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Abstract

The Basel III/CRD IV reforms to the banking system following the financial crisis of 2008–09 required banks to raise significantly both the quality and quantity of capital on their balance sheets. This econometric study provides evidence of both the long and short-term implications for ongoing activity in the UK economy of a change in the aggregate proportion of bank capital funding. We find that, in response to changes in their capital funding, banks change credit spreads applied to private non-financial corporate borrowers to a greater extent than for household borrowers in the short term, but equalise these changes in the longer term. The short-term impact reflects banks' desire to adjust their capital ratios through changes to the value of their risk-weighted assets by restricting the flow of lending to higher-risk sectors to a greater extent than to lower-risk sectors. We also find that after recent regulatory reforms banks may have modified their price-setting behaviour somewhat. We develop a vector error correction model of these effects with an innovative non-standard estimation of the short-term coefficients. Using this approach, we are able to: (i) test hypotheses about the short-term and long-term responses to changes in the aggregate mix of bank capital funding; (ii) test hypotheses about the responses of the non-financial corporate and household sectors; and (iii) enhance the accuracy of the short-term dynamics and the accuracy of the macroeconomic simulations of the effect of increasing bank capital.

Key words: Capital requirements, DSGE models, UK economy, bank competition.

JEL classification: D22, D53, E27, G21.

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1 Introduction

In this paper, we investigate the response of the UK banking sector to changes in their risk-based capital ratios. We expect that banks respond by applying different lending spreads to private non-financial corporate (PNFC) borrowers and households in the short term, but apply the same margin to both sectors in the long run. This is because, in the short term, adjusting higher-risk loans with shorter maturity has a greater effect on risk-weighted assets (and hence the risk-based capital ratio) than longer-maturity, lower-risk assets. These characteristics coincide with loans to the PNFC sector (higher risk, shorter maturity), and to the household sector (predominantly mortgages – lower risk, longer maturity). Over the long run, banks recover the increase in their funding costs (driven by an increase in their capital ratio) on average across both sectors given existing strategies for portfolio mix and as funding costs are entirely fungible.

To test this hypothesis we expand on the approach first set out in Barrell, Davis, Fic, Holland, Kirby & Liadze (2009) by estimating a multi-equation model of average bank credit spreads to the corporate and household sectors and apply appropriate restrictions to the long-run component in the equations. Our approach to distinguishing between the short and long-term behaviour of banks towards different risk types is similar to Milne & Whalley (2001) and leads to an empirical model for testing short and long-term banks' responses to capital regulation. We illustrate the utility of the model by incorporating it into the large scale macroeconomic model NiGEM[1] and estimate the costs of the higher requirements to the UK economy, shedding light on the differences between the near-term economic impacts that emerge during a period of adjustment, and the long-run equilibrium.

1.1 The general approach

The model we develop uses bank risk-based capital ratios[2] to inform how prices in lending and deposit markets develop. In this context, we use capital as a portmanteau term to capture the gamut of liability instruments, which includes common equity, that regulation allows for the purpose of meeting regulatory requirements[3]. In addition, for the purposes of discussing our approach, we need to distinguish between capital requirements and bank capital resources. We define capital requirements as the minimum capital set by regulation that a bank must hold on its balance sheet in order to avoid regulatory intervention. Capital resources are the capital that a bank actually holds on its balance sheet. The difference between capital requirements and resources is a bank's 'voluntary surplus'. We use this nomenclature to avoid confusion with regulatory buffers[4] which were introduced with the Basel III reforms and form part of the regulatory capital requirements.

The modelling approach we employ is informed by the findings of theoretical studies relating banks credit supply adjustments to changes in capital requirements. General equilibrium studies such as Diamond & Rajan (2000) show that banks respond to higher capital requirements by reducing liquidity provision and increasing the cost of credit to both households and businesses. Other related studies such as Van Den Heuvel (2008) and Kashyap, Tsomocos & Vardoulakis (2014) find that capital requirements

[1] The National Institute for Economic and Social Research (NIESR) integrated General Equilibrium Model. See Appendix 1 of Barrell et al (2009) for a detailed description of NiGEM.

