2 Impact of the order and timing of policies on benefits

The calculation of benefits in our approach has a number of limitations, particularly for the interpretation of the results. For example, although the order in which the elements of any prudential policy package are introduced does not affect the calculation of the *cumulative* benefits, the order will affect the size the benefits calculated for each policy element.

Figure 6.2 below demonstrates this. A policy package that increases banks' risk-weighted capital ratios from *A* to *B* will, *ceteris paribus*, reduce the probability that a financial crisis occurs from *D* to *G*. If one element of this overall package requires an increase in capital of size equal to *C*, the reduction in the probability of crisis that this element contributes will be different depending on the order in which we calculate the effect. Calculating this element first within the package will generate a reduction in probability from *D* to *E*. However, if we calculate this element last within the package, the reduction in probability is much smaller, from *F* to *G*.

Figure 6.2: The calculation of incremental and cumulative benefits



This means that we need to interpret with care the benefits we calculate using the crisis model. We cannot calculate the incremental benefits of each element of the Basel III package, only the cumulative benefits. If we calculated the incremental impact of each policy individually from our baseline, all policies considered would have net benefits and the sum of these net benefits would greatly overstate the net benefits of the package as a whole.

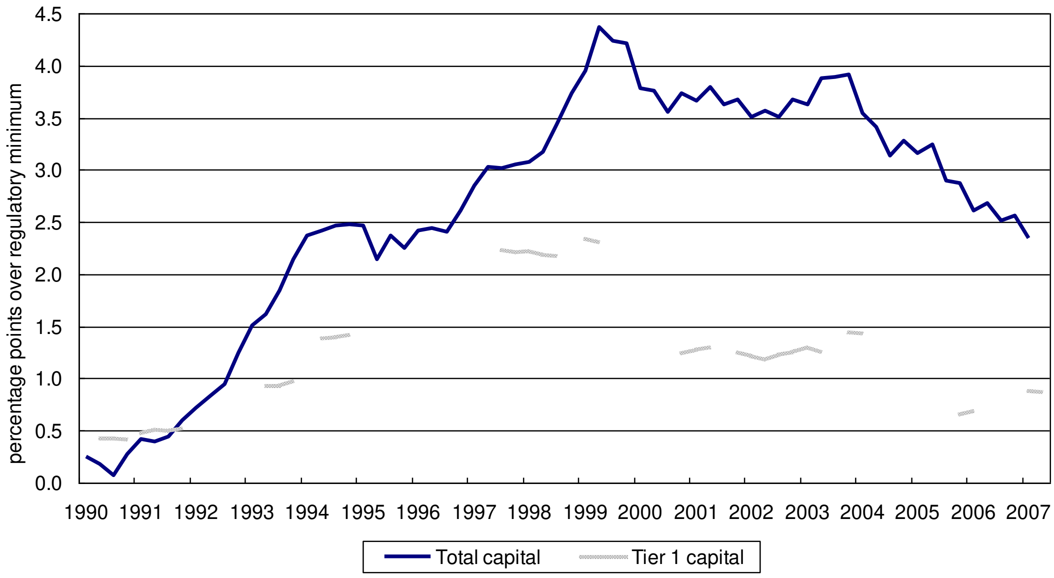
In addition, increases in prudential requirements will have a different impact on the probability of crisis depending on the initial crisis probability in the baseline. The lower the probability is, the lower are the benefits of higher prudential standards. For example, given a baseline crisis probability of 10%, the first 1% increase in capital ratio will decrease the probability by around 2.75% in our crisis model. However, since the probability of crisis is now just 7.25%, the second 1% increase in capital ratio will only cut the probability by just over 2%. This will push the crisis probability down to around 5.2% after the introduction of the two measures. Smaller values of the base probability will make this decreasing effect of individual policies more pronounced.[26]

6.1.3 Banks' buffers over regulatory minima

Banks have a number of reasons for holding voluntary buffers over regulatory minima. These reasons include the desire to avoid costly intervention stemming from a breach of regulatory requirements and the ability to weather economic downturns.[27] OP31 found that banks' voluntary buffer levels have varied substantially over time due to the risk appetite of the banks over the economic cycle. The findings also show that, holding all other factors constant, *large* UK banks maintain the size of the buffers they held over the existing minimum regulatory capital requirements when discretionary supervisory requirements change.[28] So banks' voluntary buffers will change as economic and regulatory conditions change.

Figure 6.3 below illustrates this point with data on the weighted average buffers held over the minimum required total and tier 1 capital ratios for the entire UK banking industry over the period 1990-2007. The buffer over total capital ranged from virtually zero when the first Basel Accord was introduced in the early 1990s, to 3-4 per cent of risk-weighted assets in the early 2000s, before falling rapidly to around 2½ per cent just prior to the crisis in 2007. The equivalent tier 1 figure, over which banks generally held a lower capital buffer, followed a similar path, reaching 2-2½ per cent in the early 2000s before falling back to around one per cent prior to the crisis.

Figure 6.3: Capital Ratios Buffers; All UK banks, 1990-2007



Source(s): FSA/Bank of England Banking Supervision Database

[26] Conversely, with a high base probability value (around 66%), the first few 1% increments in capital requirement would result in roughly equal reductions in the probability of a crisis.
[27] See OP31 for further discussion.
[28] The pass-through of discretionary supervisory changes in buffers for all banks (including a large number of small entities) was closer to 50%, which probably reflects the fact that large firms tend to operate with much smaller buffers over regulatory minima than do small firms. The higher rate of pass-through is more relevant to our analysis because of the concentrated nature of the UK banking sector.

Figure 6.3 suggests that we need to make an assumption about banks' voluntary buffers over regulatory minima and buffers going forward. We expect that the voluntary capital buffers banks hold over the higher requirements imposed by Basel III will be smaller than historical levels for the following reasons. The Basel III requirements are expected to reduce both the riskiness of the banking sector from the perspective of management and investors (higher capital ratios reduce the likelihood of individual bank failure as well as financial crisis) and economic volatility (lower bank risk reduces the likelihood of damaging asset bubbles). Consequently, we expect much higher regulatory minima will be accompanied by smaller voluntary capital buffers over time.

In addition, Basel III restricts payouts to shareholders and employees if banks breach the new capital conservation and countercyclical buffers. These regulatory buffers have a similar role to banks' own voluntary capital buffers and, as the penalties for breaching the regulatory buffers are less severe than those attached to a breach of the minimum capital requirement[29], we might expect that firms will hold a smaller voluntary buffer over the regulatory buffers.

A further complication is that banks have recently *increased* their voluntary buffers over current regulatory minima, most likely for reasons similar to those discussed in Section 6.1.1 (existing regulatory actions, poorer economic conditions, and anticipation of Basel III). However, as economic conditions improve and banks adjust fully to the Basel III requirements, we expect that banks will reduce their voluntary buffers over the longer term.

Unfortunately, we do not have empirical evidence of the extent to which banks may reduce their voluntary buffers over the longer term, particularly given the novelty and scope of the regulatory changes to be introduced by the Basel III programme. We have therefore made the assumption that banks will reduce the level of their buffers gradually, as they fully adjust to Basel III, from around 4 percentage points currently to around 2 percentage points[30] in terms of total capital. If we assumed that banks' current buffers, exaggerated by the pressures noted above, would be maintained into the future, we would overestimate the costs of the change in regulatory requirements.

6.1.4 Multilateral Implementation of Basel III

Calculating the impact of the Basel III proposals on the UK economy raises an additional challenge due to the international nature of the proposals. The Basel III proposals will have an impact on the economies of other countries similar to the impact on the UK. As international economic trends affect the economic outcomes of an open economy such as the UK, we need to take

[29] Under the Basel III proposals, when a bank's capital falls below the level of the capital conservation buffer, the bank will face increasing restrictions on their ability to distribute earnings to shareholders. In contrast, the penalties for breaching the regulatory minimum capital requirements can include restrictions on new business, suspension of permissions, and, ultimately, wind-down of the firm.

[30] The buffer for core capital is also around 2 percentage points while, as already mentioned, the buffer over tier 1 capital is smaller. See Figure 6.3.

account of the response of other countries to the Basel III package if we are to fully measure the impact on the UK economy of the prudential reforms.

NiGEM is a general equilibrium world economic model, which allows us to take account of the impact of the Basel III package on other countries and the subsequent feedback to the UK economy. However, we need to make a number of assumptions about how other countries will respond:

- We lack detailed information on the balance sheets of non-UK banks and assume that regulators in other countries will require similar increases in the capital ratios of banks operating in their respective economies.
- We assume that the aggregate increase in capital ratios affects other countries' banks net interest margins (lending wedges) in similar ways to the UK. This, in turn, increases the cost of physical investment and household liabilities for these countries. We need to impose this 'average-effect' assumption as we do not have country-specific banking models that can calculate differentiated effects for each economy. In reality, different economies will have different response levels to prudential policy and our approach is reliable to the extent that the average global bank cost pass-through is similar to that of the UK.
- We assume that increases in liquidity standards operate in other countries in a similar way as they do in the UK (as with capital standards).
- Finally, we assume that the timing of implementation of Basel III in these countries is the same as for the UK.