[2] In this approach, we consider only changes in banks' risk-based capital ratios, and not to other formulations of capital ratios such as the leverage ratio based on total, rather than risk-weighted, assets.

[3] The need to use "capital" rather than "equity" arises from the fact that regulation does not simply target equity as the sole, loss-absorbing liability instrument. Capital requirements allow, in part, the use of a number of liability instruments other than equity, but which cannot be classified simply as "debt".

[4] Basel III introduced a number of new regulatory buffers, such as the capital conservation and counter-cyclical buffers. Regulatory buffers differ from minimum requirements in that banks holding capital resources below the upper bound of their regulatory buffers face (various) restrictions on their activities until their resources once again exceed the buffers. In contrast, a breach of minimum capital requirements results in regulatory foreclosure of the bank's business. In effect, regulatory buffers duplicate to some extent banks' own voluntary surplus over minimum capital requirements pre-Basel III.

reduce the efficiency with which deposits can be used to finance real investment, even after taking into account the risk reduction associated with higher bank capital.

Supported by the general equilibrium results and incorporating short-term frictions, we develop an approach that incorporates the riskiness of borrowers by sector, demand side factors, bank competition, bank concentration and banks' aggregate capital ratio. We estimate the model using UK aggregated banking industry time-series data from 1989 to 2013 and macroeconomic controls.

Our empirical approach to estimating loan supply is to use a vector error correction model (VECM) similar to Gambacorta (2011). We use impulse responses to illustrate the relationships and the differences that arise in the short and long term. We show that lending relates to capital ratios through a time-evolving and complex relationship.

We perform a number of model adequacy tests and robustness checks to ensure that the estimated equations are stable and that the hypothesis tests on the coefficients are reliable. These checks include: testing for the stationarity of residuals; tests of restrictions; accurate representation of the dynamic structure; and tests of stable and significant coefficient values. As we control for changes in aggregate risk by sector and competition in the banking sector, we identify which factors are weakly exogenous. This helps us to deliver the most efficient possible estimation which includes only the relevant short-term variables.

We then simulate the impact of increases in bank capital ratios on credit supply and the transmission to overall activity in the UK economy by incorporating the VECM into NiGEM. Barrell et al (2009) explain this transmission through three main mechanisms: (i) the effects of credit spreads on household liabilities; (ii) the effect of credit spreads on the cost of physical investment; and (iii) the effect of lower credit supply on house prices. Each of these mechanisms affect aggregate demand in different ways as households, PNFCs and the housing market respond differently. The simulation illustrates these mechanisms and the role of our model enhancements to NiGEM. The model can be used to examine the impact of changes in regulatory capital requirements assuming these are binding on banks.

The remainder of this paper is organised as follows. Section 2 reviews the theoretical literature and describes the possible bank responses to increases in binding capital requirements setting out our empirical model. Section 3 discusses the data, estimation, hypothesis testing and derivation of the final dynamic model. We also present impulse responses showing the overall effect of changes in banks' funding mix on spreads. Section 4 implements a simulation exercise to illustrate the effect of changes in banks capital ratios on UK economic activity using the VECM models of section 3 incorporated into the NiGEM model. Section 5 then concludes with some comments on directions for future research.

2 Capital requirements, portfolio risk and bank costs

The Basel III proposals introduced in response to the 2008–09 financial crisis, significantly increased regulatory capital requirements for banks. Higher capital requirements and other new prudential requirements such as improved quality of capital, additional loss absorbing capital, liquidity requirements and the development of counter-cyclical macroprudential policy have the potential to increase bank funding costs and the cost of intermediation for all firms, thereby affecting the economy more broadly. Of primary concern is the overall impact that these changes have on the aggregate supply of credit from the banking sector to the economy[5]. In this section, we review the relevant literature and discuss the motivation for our approach.