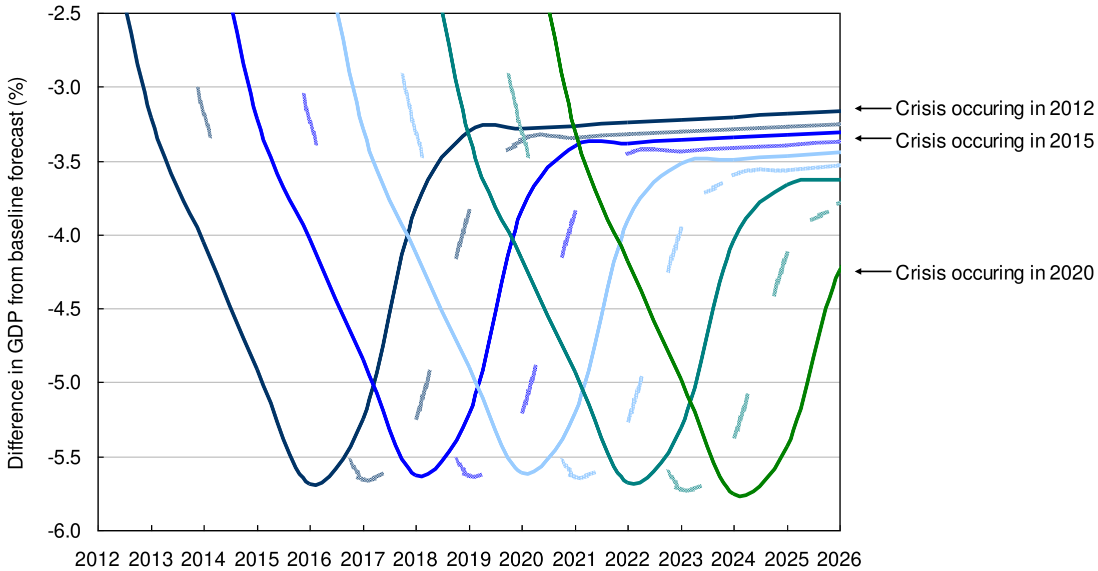
While we assume that the size of the impact on the banking sector and other key variables is similar to the UK, treating these changes as exogenous shocks to other countries' economies allows all other country-specific parameters in NiGEM to respond to the changes in demand implied by these changes in the international financial environment. Consequently, international trade and financial flows between the UK economy and other countries are determined endogenously to help us understand the likely impact of a multilateral implementation.

6.1.5 Calculating the cost of crises to the UK economy

As discussed in Section 5.2, some banking crises are expected to reduce permanently the level of GDP, while other crises have only a much smaller, temporary impact on the level of GDP. In Figure 6.4, we show the reduction in the level of GDP over time for a single hypothetical crisis with permanent effects occurring in each year over 2012 to 2020 compared with a baseline of a 'no crisis scenario'. Each profile shows the reduction in the level of GDP, illustrating the initial losses, subsequent recovery and permanent long-term GDP short-fall from the level of GDP that would have happened in the absence of a crisis with permanent effects. The profiles in Figure 6.4 represent our best measure today of all future losses in GDP resulting from a single permanent-effect crisis occurring in the year noted. The UK scarring effect has been estimated from historical data on economic crises and sets long-term UK GDP around 3% below the long-term growth projections made before the onset of the current financial crisis.

The scarring profile varies somewhat depending on the point of the cycle at which the financial crisis begins. For example, as the economy begins to recover from the trough of the recession following the current crisis, the long-term scarring (permanent effect) is less pronounced. This is because banks have already suffered losses which are not subsequently repeated, and the impact on the economy is consequently reduced. The expected net present value of the costs of higher prudential standards will also be lower when the time of implementation of a prudential initiative is close to the low point of the cycle.

Figure 6.4: Profile of GDP losses in each year (2012 to 2020)



Source(s): NIESR, authors' own calculations
Note(s): The curves show a stylised representation of the percentage difference in GDP from its baseline forecast today in the event of a banking crisis with a permanent impact arising in each of the years shown, under the assumption that there is not a further crisis in any of the other years shown.

6.2 Estimating the economy-wide response to policy changes

We now estimate the macroeconomic impact of the regulatory initiatives to strengthen capital and liquidity standards under Basel III, which are described in detail in Annex 3. We use NiGEM, including our changes to the credit markets discussed in Chapter 4, to allow for endogenous changes to monetary policy and multilateral implementation.

6.2.1 Macroeconomic costs and benefits of policy package

Table 6.1 below provides a summary of the costs and benefits of the total policy package described in Annex 3. **The entire package is expected to result in net *benefits* of £11.9bn per annum.**[31] This is the annualised, present value of all cumulative future changes to real GDP.[32] The present

[31] This measure of the net benefits should be considered in the context of overall GDP for the UK economy, which was around £1.3 trillion p.a. in chained volume terms for 2010.
[32] The chained volume measure of GDP as defined in the UK Economic Accounts published by the Office for National Statistics (ONS).

value is discounted using the methodology developed by HM Treasury for policy calculations.[33]

Table 6.1: Impact of all policy measures on UK GDP

	Impact on GDP £bn p.a.[1]	
	Incremental	*Total*
Total benefit of package[2]:		16.8
Incremental costs of package[3]		
Introduction of the 8-6-4 regime[4] and CRD III[5]	2.9	
Basel 3 Minimum Requirements[6]	0.6	
Capital conservation and countercyclical buffer	1.5	
Systemic surcharge	0.6	
Assumption: Banks' voluntary buffers shrink by 50%	-0.9	
Introduction of liquidity coverage ratio	0.2	
Total cost of package		4.9
Net benefit of package		11.9

Notes:

[1] The net present value of the change in the annual, chained volume measure of 2010 GDP (£bn) due to all policy measures included in the table.

[2] As discussed in Section 6.1.2, the benefits of individual are not meaningful as they are dependent on the order in which the policies are assessed.

[3] See Annex 3 for definitions.

[4] The financial crisis followed the collapse of Lehman Brothers in August 2008. The FSA's 8-6-4 regime was announced in Q4 2008 and implemented in 2009. The impact we have measured as the introduction of the 8-6-4 regime includes the impact of banks' own attempts to rebuild capital following losses and their anticipation of future regulatory change since, without new regulations, banks would be expected to reverse their voluntary actions as the economic cycle improves.

[5] The FSA's implementation of these policies is discussed in detail in FSA (2009c) and FSA (2011).

[6] The Basel 3 Minimum Requirements include the introduction of contingent or alternative capital instruments. The specific features of the new alternative tier 1 and tier 2 instruments have not yet been agreed, so there is uncertainty about their likely marketability and costs. In our analysis, the cost to banks of the new alternative tier 2 capital is assumed to be equal to the Basel 2 non-core tier 1 capital definition. The cost of new alternative tier 1 capital is assumed to be at the midpoint between the cost of equity and Basel 2 non-core tier 1 capital. The cost of the alternative capital instruments may be higher if markets perceive that these instruments are not significantly different from equity.

The calculations are derived from long-run simulations using version 1.11 of NiGEM. This includes UK national accounts data available to the December quarter, 2010. For those measures that were implemented prior to the December quarter, 2010 (and to take account of banks' actual responses to date), we construct a 'counterfactual' baseline using NiGEM to simulate the likely economic outcome for the period 2008 and 2010 in the absence of the FSA's policy interventions. The difference between the 'counterfactual' baseline and the actual outcomes in the economy is then used as the

[33] Discount rates vary between 3.5% in the short-run and 1% in the very long-run. See HM Treasury (2003)

measure of the policy impact from the onset of the financial crisis to the present time.

As discussed in section 6.1.2, the order in which policies are introduced into the analysis affects the size of their individual effects as well as the size of any sub-packages of measures but it does not affect the total cumulative estimates we have made. The costs of higher prudential standards, which arise from increases in the cost of borrowing, rise roughly linearly, whereas the benefits of higher prudential standards, which arise from reductions in the probability of crisis, increase at a declining rate[34].

From this relationship, we estimate that bank regulatory capital ratios can rise by a further 22 percentage points before total net benefits are exhausted and regulatory capital ratios have net economic costs. This estimate suggests that there is significant space for supervisory initiatives to supplement beneficially minimum Basel standards. In making this estimate, we assume that banks achieve the higher capital ratios by 2019, and do not move significantly in advance of the implementation timetable. In addition, we note that the costs of requiring higher capital ratios beyond the policy package described in Annex 3 rise faster than the benefits, even though the overall net benefits remain positive for the additional capital range. Our measures also consider only the expected change to UK national income, ignoring any other measurement considerations. We discuss some alternative measures that address consumer welfare and wellbeing in Section 6.2.3 below.

One important result observed in our estimates is that the adoption of Basel III in other jurisdictions reduces its overall cost to the UK economy relative to unilateral implementation. This seems counterintuitive. However, simultaneous implementation of Basel III in other countries reduces world trade activity and internationally-driven inflation, allowing easier monetary policy in the UK. This stimulus to the UK economy, relative to unilateral implementation, from reduced inflation and interest rates more than offsets the depressing effect on UK exports of others' implementation of Basel III and therefore lowers the overall cost of Basel III to the UK economy.[35]

There is a wide degree of uncertainty around the point estimates shown in this section. We estimate that the net benefits could be as low as £4bn per annum but as high as £66bn per annum if we calculate a 90% confidence interval around our central estimate using stochastic simulation methods. This calculation provides confidence that the policy package we estimate does, in fact, generate net benefits to the UK economy. However, our *confidence* that net benefits will be achieved will be considerably lower if regulatory capital ratios rise significantly beyond the Basel III requirements. Note that the range for our central estimate is skewed towards higher benefits because the

[34] While we expect that our measure of net benefits is appropriate, we note that our methodology may mis-identify some costs and benefits. For example, some lending undertaken by banks ahead of the crisis may have been non-productive and reducing this lending would represent a benefit, rather than a cost, as calculated in our methodology. However, reducing non-productive lending should also lower the probability a crisis occurs, which is captured in our measure of benefits.

[35] A more detailed discussion of our calculations is included in Annex 4.

probability of crisis cannot be lower than zero. In comparison, the range of costs to GDP from the simulations is symmetrical.

6.2.2 Macroeconomic impacts of the transition to Basel III

We now turn to the impact that the Basel III policy package is expected to have on the UK economy. We distinguish between: actual outcomes in the UK; and our simulations of both the forward looking baseline; and the forward looking counterfactual (that includes the policy package).

The Basel III requirements initially affect the cost and volume of lending as banks widen their interest margins, and corporate and household demand for loans reduces in response. On average, the lending wedge for the UK economy rises by 67 basis points once banks have fully adjusted their balance sheets to the Basel III requirements. However, the short-term impact on the corporate lending wedge is much higher, rising by 126 basis points by December 2017, before slowly falling to the long-run average of 67 basis points. Household borrowing costs increase continuously over the period.

As discussed in section 4.2, banks raise the prices of riskier corporate loans more than the prices of less risky, household loans as it allows them to adjust their risk-weighted assets more efficiently in the short term. Secured mortgage loans predominate in household lending and enjoy a low regulatory risk weight. Most lending to corporations (for investment, trade and cash-flow financing) is unsecured and therefore attracts a greater risk weight.

Figure 6.5: Long term effects of Basel III on UK lending

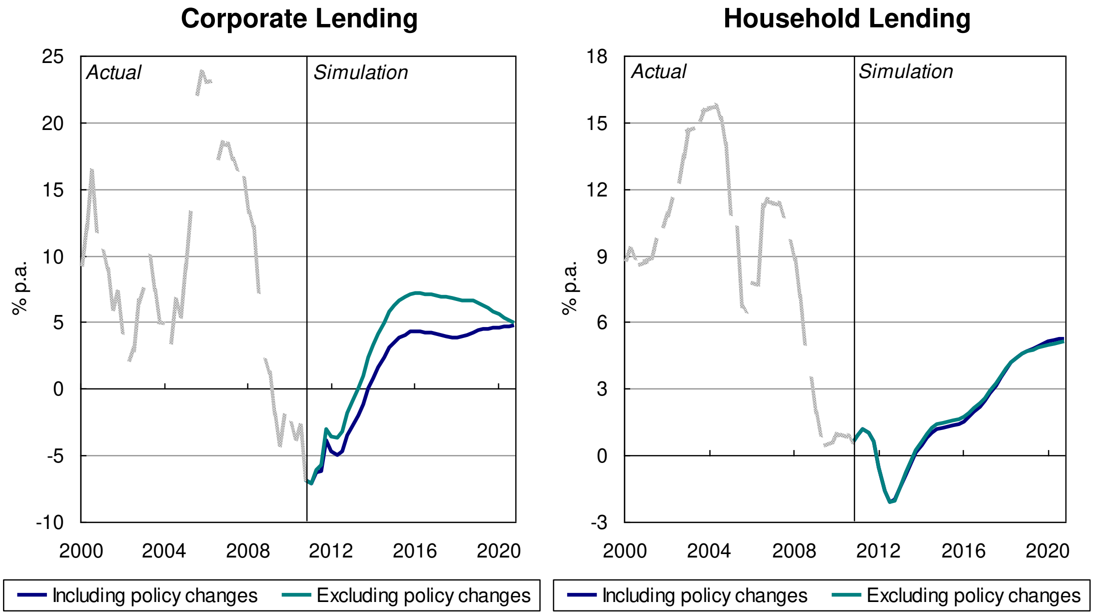


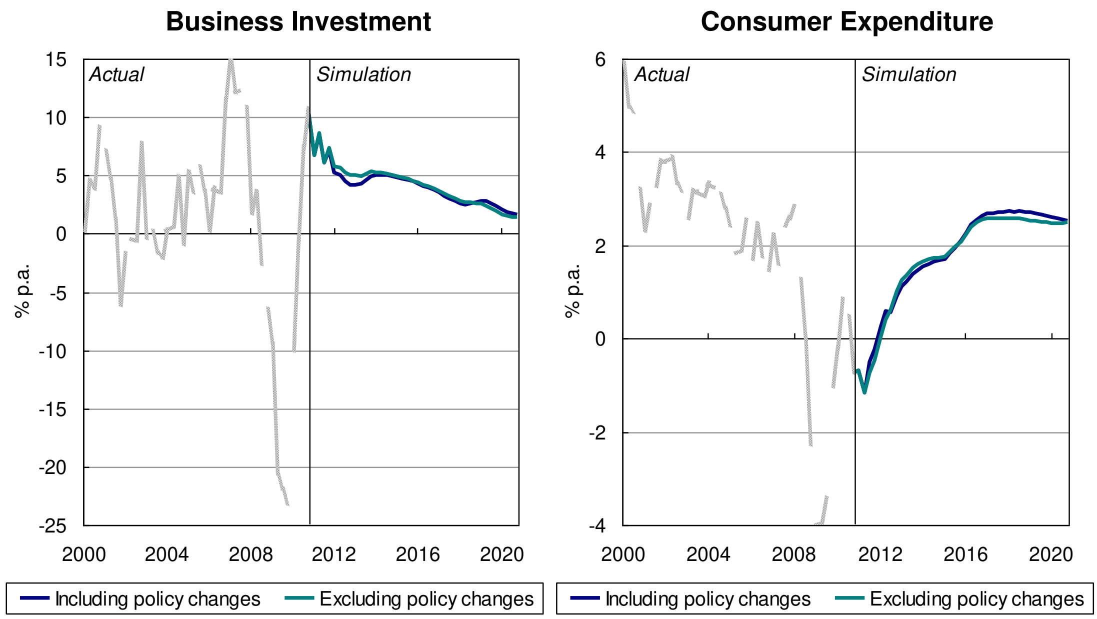
Figure 6.5 above shows the impact on UK borrowing through time for both the corporate and household sectors. In the long-run, the annual *growth* of the banks' entire lending portfolio (corporate and household lending) is unaffected, reaching this equilibrium point around 2025. In aggregate, total bank lending is reduced by a maximum of around 1 percentage point in the short term. This contrasts with a larger reduction from the baseline of around

3½ percentage points for corporate lending, achieved around 2015. The impacts on economic activity of reduced lending lag the lending reductions by about two years.

The changes in borrowing costs and loan allocation affect the macroeconomic environment in two distinct ways: via inter-temporal consumption smoothing and long-term investment. As discussed in OP38, even as households face higher costs of borrowing, the reduction in consumer expenditure is smaller and stems from a reduction in real house prices. Other effects include the impact of changes in economic activity on prices and inflation, real interest rates, asset prices, and central banks' decisions on base interest rates. These second order effects impact on consumers' perceptions of long-term wealth and financial decisions and on decisions made by businesses. It takes some time for the new equilibrium to evolve.

The increased borrowing costs for corporations raise the cost of physical investment, and total investment and total capital in the UK is reduced. The reduction in business investment also has a direct impact on the equilibrium level of output. Figure 6.6 below shows the estimated impact of Basel III on growth in consumer expenditure and business investment.

Figure 6.6: Effects of Basel III on UK domestic demand



A comparison of Figure 6.5 and Figure 6.6 shows that the impact on total bank lending to corporations is far more pronounced than the impact on business investment itself. This, most likely, reflects firms' ability to access alternative sources of funding for business investment. As noted in OP38, there is a strong empirical relationship between changes in bank lending margins (represented by the lending wedge) and the corporate bond markets. This outcome could reflect substitution between bank lending and alternative sources of funds, such as bond markets or shadow banks.

The relationship between bank lending and bond markets is not, however, straightforward. As banks adjust to higher capital requirements by raising equity and reducing lending, they are also reducing the amount of debt on their balance sheets (and hence their participation in bond markets). There are therefore likely to be a number of offsetting influences on prices (and quantities) in bank lending, bond and equity markets. First, as banks raise additional equity, they push up equity prices at the margin, thus increasing the cost of equity finance for other firms. So other firms may look to rebalance their funding mix by raising additional debt funding. Secondly, as banks raise their lending charges, they reduce the supply of loans to firms. At the same time, banks are reducing their demand for bond financing, putting downward pressure on bond prices[36]. Such an outcome would make bond financing more attractive (at least for larger firms able to access bond markets).

Also, changes in the relative prices of equities and bonds will change asset allocation decisions in the economy, with redirection of funds into either bank deposits or equity markets reducing the supply of funding to bond markets. The new supply and demand balance, and hence impact on prices, will depend on the relative price elasticities of the demand and supply of bonds, bank loans and equities. The relationships between business investment, bank lending and the bond markets are represented in the reduced form equations in NiGEM so it is not possible to see these linkages very clearly. This is a limitation in our modelling of the impacts of Basel III, and is a key area for further development.