2.1 Literature review

We start by discussing several views on the Modigliani & Miller theorem and how they shape the approach we take in this paper. In particular, the extent to which higher amount of equity in bank funding results in higher private costs for banks and changes in credit supply. We also discuss how banks use the surplus of capital they hold above regulatory requirements. We discuss the relationship between competition and bank equity funding; and the ability of banks to pass on to their customers an increase in funding costs. We also review general equilibrium models to understand the impact of capital requirements and credit supply on output. Finally, we discuss empirical evidence of the impact of Bank's cost pass-through on the overall economy.

2.1.1 The debate on bank cost of capital and credit supply

The Modigliani & Miller (1958) theorem established the corporate finance paradigm that a firm's choice of the composition of liabilities used to fund additional marginal projects should have no impact on the firm's value and its average funding costs. This proposition is a theoretical implication of equilibrium in perfect capital markets. However, the empirical significance of the Modigliani and Miller value-invariance proposition is less clear (see Miller (1988)). There may be several frictions that allow for departures from this theorem, both in the short and long run. The tax deductibility of debt as well as information asymmetries about the value of investment opportunities between managers and outside investors (Myers & Majluf (1984)) create disadvantages for equity funding with respect to debt. The consequence is that funding costs associated with higher levels of bank equity funding may not be offset by changes in the relative prices of equity and debt, leading to an overall increase in average funding costs.

Much of the work on bank capital and credit creation has focused in the past on how capital affects banks' safety and their ability to create liquidity. Froot & Stein (1998) model the relationship between capital structure and risk management under asymmetric information between external investors and bank managers. Their model is shaped by two key frictions: (i) it is costly for banks to raise new external capital at short notice, and (ii) it is costly to hold surplus capital over regulatory requirements, regardless of whether this capital is raised directly in markets or through time by retaining earnings. These frictions arise because some risks are illiquid and cannot be hedged in markets. Banks therefore hold some surplus capital to absorb these illiquid risks, but the optimal amount of surplus capital is limited. Kashyap, Stein, & Hanson (2010) argue that banks most important competitive advantage is their low cost of funding (and hence lending rates) compared to direct funding of non-financial business by another non-financial firm. Banks are thus vulnerable to even small changes in the cost of funding. However, they argue that banks should be able to operate with a less-leveraged capital structure (for example, after an increase in capital requirements) as long as they can raise this capital over time via retained earnings. This behaviour is consistent with the 'pecking-order' account of capital structure (Myers (1984), Myers & Majluf (1984)) – the hypothesis that managers prefer to finance new investment using retained earnings first, then by debt issuance and, finally, issuing equity only as a last resort. Under this hypothesis a bank may prefer to move to a higher capital ratio (and reduced leverage) by reducing new lending rather than by raising additional external equity.

[5] We are describing here the private costs to banks and the subsequent pass through to real economic activity in a state of the world absent financial crises. Benefits of higher capital requirements arise from avoiding costs associated with financial crises, which need to be modelled separately to understand the net benefits of financial regulation. See de-Ramon et al (2012) for discussion of both costs and benefits of capital regulation.

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In contrast, Admati, DeMarzo, Hellwig & Pfleiderer (2010) argue that changes in capital requirements should not have an impact on economic costs. They argue that even if there are costs from increasing capital ratios these are private costs to banks and not social costs. Their key arguments are that: (i) in the long run banks can adjust to higher capital ratios and, if there are short run frictions to raising new equity, the adjustment can be managed via alternative strategies (e.g. dividends policy or rights offering); and (ii) while the long-term tax-deductibility of debt creates private costs for banks and encourages debt issuance over equity there are no associated social costs if the tax is not distortionary[6]. However, they also recognise that aspects of regulation, e.g. deposit insurance, allows banks to borrow cheaply but high capital requirements prevent them from taking advantage.

2.1.2 Capital requirements and banks' voluntary capital surplus

One factor that could have an influence on the pass-through of costs associated with higher capital requirements is the extent to which banks flex their voluntary capital surplus. Banks have a number of reasons for holding a voluntary surplus, including: reducing the risk of costly, regulatory intervention due to a breach of minimum regulatory requirements; and a more cautious approach to certain risks not reflected in regulatory requirements to reduce the risk of bankruptcy.

Francis & Osborne (2009a, 2009b and 2012) studied banks' voluntary surplus for a large sample of UK banks between 1996 and 2005 and found that the surplus has varied substantially over time due to the risk appetite of the banks over the economic cycle. They also show that, holding all other factors constant, large UK banks maintain the size of their voluntary surplus' when discretionary supervisory requirements change.

When simulating the impact of changes in capital requirements we appeal to an assumption that the size of the buffer going forward and the results from a satellite bank by bank model hold[7]. In the future we expect that higher regulatory minima will be accompanied by smaller voluntary capital buffers. This is because the higher capital requirements will 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). We discuss this assumption further when we turn to the simulations of the model in Section 4 of the paper.

2.1.3 Competition, risk taking and capital ratios

Another factor that may affect the extent to which banks pass through costs to their customers is the extent of risk taking and competition between banks. Diamond (1984) showed that portfolio risk diversification (i.e. reduction in risk) is the key economic benefit of credit intermediation. Diamond presented a model where competing banks either duplicate fixed costs from monitoring, thereby increasing intermediation costs; or reduce the amount of risk monitoring, leading to higher risk in their loan portfolios. Dewatripont & Tirole (1994) take this result further, showing that higher rents enjoyed by banks in less competitive banking systems can sustain more stable banking systems. However, the relationship between financial stability and competition is less than clear and other theories argue that more competition can increase capital ratios and bank stability[8] as well as banking system stability[9].

[6] They further argue that other problems like shareholders' resistance to leverage reductions ('debt overhang' Myers (1977)) or the disciplinary role of leverage, neither create social costs nor have empirical support.
[7] For more details see de-Ramon et al. (2012).
[8] See for example Dewatripont and Maskin (1995) who show that competition reduces adverse selection. In addition, Perotti and Suarez (2003) develop an theory where forward looking banks gain market share by making more prudent loan decisions.
[9] Beck (2008) argues that smaller banks are easier to supervise and lead to a more stable banking system.

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Holding more loss-absorbing capital is one way banks can improve stability. Bolt & Tieman (2004) examined the relationship between competition and banks' voluntary capital surplus. Their main argument is that stronger competition reduces the weight on immediate profits relative to the expected stream of future profits. In response, banks increase their capital surplus to increase the chances of survival. A related theory by Allen, Carletti, & Marquez (2008) is that, in a competitive equilibrium, banks may hold levels of capital well above the levels required by regulation as higher capital provides greater incentives to monitor borrowers, lowering both the risk to capital and interest rates at which banks lend, which borrowers prefer[10]. This suggests that banks' capital surpluses should increase with competition. However, an opposing view argues that lower profitability can reduce loss absorbing capacity. Under intense competition banks generate lower interest rate margins and charge lower fees. Together these changes lead to lower profits and less financial resources to absorb shocks[11]. Reflecting these contrasting results, we again take an agnostic approach and incorporate a proxy for competition into our lending rates and capital ratio system of equations but do not hypothesise *ex-ante* on the direction of the effects that competition has on the system.

2.1.4 Insights from general equilibrium models

Even where an individual bank faces a rise in funding costs when moving to a higher capital ratio, the implications for the aggregate supply of credit depend on the response of both suppliers of funds (e.g. depositors and other investors), borrowers and other banks which may meet any unmet demand for credit in the economy. In this section, we review the insights on the question of aggregated impacts from general equilibrium models.

Diamond & Rajan (2000) develop a model where banks create liquidity for both depositors and entrepreneurs (borrowers) by reducing the uncertainty around likely returns from projects (and thereby reducing the likelihood of deposits runs). Outside bank capital can help to reduce the probability of financial distress at a bank, but does so at the cost of reduced liquidity (deposits) and credit creation. In addition, their model shows that higher capital funding either increases the bank's ability to extract repayments from borrowers or increases its willingness to liquidate projects.