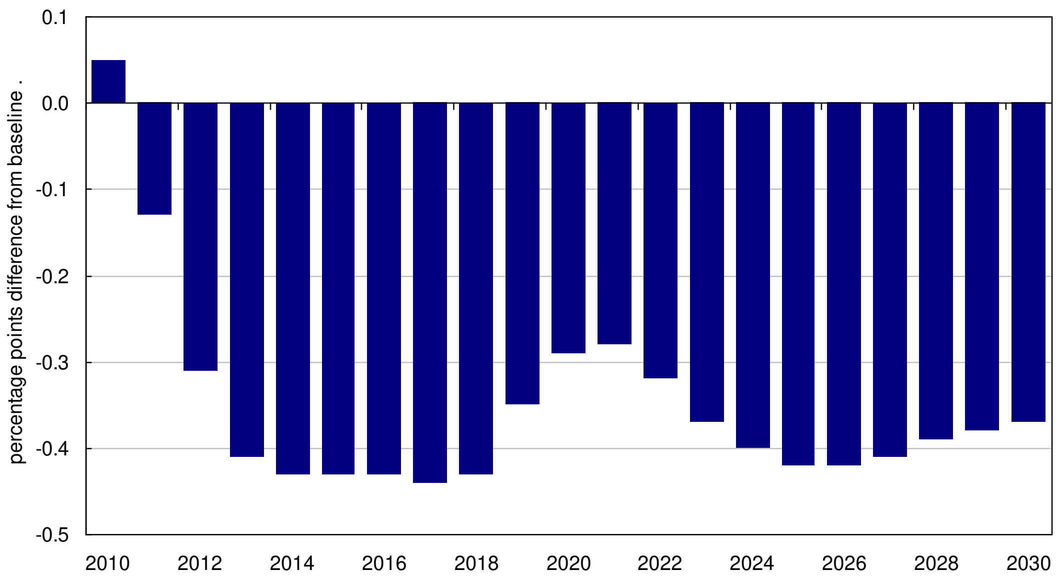
Figure 6.6 al so shows that corporate investment is lower than the baseline in the short-term, but may exceed baseline growth temporarily in the longer term. As noted above, this occurs because banks temporarily reduce corporate loans more rapidly than other loans. In effect, firms face a tightening of lending conditions in the short term, followed by an easing of lending conditions over the longer term. This dichotomy between the possible short- and long-term impacts highlights the fact that, in implementing a policy package of the scale of Basel III, regulators are making trade-offs between long-term financial stability and short-term reductions in economic activity.

Banks are expected to have fully adjusted their balance sheets to take account of the Basel III policy measures by 2020, although the full economic impact materialises some years after that. Figure 6.7 shows the total effect on GDP of the Basel III package through time. The level of GDP is subject to different influences that have impacts over different time horizons. In the short term, GDP is reduced quickly relative to the baseline as banks adjust their balance sheets. The reduction in consumer loans, while smaller than for corporate loans, has a larger impact as consumer spending (a major driver of GDP) reacts relatively quickly. Once banks have fully adjusted their balance sheets to the new requirements, lending is less constrained and consumer spending recovers. In contrast, reductions in corporate lending and business investment, which reduce production in the economy, take considerably longer to have an impact on GDP. These differences in the timing reduce the medium-term impact of Basel III on GDP. A long-term fall in GDP of around

[36] The banking sector affected by Basel III may be large enough to have an influence on bond market prices, at least in the UK.

0.4% relative to the baseline arises from all changes in bank capital requirements.

Figure 6.7: Effects of prudential policy on the level of UK GDP



6.2.3 Welfare and wellbeing implications

The calculations of benefits discussed above reflect only the impact of policy changes on national income, with the underlying assumption that agents in the economy always prefer higher levels of income. However, there are other measures which we could use to evaluate the costs and benefits, such as economic welfare or consumer wellbeing. We need to be clear here about the differences between welfare and wellbeing:

- Welfare is concerned with consumers obtaining what they most prefer. Welfare benefits (costs) arise when consumers obtain a more (less) preferred option.
- Wellbeing is concerned with consumers' psychological state, and is generally based on reports by consumers themselves.

First, we consider economic welfare. Consumers (and some firms) are most likely willing to trade off higher income for greater stability of income – that is, they have some preference for stability – giving rise to additional welfare benefits of prudential policy. In contrast, lower income in the economy may reduce opportunities for employment and household consumption, giving rise to additional welfare costs. Accurate measures of welfare are notoriously difficult to achieve. One theoretical approach undertaken by NIESR to calculating welfare benefits proceeds from improvements in the stability of employment. It was, however, only a brief theoretical exercise not based on substantial empirical evidence.[37] Other approaches demonstrate that there may also be welfare *losses* arising from prudential regulation. Van den Heuvel (2008), for example, includes estimates of the welfare loss for the US of the

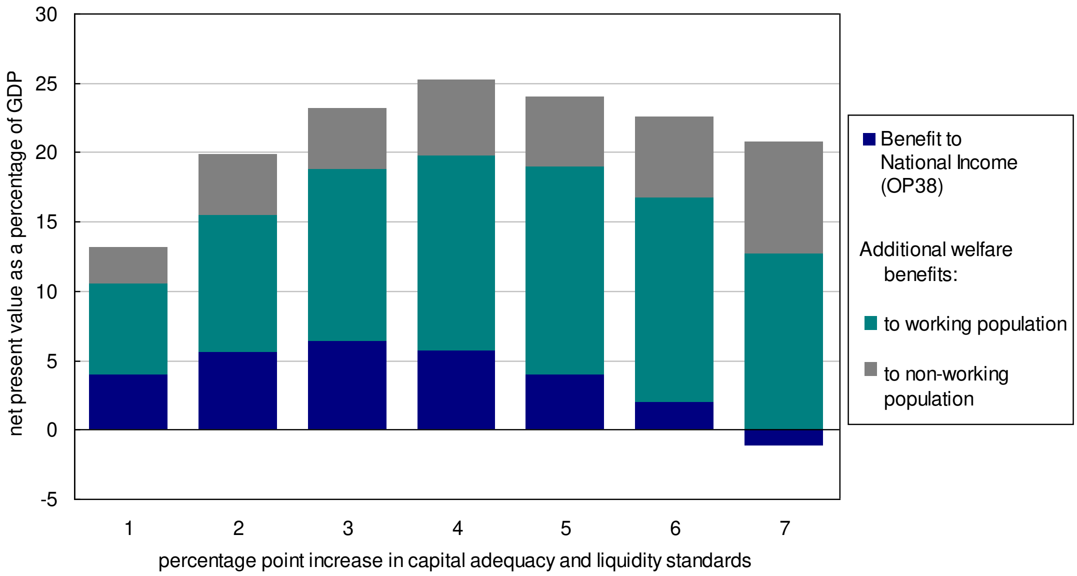
[37] This theoretical approach was discussed with the FSA, but is otherwise unpublished.

reduced ability of banks to create household liquidity in the economy arising from regulatory limits on the fraction of bank assets that can be funded by deposits.

We have no accurate measure of the net effect on welfare of the policy proposals under consideration here. We are also unaware of any study that sets out the welfare benefits and costs of prudential regulation and attempts to estimate them. We can, however, say that the value placed on stability by the population is very probably large, implying that welfare benefits could be many billions of pounds. This is borne out by the limited work done so far on this topic.

An approach to measuring the additional wellbeing generated by prudential policy, an LSE 'Capstone' project[38], looked at the benefits of stability[39] by using the economics of happiness literature and subjective measures of life satisfaction. Figure 6.8 below shows the outcome of the LSE-Capstone approach as applied to the net benefit calculations published in OP38.[40] Measured net benefits increase significantly when the wellbeing of people involved in the labour force (whether employed or unemployed) and not involved in the labour force is taken into account.

Figure 6.8: Calculation of net benefits with and without welfare effects



Source: LSE-Capstone (2009)

These results, however, must be treated with caution as there are important limitations to the analysis, including the limited dataset for the UK and the possibility that important variables may have been omitted in this limited analysis. Therefore, overall, the results of this work should not be seen as reliable enough to be used for calibration of policy. However, it is of material interest that the chart shows the wellbeing benefits of higher prudential standards to be possibly much greater than the income benefits.

[38] The study was undertaken, with academic oversight, by students undertaking the MPA course at the London School of Economics and Political Science as their 'Capstone' project
[39] 'Quantifying the Benefits to Consumers of Having a More Stable Banking System' LSE-Capstone (2009).
[40] We have not attempted to update this analysis for Basel III.

7 Assessing the uncertainty of our point estimates

Any modelling approach that we take to estimate the costs and benefits of prudential policy will depend on estimated parameters, and uncertainty around these parameters can arise from a number of sources. We discuss below the impact on our net benefit estimates of relaxing or changing our model assumptions. We first use stochastic simulation techniques to draw a distribution around our central estimate of the net benefit. Stochastic simulations allow us to relax the model assumptions that drive the baseline solution, and thereby evaluate the change to net benefits arising from different macroeconomic assumptions.

We then study the effects on net benefits of changing the frequency in future scenarios of financial crises with permanent effects on GDP. Finally, and in the light of the alternative parameterisations of the cost pass-through noted in Chapter 4, we allow for changes in the cost pass-through parameter. A smaller cost pass-through is consistent with a view that banks are able to reduce lending charges over the long-term (e.g. see Bank of England (2010b)).

7.1.1 Calculating uncertainty from the model equations and assumptions

In addition to providing a point estimate of the net benefits of policy, NiGEM allows us to measure the uncertainty around this estimate. This is done by running the model under alternative assumptions and by isolating the error component of the macroeconomic equations. Running the model under alternative assumptions changes both the baseline forecast, which we use as the 'no-policy' counterfactual, and the subsequent estimates of the policy impact.

NiGEM contains a number of stochastic equations which seek to provide a full stochastic representation of the macroeconomic environment. We calculate the uncertainty in the results due to our model assumptions by randomly assigning values to the error terms (or stochastic component) in these individual equations. All the economic variables in the model are randomised in a similar fashion in the stochastic simulation process. Given some regularity assumptions[41], the unconditional assessment of uncertainty through stochastic simulation for a given variable should provide a realistic representation of the overall model error. The results are comparable to error bands around macroeconomic forecasts, such as the Bank of England's fan charts of inflation and growth in its quarterly Inflation Report[42].

We implement a standard approach followed in NiGEM to generate the stochastic shocks for all the stochastic equations and apply these shocks to our policy simulation. This methodology randomly draws shocks from the observed historical errors[43]. These artificial shocks can be added to an

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[41] Forecasts error bands will be accurate when: all equation parameters are unbiased and consistent, and some regularity conditions of the error component hold (e.g. normally distributed around zero, homoskedastic, stationary and so on).

[42] The Bank of England's fan charts are described in detail in BoE 2010 and Britton et al. 1998. In the Bank's approach, forecast uncertainty depends on stochastic components of the equations and other quantitative and qualitative analysis.