Van Den Heuvel (2008, 2009) builds on Diamond & Rajan's model with the objective of measuring the social (welfare) cost that capital requirements impose. As in Diamond & Rajan, Van Den Heuvel's model shows that increasing bank capital increases stability and also reduces the moral hazard problem created by deposit insurance. However, there is an additional welfare cost of capital requirements which depends on the value households place on liquidity services derived from their deposits. Banks provide liquidity to households by accepting deposits and making loans to the productive sectors of the economy. Regulatory capital requirements reduce the ability of banks to perform this role, thereby reducing overall welfare. This model suggests that, in a general equilibrium context, the cost of real investment in the economy increases with capital requirements and estimates that the resulting welfare costs can be very large[12].

In a more recent paper, Kashyap, Tsomocos & Vardoulakis (2014) develop a model[13] of prudential regulation and bank runs which include externalities in the banks' portfolio risk choice. Their model incorporates some of the market failures behind the recent global financial crisis, in particular: over-

[10] In this analysis, deposit insurance reduces, but does not completely undermine, banks' incentives to finance themselves with higher capital.
[11] See for example Allen and Gale (2004).
[12] Study is based on data for the US banking system.
[13] Based on and extending the Diamond and Dybvig (1983) model of bank runs.

investment and excessive risk taking; as well as funding vulnerabilities that lead to under-investment[14]. The authors find that capital regulations affect real investment and households in different ways. Higher capital requirements reduce the externality associated with banks' risk taking decisions. Banks respond by investing in less-risky projects. Although this outcome may reduce investment, the effect is counterbalanced by lower risk of bank failure. The reduction in overall bank risk also has counterbalancing effects on deposits: deposit rates fall increasing households' finance costs, but household returns on deposits benefit from a lower probability of bankruptcy. However, beyond the point where the probably of a bank run is reduced to zero, higher capital requirements can only increase banks' private costs. This suggests that after an increase in capital requirements banks may adjust credit spreads for households and for PNFCs differently, but does not prescribe the size of any differences.

The Macroeconomic Assessment Group (MAG) established by the Financial Stability Board (FSB) and Basel Committee on Banking Standards (BCBS) developed an empirical assessment of the macroeconomic costs of transition to Basel III (Bank for International Settlements (2010b)). They focused on the economic outcomes when capital requirements increase for all banks. The report drew heavily on the Hölmstrom-Tirole and Diamond-Rajan models to assume that, to raise their capital ratios, banks can raise equity ratios from new equity issues and retained earnings, and may also respond by cutting back on lending. The latter effect is driven by much tighter monitoring and screening of borrowers. The report argued that banks ration credit advances to lower-quality borrowers but also see an increase in their costs from greater monitoring and screening activity increasing the cost of credit for all borrower types. This may result in high risk borrower types facing even higher increases in cost of credit.

The discussion of bank capital costs and general equilibrium models suggests two potential tests for a model of credit intermediation with regulatory intervention. First, as regulatory capital requirements rise there are private costs to banks that they will seek to recover from its customers. Second, high-risk borrowers may experience larger increases in the cost of credit than low-risk borrowers as banks adjust to higher capital funding, although it is not clear if such effects are permanent or transitory. We take an agnostic approach in our empirical model and implement an econometric test of the differences between households and PNFCs based on historical data in section 3.2.4.

2.2 What factors do banks' adjust to meet changes in capital requirements?

In this section we set out how the VECM framework can be used to model the bank industry price setting behaviour. We start with an approach similar to that of Barrell et al (2009) and Gambacorta (2011). We expand on these approaches by allowing different short and long-term effects, and different cost adjustments to different economic sectors, taking into account the various lesson from the literature noted in section 2.1.