[43] The stochastic simulation process in discussed in Barrell et al. (2000).

equation over the historical or the forecast periods, each time producing a different model solution. This technique can provide an asymptotic estimate of the covariance matrix of the stochastic components if the set of historical disturbances is large enough.[44]

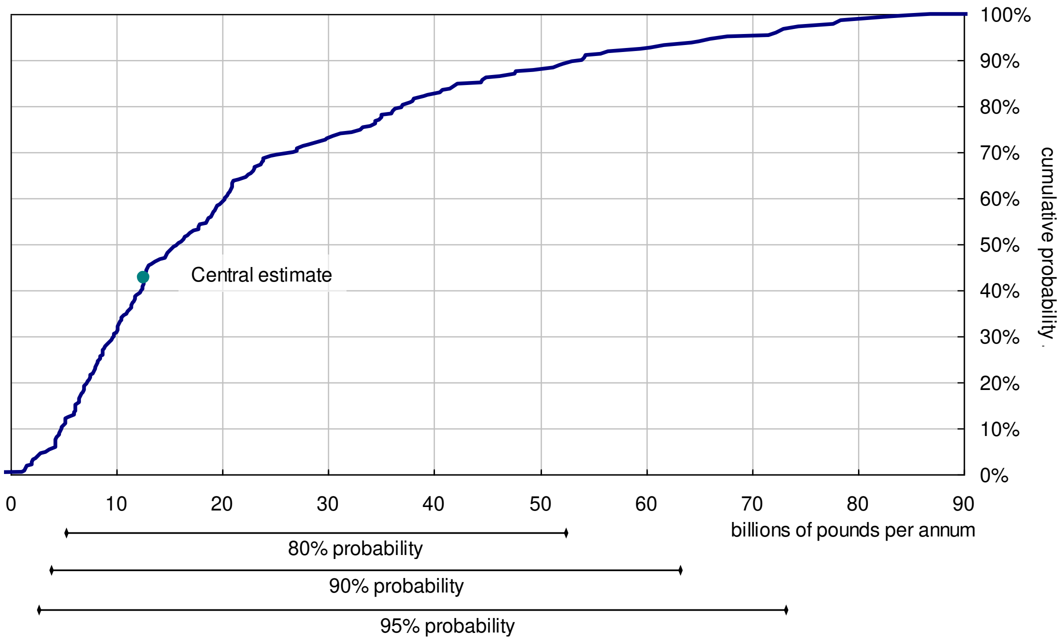
In stochastic simulation, the uncertainty about the macroeconomic conditions that often are given as assumptions (for example future commodity prices and other world variables) is transmitted through model relationships. The NiGEM framework is comprehensive and as a result the stochastic simulation process can assess changes to a broad range of assumptions, for example changes to central bank base rates in other countries, different world commodity prices, or variations in overall world economic activity levels.

We proceed by assessing the errors associated with model assumptions on banks' behaviour. We then. test some of the assumptions that stochastic simulation cannot address in sections 7.1.3 and 7.1.4. At the end of this chapter we then explore the effects of changes in banks' cost of capital pass-through and changes in banks' voluntary capital buffers.

7.1.2 Stochastic bands around the costs and benefits

Figure 7.1 shows the cumulative probability distribution for the *net* benefit for the whole package of policies described in Annex 3. The 80%, 90% and 95% probability bands at the bottom of the chart show the maximum and minimum deviations expected from the central estimates for these level of statistical confidence. The chart demonstrates clearly the extent of uncertainty around the size of the net benefits.

Figure 7.1: Probability distribution of net benefits of the policy package.



[44] This methodology exploits the historical error correlations maintaining them across variables. When applied over a forecast period there is an implicit assumption that the covariance matrix will not change over the forecast period.

In our central estimate of the policy impact, the *gross* benefits from reducing the probability of financial crises corresponds to an ongoing increase in GDP of £16.8bn per annum. This estimate of the benefit varies widely, depending on the probability of crisis estimated by the crisis model in our baseline forecast. Changes in the economic environment make the probability of crisis shift from its historical average. For example, an economy running a large current account deficit or experiencing fast real house price growth has a higher probability of a financial crisis occurring. Benefits from lowering the crisis probability can be much larger for the same prudential policy package if the probability of a crisis is larger than we predicted in the baseline forecast used for our central estimate. At the lower end of the scale, benefits (though not of course net impacts) are bounded by zero. So, when the crisis probability is close to zero, the benefit of reducing it further is small or zero. The distribution around the point estimate of the benefit of the policy response is consequently asymmetric, and skewed towards significantly higher benefits.

In the baseline case, the output loss due to higher costs in the economy associated with the policy package corresponds to an ongoing reduction in annualised GDP of £4.9bn. The baseline forecast (which assumes no increase in capital or liquidity requirements) is one of slow economic recovery, with growth rates below 2% per annum in 2011 and 2012, rising to 2½% on average in the long-run. Stochastic simulation generates alternative scenarios using greater and lesser supply constraints, higher and lower world activity levels, higher and lower world inflation and so on. The policy package would impose higher borrowing costs vis-à-vis the baseline forecast in all of these alternatives and our modelling approach reflects this. However, unlike in the case of benefits, the distribution around the point estimate of the costs of prudential policy is broadly symmetric.

We find that under a benign economic environment the package has a smaller impact on the measured costs; for example in a low inflation scenario, where UK GDP grows at a relatively fast 3% per annum in the long-run, the annual ongoing reduction in output is estimated to be £3.0bn. If central bank interest rates stay low, we find that the effects of the package on the cost of business investment are less significant. In a more negative macroeconomic environment (e.g. greater energy supply constraints), the package has larger detrimental effects on output. This is because the model shows that in a negative macroeconomic environment, remedial government or central bank action (e.g. attempts to target higher growth by lowering interest rates) has only a limited mitigating impact and the cost of prudential policy remains high.

The overall distribution of *net* benefits shown in Figure 7.1 is skewed towards higher net benefits as the distribution of benefits is skewed while the distribution of costs is symmetric. Figure 7.1 also shows that the policy calibration is net beneficial for the vast majority of the cases analysed. Net benefits could be much higher, more than three times larger than in our central estimate, amounting to more than £53bn per annum in 10% of the cases. The 90% confidence levels stretch from net benefits of around £3.7bn to net benefits of £66bn.

7.1.3 Uncertainty of the frequency of crisis with permanent effects

We also tested alternatives to our assumptions on the likely loss to the UK economy of crises that have permanent effects. The historical evidence from Reinhart and Rogoff (2009) and the observation that today's banking system is a more interconnected network than it was in the past leads us to assume that one in three banking crises have produced permanent losses in GDP. Here we replace this frequency with two alternatives: a higher assumption (one in two) and a lower assumption (one in four).

Table 7.1: Impact of a change in the frequency of crises with permanent effects and size of voluntary buffers

	Accumulated net benefit	Net benefit	Gross benefit
	(% of GDP)	*(£bn per annum)*	
Assumption:			
1 in 2 crises has permanent effect[1]	48.4	20.2	25.2
1 in 4 crises has permanent effect[1]	18.3	7.6	12.6

Source(s): Authors' own calculations, NiGEM
[1] Costs and benefits are calculated for the full package in Table 6.1, including multilateral implementation. Net benefits are calculated as the sum of the corresponding gross benefits and costs.

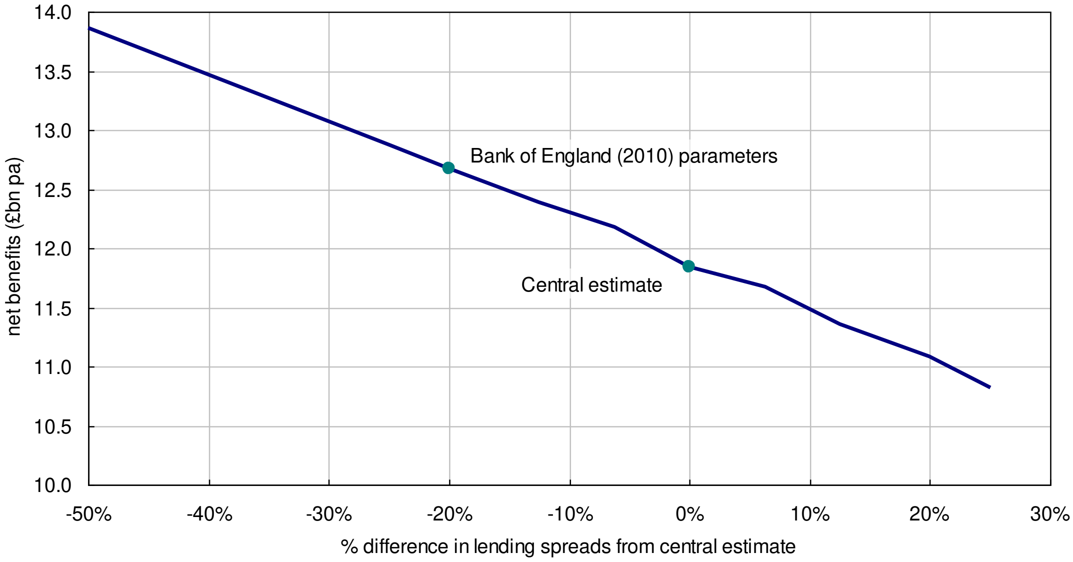
Table 7.1 above summarises the results of these two exercises. If crises with permanent effects are more frequent than we assume in our central scenario, the net benefits are much higher; we obtain an annualised £20.2bn net increase in GDP compared with £11.9bn in Table 6.1. In contrast, a lower frequency leads to a annualised net GDP increase of only £7.6bn.

7.1.4 Uncertainty of cost of holding additional capital

In Chapters 3 and 4 we discussed a number of alternative approaches to estimating the cost to banks of holding additional capital. We have repeated the exercise undertaken in Chapter 6 using a range of values for the cost of holding additional capital, from 4½ basis points to 11½ basis points for the marginal cost of holding a higher capital ratio suggested by the different studies reviewed in Chapter 4. Based on the standard deviation from the regression equation of the lending wedge shown in Table 4.1, the higher value corresponds to a 90% confidence bound from our existing estimate while the lower value corresponds to the 99% confidence bound.

Figure 7.2 shows how the net benefit calculation of the full policy package (on the vertical axis) varies as the marginal cost of holding a higher capital ratio changes. The relationship is roughly linear as the total cost changes linearly as the marginal cost changes, while the benefits are broadly unchanged.

Figure 7.2: Sensitivity to the lending spread response to capital



Note(s): All the points are net benefit estimates corresponding to all policies of Table 6.1 and including multilateral implementation.
Source(s):NiGEM 1.11c.

8 Conclusion

We have attempted to estimate the impact on the UK economy of the Basel III proposals. The methodology that we have developed uses both microeconomic models to estimate the impact on individual institutions, and macroeconomic models that use the aggregated microeconomic model outcomes to estimate the impact on the UK economy as a whole. Our approach also attempts to fully capture the impact of the full regulatory response to the financial crisis to ensure that all costs and benefits are properly captured. Any such modelling process is subject to a large number of assumptions and caveats that we have discussed in this paper.

Given the assumptions that we have made, we estimate that the Basel III package will provide net benefits to the UK economy of £11.9bn per annum. The benefits arise from the reduction in the probability that a systemic crisis, one which permanently reduces the level of UK GDP, occurs. Clearly the benefits are not observable as they represent outcomes that are *not* expected to occur as a result of the policy implementation. The costs are driven by the higher price of intermediation in the economy as banks must hold a greater proportion of capital and liquid assets on their balance sheets, and the effect this has on both corporate and household investment and spending decisions. Our calculations also show that prudential standards could be raised further, by up to an additional 22 percentage points in terms of banks' aggregate risk-weighted capital ratio, and still be expected to produce overall positive net benefits *in the long run*. In principle, this provides some useful headroom for supervisory and FSB initiatives that go beyond Basel III. Bank supervisors might also note that, at least for the UK, implementation of prudential standards somewhat higher than Basel III in other jurisdictions will reduce the costs to the UK economy, and raise net benefits.

The uncertainty around our estimates of the benefits is the greatest source of possible error in our analysis, but clearly skewed towards benefits being higher than shown in our central estimate. Our analysis of the stochastic errors around our central estimate indicate that net benefits could be as high as £74bn, but only as low as zero net benefits within a 95 percent confidence interval.

Other estimates of the impact of Basel III generally focus only on the costs of the policy measures, and are reasonably close to our central estimates of the costs. Indeed, only small changes to the assumptions behind these estimates can lead to very similar results to ours, even though these estimates use different methodologies.

8.1.1 Other limitations to our work

We have identified many caveats to our research, some of which we have addressed directly, and others which we have noted. However, there are some broader caveats that could be worth exploring further as they represent significant unknowns in our analysis. First is the extent of competition in the banking sector. The empirical estimates in our modelling reflect the extent of competition existing in the market over the period in which the model equations were estimated. However, given the scale of the prudential policy changes, the extent of competition in the market could change, particularly if higher prudential standards raise barriers to entry into the UK banking sector. This, however, may be offset by implementation of the recommendations of the Independent Commission on Banking.

Secondly, one response to the costs of regulation in the banking sector is credit extension by the non-bank sector. New regulations may make past forms of non-bank lending (for example, securitisation) more costly in future, which may curtail this sector. However, forms of non-bank lending that we cannot predict may also emerge, which could change the structure of the industry. A better understanding of the non-bank sector and the interaction with the banking sector could help us to understand better the impact of alternative sources of finance when banks reduce lending in response to higher prudential standards.

Finally, the response of firms to such wide-ranging reforms is always difficult to predict. For example, large, globally systemic UK banks will be subject to considerable additional capital surcharges. Under these conditions, banks may choose to change their business models to avoid the surcharge, possibly altering the structure of the UK banking sector. Firms may also alter their accounting approaches to help minimise the impact of new standards and innovation could lead to new products that reduce costs to banks. We already have evidence that firms are developing new instruments and strategies to reduce the impact of the Basel III policy proposals. Firms may also alter their internal models to help minimise the impact of the new policies. If these strategies effectively reduce the impact of the new policy on banks, the benefits of reducing the likelihood that a financial crisis occurs, as well as the costs to the economy, will be reduced.

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Annex 1: Modelling banks' responses to changes in capital requirements

Here we briefly set out the three step approach used in OP36[45] to model the relationship between changes to banks desired capital ratios and banks' balance sheets movements.

First, we express internal target capital ratios for each bank in the sample as a function of a range of regulatory and **market** factors. The model proceeds as follows. A bank i targets a desired capital ratio at time t, $k^{*}_{i,t}$. Bank i's desired capital ratio is a function of N factors which capture specific characteristics, denoted by the matrix $X_{n,i,t}$, and a fixed effect for each bank, denoted η_i:

$$k^{*}_{i,t} = \eta_i + \sum_{n=1}^{N} \theta_n X_{n,i,t} \qquad \text{A1.1}$$

The specific characteristics, $X_{n,i,t}$, driving banks' desired capital ratios include bank- and time-specific capital requirements imposed by the regulator[46]. The vector θ_n contains the parameters describing the impact of the characteristics in $X_{n,i,t}$, pooled across all banks. The fixed effect, η_i, captures idiosyncratic factors for each bank such as business model, management strategies and risk aversion.

Second, the parameters θ_n and η_t in equation A1.1 are derived indirectly as bank i's desired capital ratio $k^{*}_{i,t}$ is not directly observable. We use a partial adjustment model (consistent with Hancock and Wilcox (1993; 1994)) that lets each of the i banks adjust towards their desired capital ratio by some fraction λ in each period to estimate the long-run drivers of banks' capital targets – the industry-wide factors θ_n and bank idiosyncratic factors η_t – and thus estimate the desired capital ratio $k^{*}_{i,t}$, for all banks[47]. We then calculate the percentage difference between each bank's actual capital ratio in the preceding period and the estimated desired capital target. This surplus (or deficit) v*is-à-vis* the desired capital position is denoted $Z_{i,t}$**:**

[45] Francis and Osborne (2009b)

[46] The FSA imposes individual capital guidance (ICG) for each bank under the supervisory regime, which sets a different capital requirement for each individual bank in the UK. It is the effect of this variable on banks' behaviour that is of primary interest in this stage of the analysis. To control for other systematic differences in bank behaviours, the vector X also includes a measure of regulatory risk (ratio of risk weighted assets to total assets), a measure of a bank's own assessment of risk (ratio of loan loss reserves to total assets), a proxy of market discipline (ratio of subordinated debt to total liabilities), a measure of the quality of bank capital (ratio of tier 1 capital to total capital), a cost of capital proxy (the return on equity), an indicator variable to capture trading book activities and a measure of asset size. For more detail on these variables and the rationale for their use, see OP36.

[47] Derivation and estimation of the partial adjustment model is described in detail in OP36.

$$Z_{i,t} = \left(\frac{k_{i,t-1}}{k_{i,t}^{*}} - 1 \right) \qquad \text{A1.2}$$

Third, estimates of the rate at which banks adjust their levels of capital and assets to achieve their desired capital ratio can then be calculated by simultaneously regressing the percent growth in the level of assets ($\Delta A_{i,t}$) and capital ($\Delta C_{i,t}$) on:

- the surplus (or deficit) of capital ($Z_{i,t}$);
- a number of macroeconomic and sector-wide control variables which may affect bank behaviour, such as real GDP growth (GDP), inflation (INF), the change in the bank rate ($BANKR$) and bank charge-offs (the value of banks' write-offs of loans) as a proportion of total bank assets ($CHARGE$); and
- variables to control for any (quarterly) seasonal factors not captured elsewhere (Q):

$$\begin{Bmatrix} \Delta A_{i,t} \\ \Delta C_{i,t} \end{Bmatrix} = \sum_{j=1}^{2} \lambda_j \Delta A_{i,t-j} + \beta Z_{i,t} + \delta_4 CHARGE_{t-1} + \sum_{s=1}^{4} \rho_s Q_s + \sum_{j=1}^{2} \left(\delta_{1,j} \Delta GDP_{t-j} + \delta_{2,j} \Delta BANKR_{t-j} + \delta_{3,j} INF_{t-j} \right) + \varepsilon_{i,t} \qquad \text{A1.3}$$

The coefficient vector β contains the estimates of the differential rates at which banks adjust key elements[48] of their balance sheet (the adjustment parameters) to reach a desired capital ratio.

[48] The key elements modelled are: total capital, tier one capital, risk-weighted assets, loans and total assets. See OP36 for details.

Annex 2: The accounting approach to measuring the pass-through of the costs of holding additional capital

We would expect the relationship between the capital ratio and the cost of lending to be positive in the long-run if banks are constrained by regulatory capital requirements and face limits in their access to capital markets, and if customers face some switching costs. However, achieving a robust parameterisation of this relationship is challenging. One approach which we term the 'accounting approach' is based on banks' balance sheets and estimates the long-run spread between the cost of equity and the cost of debt. In this approach, one calculates the increase in a bank's cost of funding resulting from an increase in the capital ratio, using estimates of the long-run return on equity and the required rate of return on debt and adjusting for the effects of taxation. Then, using data on banks' balance sheets, one calculates the extent to which interest rates on loans would have to increase in order to offset the increase in funding costs. This approach assumes that banks adjust loan prices only. Banks have less discretion to re-price other assets on their balance sheets, such as deposits, bonds and equity. If loans account for half of the balance sheet, for example, then the increase in the interest rate on loans will be twice the increase in the average cost of funding.

The accounting approach has the advantage that it is simple and transparent, and it can be calculated based on publicly available data. Hence it has been adopted by several recent studies (Bank of England (2010b); Elliott (2010)). However, the accounting approach has a couple of key drawbacks. One is that it sidesteps the issue of how default risk affects the cost of funding. Under the strict assumptions of the Modigliani-Miller (M-M) theory[49], increasing the capital ratio has no effect at all on the weighted average cost of funding. The accounting approach can be used to calculate this outcome using the appropriate assumptions, but can also be used to calculate the opposite extreme, where the required return on debt and equity remain invariant to the capital structure of the firm. A more plausible estimate lies in between these two extremes, not least because the assumptions of the M-M theory do not hold which suggests that the accounting approach could be useful to use in calculating a range for the expected change to banks cost of funding resulting from higher capital holdings, rather than providing a point estimate of the likely impact[50].

Another issue with the accounting approach is that it does not take into account the interactions between bank loan pricing and supply and demand in credit markets. Increases in the cost of borrowing from banks will reduce lending, both by reducing demand for credit and by encouraging borrowers to substitute into other sources of credit. If borrowers are easily able to source funds from alternative, non-bank, sources that are not subject to regulatory change, then banks will be constrained in their ability to raise loan prices. In

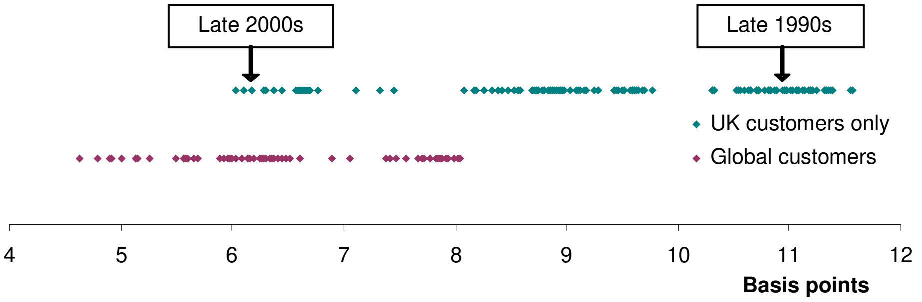
[49] See Stiglitz (1969) for a description of the Modigliani Miller theorem and key extensions.

[50] Without evidence from exogenous shifts in the capital ratio (i.e. those motivated by increases in capital standards rather than a change in a bank's asset risk), it is difficult to identify empirically exactly by how much investors adjust their required return. For example, investors in banks may not react as would investors in other industries, given the extent of implicit and explicit government guarantees on too-big-to-fail banks' debt.

contrast, if borrowers are effectively 'captured' by banks, then banks may be able to fully pass on costs to borrowers. The accounting approach may, therefore, provide more or less accurate results depending on prevalent competitive conditions in banking markets.

To illustrate the possible range of estimates, we have used the accounting methodology to estimate a range of possible costs of higher capital requirements. Using balance sheet data from the second half of the 1990s to the present for UK banks, we have estimated the change in banks' funding costs using the approach outlined by the Bank of England (Bank of England (2010b)). Figure A2.1 below shows the range of estimates over time.

Figure A2.1: Estimates of the impact on banks' spreads



Source(s): FSA regulatory returns, authors' own calculations
Note(s): The green dots show the spread increase (in basis points) if only UK customers' loans are used to recover the cost of higher capital requirements. The purple dots use banks' global loans to recover the same cost with a smaller impact on spreads. The calculations assume 10% cost of equity and 5% cost of debt.

The graph highlights a number of factors. First, that the range of estimates is quite large and dependent on the structure of banks' balance sheets at a point in time. For example, in the late 1990s, data shows that banks generally had a smaller ratio of loans on their balance sheets to risk-weighted assets. The accounting method calculates that banks would need to raise lending costs in the economy by up to 12 basis points to recover the increased costs of a one percentage point increase in capital requirements. Using more recent data, for example data from the second half of the 2000s, the calculated increase in lending costs can be much smaller.

A related issue is whether UK banks seek to recover any cost increase over loans to customers in the UK, or loans globally. In Figure A2.1 we also show the accounting method's results by considering UK banks' global, rather than just UK, loans. Global loans of course form a larger pool from which to recover the cost increase and thus the unit cost is lower. On average the cost pass-through falls by 2.7bp when related to global loans instead of UK-only loans. However, the ability of UK banks to pass-through costs on their foreign loans portfolio will depend on prudential and supervisory measures faced by local banks in those markets and other local market characteristics.

One further issue to highlight is that the accounting method is sensitive to the level of the return on banks' debt and equity used for the calculation. If we increase the cost of equity from 10% to 11% while maintaining the difference between the cost of equity and debt at 5%, the cost pass through increases by an additional ½ basis point.

Annex 3: Summary of the policy package

To calculate the aggregate impact of all new capital rules on the UK banking sector of Chapter 6, we considered the following. Our calibration of the impact of the Basel III prudential standards and the transition arrangements reflect the 16 December 2010 agreement (BCBS 2010c, 2010d, 2010e), and are set out in detail in Table A3.1. We estimate the impacts of the policy proposals on the balance sheets of the major UK banks by applying the model of the banking system described in Chapter 3. The measures in Table A3.1 result in an aggregate, quality-weighted increase in the total capital ratio of the UK banking system of 9.6 percentage points from Basel II levels. As this analysis requires use of regulatory data on individual banks, we are unable to provide more detail on how we derived the aggregate capital increase for the UK banking sector, or provide illustrations of firms' behavioural responses in the model framework.

As discussed in Section 6.1.2, we assume that banks will adjust their capital ratios in advance of Basel III implementation, although there is a great deal of uncertainty as to the extent to which banks will continue to pre-empt the new capital requirements. Banks raised their capital ratios, in aggregate, by around 2 percentage points in 2010, and we expect them to continue to raise their capital ratios ahead of the official implementation date. We have assumed that banks will continue to raise their capital ratios at a similar pace to that implied by the capital accumulation in 2010. This path ensures that individual banks in our model of the banking system are compliant with Basel III measures as they are introduced, and that banks reduce their voluntary buffers linearly with the move to higher capital ratios as discussed above (see Table A3.1). We note that our estimates of the net benefits are unlikely to be materially different if calculated using a moderately accelerated path[51]. This is because, while costs are marginally higher, benefits are also achieved sooner.

In order to capture the likely full scale of the new prudential requirements for the financial sector, we have included a measure of the likely additional tightening of prudential standards for systemically important firms. While the specific calibration of the proposed capital surcharge for these firms has not yet been confirmed, we have assumed it to be 2% of risk-weighted assets for UK banks likely to be classified in the high risk buckets (referred to as globally systemically important financial institutions, or G-SIFIs) and 1% of risk-weighted assets for banks in lower risk buckets (local systemically important financial institutions or SIFIs)[52].

[51] For example, a path that saw banks achieve new Basel III capital requirements two to three years in advance of the transition period is not expected to change our results materially. However, if banks were to attempt to achieve full compliance with Basel III five to six years in advance (i.e. by 2013-2014), we would expect costs to be much higher, and benefits potentially lower.

[52] See BCBS (2011b) for details of the approach to defining systemic importance, the most recent publication on the issue at our time of writing.

Table A3.1: Detail of policy calibrations used for estimation of costs and benefits of prudential policy measures

Measure	Calibration / Description	Implementation Date
FSA's enhanced prudential regime	Minimum core capital ratio of 4%, tier 1 capital ratio of 8%, total capital ratio of 10%. Includes changes to the definition of regulatory core tier 1 capital (most notably the deduction of intangible assets from the definition) from the Basel II definition.	December 2008 (minima) May 2009 (definitions)
European Capital Requirements directive (CRD) changes to the treatment of banks' trading book and re-securitisation exposures	Firms required to: calculate additional market risk capital requirements for interest rate and equity positions in their trading books and all commodity and foreign exchange positions; apply more capital to re-securitisation positions to reflect the higher risk of 'unexpected impairment losses' (see European Union (2010)). The size of the impact is calculated using data from an FSA QIS exercise.	January 2012
Basel III changes to the definition of capital	Changes to: definitions of core capital (including all deductions from core tier 1 capital); eligibility criteria of non-core tier 1 (alternative tier 1, or AT1) and tier 2 (T2) instruments. Instruments that become ineligible under the new definitions are assumed to be replaced through the grandfathering period with higher-quality eligible instruments. The size of the impacts is calculated using FSA QIS data.	Phased implementation from 2013 to 2019
Basel III changes to risk coverage	Revised metrics to calculate: counterparty credit risk, credit valuation adjustments and wrong-way risk. The size of the impacts is calculated using the data from the FSA QIS exercise of December 2009.	January 2013 (most proposals)
Basel III change in the minimum capital ratios under Basel III	Minimum core capital ratio of 4½%, tier 1 capital ratio of 6%, total capital ratio of 8%. The definition of these ratios reflects the Basel III changes to the definition of capital and risk coverage.	January 2015
Capital conservation buffer and countercyclical buffer	Regulatory buffers are assumed to be constant over the cycle and are treated as a new minimum by firms since market pressure is expected to prevent them from operating in the conservation range. The assumption for the capital conservation buffer is based on the December 2010 Basel III rules (Annex 4) and the countercyclical buffer over-the-cycle value is our estimate of the size of the buffer.	Phased in between 2016 and 2019
Systemic surcharge	The size of the systemic surcharge has not yet been agreed. Calibration is based on our estimate of plausible mid-ranges for the final calibration of the surcharge for global and local systemically important firms: 2% of risk-weighted assets for UK banks that are likely to be classified globally systemically important and 1% of risk-weighted assets for banks with local systemic importance. We have assumed that small banks in the UK system are non-systemic and do not face an additional surcharge.	Phased in between 2016 and 2019
Shrinkage of banks' voluntary buffers	Banks' voluntary buffers over minimum regulatory buffers are assumed to fall by 50% from December 2009 levels.	Phased in between 2016 and 2019
Introduction of liquidity coverage ratio	Banks are assumed to increase the ratio of liquid assets to total assets by 4½ percentage points. (Informal FSA estimate). Firms meet 60% of the requirement through high-quality tier 1 liquid assets (government debt) and 40% of their total liquidity coverage ratio requirement through tier 2 assets (comprising US agency securities, high-quality corporate bonds and covered bonds).	January 2015

We then added our estimates of the impact of the liquidity coverage ratio (LCR) to the package of changes in capital standards outlined above. The impact of liquidity standards is an area of substantial uncertainty. This is because firms' behavioural responses to liquidity standards are highly uncertain, especially considering the wide range of assets that can be used to meet the requirements and the potential interaction between liquidity and capital standards. In addition, as the LCR specified in the Basel III agreement is novel, we have no past behaviour from banks that we can rely on to make empirical judgements.

In principle, liquid assets such as cash and government bonds attract a zero risk weight, so if banks substitute them for loans (holding the rest of the assets constant), their risk-weighted assets will fall. This effect, however, is difficult to quantify since increases in holdings of low-yielding liquid assets may lead to changes in the portfolio of non-liquid assets towards higher-yielding assets that may attract higher risk weights. Alternatively, banks may change their funding maturity profile to comply with the new rules or hold existing assets constant and purchase additional liquid assets, leading to no change in the absolute value of risk-weighted assets.

For the purpose of the analysis presented in this paper we assume that firms choose to meet the new LCR requirement purely through purchasing new liquid assets. Based on results from the recent QIS exercise, we estimate that the LCR requirement will lead to an increase in the aggregate banking sector liquid asset ratio of around 4.5 percentage points, from December 2009 levels. However, these estimates are only indicative and we will continue to refine the accuracy of our liquidity policy calibration and our general methodology for modelling the impact of liquidity standards.

Annex 4: UK unilateral versus multilateral implementation of policy measures

In Section 6.1.4 we noted that, to account for the impact of Basel III on the UK economy, we need to take account of its impact on other countries. In this Annex, we discuss how these international spillovers occur and compare the overall effect on the UK economy of a multilateral implementation of Basel III with a hypothetical unilateral implementation in the UK. A coordinated international introduction of Basel III has indirect negative impacts on the UK growth through changes in world demand. Lower demand outside the UK reduces exports to those countries. In addition, falls in international equity values can reduce the value of some UK portfolios with negative effects on wealth and consumption.

In contrast, the costs to the UK economy are lower as reduced GDP growth elsewhere lowers international demand for traded goods (in particular energy, food and other commodities), easing inflationary pressures on the UK economy. Monetary policy responds by reducing UK base interest rates from where they would be otherwise, reducing the impact on investment. Finally, exchange rates adjust as a result of changes in interest rate differentials which has additional demand and price effects. The NiGEM model includes all these interactions through econometrically estimated equations and up-to-date data-based international trade weights.

Roger and Vitek (2012) use a small multi-country macroeconometric model to assess the international spillover effects. They find there is a large scope for monetary policy to mitigate such effects. For each one percentage point increase in regulatory capital requirements, world GDP would experience a maximum additional fall of 0.01% compared to an hypothetical case where countries implement Basel III unilaterally. They conclude that the positive and negative effects of multilateral implementation cancel each other out at the world level. Country by country, however, the results vary as, for example, they find zero spillover effects for the UK but more significant negative spillover effects in Germany and China[53]. Their study does not consider the benefits of higher prudential requirements.

For the UK, we find that the positive effects from lower inflation and interest rates overcome the negative effects from lower exports and wealth on GDP. We calculate that unilateral implementation would increase the costs of the policy response to around £8bn per annum. This compares with the estimated £4.9bn per annum cost of Basel III implemented multilaterally (see Table 6.1). We measure a negligible fall in benefits[54] from multilateral implementation relative to implementation by the UK alone as we are only considering the benefits to the UK economy. However, improving financial stability in other countries would further reduce the probability of a crisis in the UK, as cross border banking networks would also be more stable. We have not included the additional benefits of multilateral implementation in our calculations.

[53] NiGEM reproduces similar results with large negative spillover effects in China and Germany and with alleviating effects in the UK and the US.

[54] This arises from the view that higher economic activity in the UK generates a slightly higher chance of asset price bubbles forming in the UK.

Figure A4.1 shows the difference in inflation and central bank targets due to international implementation. Unilateral implementation increased borrowing costs by around 20bp through central banks targeting higher base rates.

Figure A4.1: Effects on UK inflation and interest rates

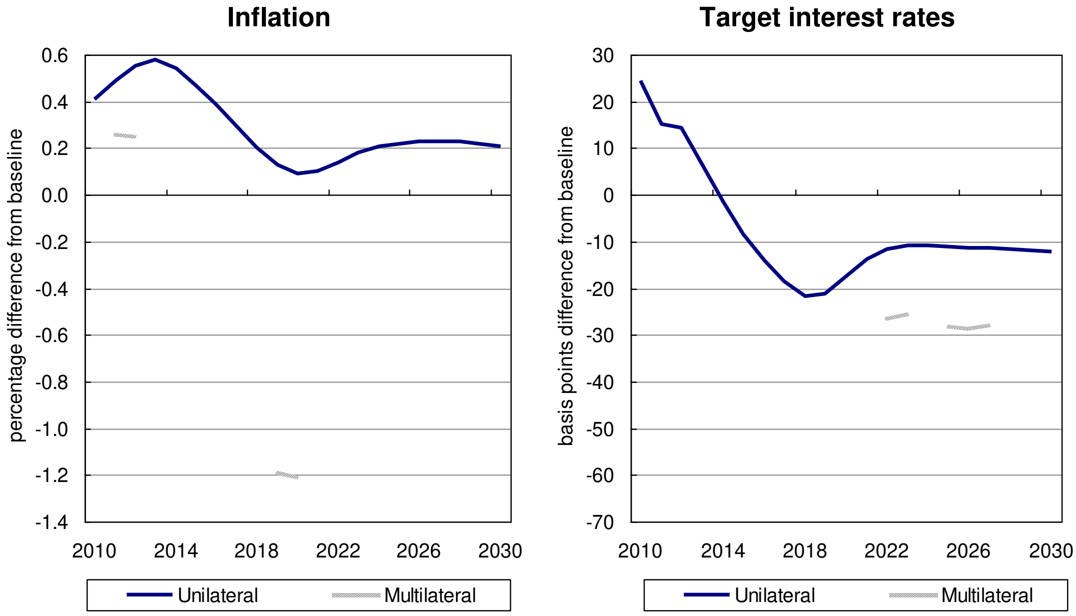
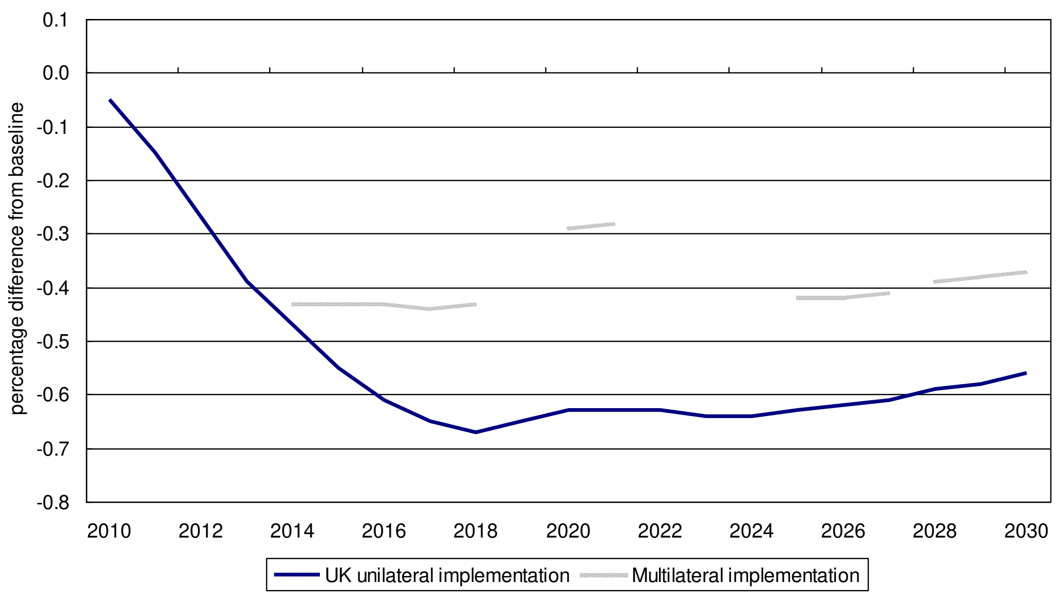


Figure A4.2 compares the fall in GDP from the baseline under unilateral implementation and multilateral implementation; unilateral implementation increases the UK GDP shortfall by additional 0.2%. In the multilateral implementation case there is a higher GDP cost to the UK in the short run. This is directly linked to lower levels of international trade that cut UK exports and keeps the current account balance below the UK solo implementation levels by close to 0.3 percentage points of GDP.

Figure A4.2: Impact on GDP of unilateral and multilateral implementation



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