We start by assuming that banks compete with each other imperfectly and have some market power which allows them to set prices. We assume banks' assets are loans to different sectors of the economy (e.g. households or PNFCs) that generate future returns for which an assessment of the idiosyncratic risk is made reflecting the likelihood of loan losses. On the liabilities side of the balance sheet, banks hold deposits and capital[15] from which the risk-based capital ratio is calculated as the bank's capital stock

[14] In summary this research finds that the regulator can produce Pareto improved outcomes by imposing limits on certain quantities (e.g. bank capital ratios) or prices (e.g. deposit rates). After a regulatory tool has reduced the risk of a bank run, additional regulation only makes sense for income redistribution purposes. For these reasons, optimal regulation can lower or raise investment depending on the weights put on different agents in society.
[15] For convenience we do not specifying wholesale funding separately. The influence on margins of both equity capital and other forms of funding are captured indirectly by the capital ratio.

divided by total risk-weighted assets such that $k = K/\sum_i r_i A_i$, where k is capital ratio, K is capital resources , r_i is the measure of idiosyncratic risk and A_i are assets for each sector i.

Banks face a capital[16] requirement k^* in terms of a minimum capital ratio below which banks cannot operate and which is a binding constraint on banks' balance sheets.[17] Banks optimise their own capital ratio by maintaining a voluntary surplus $(k - k^*)$ above regulatory requirements.[18] Banks apply a spread or margin (in terms of the interest rate charged) over their funding costs which may be different for different loan types to earn an overall return on assets.[19] Funding costs are driven by the deposit interest rates paid to customers and overall capital ratio k.

Now consider a change to regulatory requirements k^* which requires banks to change their capital ratios as the requirement is binding.[20] Banks can adjust their capital ratio to maintain their capital surplus by changing either the stock of capital K (either by raising new capital or retaining earnings), or total risk-weighted assets $\sum_i r_i A_i$, or both. Given that different loan types have different idiosyncratic risks, banks can change risk-weighted assets more rapidly by adjusting higher-risk assets relative to lower-risk assets. A further observation is that the capital ratio is dependent upon the stock of assets on banks' balance sheets. Changes to current loan spreads will not instantaneously adjust assets to the desired level but will adjust assets over time depending on the different maturity structure and risk profile of different loan portfolios. Different outcomes are therefore possible in the short term as banks make long-term adjustments to their balance sheet structures. That is, banks can change the rate of accumulation of loans in each sector by adjusting the spread charged to each sector differentially. In contrast, in the long run banks may grow the loan portfolio more evenly in all sectors and apply similar changes in spreads once a change in capital requirements has been fully absorbed and short-term constraints have passed.

So banks are simultaneously determining: lending spreads for different loan types based on their assessment of idiosyncratic risks for each type; capital resources (applied on average across loan types) which affect the overall cost of funding; and other market constrains such as competition and economic activity that may affect banks decisions on spreads and capital resources.

A VECM system allows us to model jointly the long-run and short-run interactions between the capital ratio, sectoral spreads, demand and risks, and competition in the banking industry as a whole. We include six variables in this system: two loan types representing the industry average PNFC and household credit spreads, the weighted average risk based capital ratio, UK company insolvencies (as a proxy for PNFC lending risk), the unemployment rate (a proxy for household sector lending risk) and measures of the extent of competition and market concentration (the Boone Indicator and loan concentration).[21] In general, the VECM system can be written as:

$$\Delta X_t = (\boldsymbol{\alpha}.\beta')X_{t-1} + \sum_{j=1}^{k-1} \boldsymbol{\Gamma}_j \Delta X_{t-j} + \boldsymbol{\Phi} D_t + \boldsymbol{\varepsilon}_t \tag{1}$$

[16] For the purpose of this discussion, we assume that all firm capital is regulatory capital and abstract from any further distinction.

[17] This assumption is reasonable for an informationally opaque banking system in which there is a principle-agent problem. The true risk of a bank's operations is hidden from the bank's counterparties (shareholders, depositors and other creditors) so managers have an incentive to maximise leverage and minimise capital. Regulators, attempting to correct this market failure, will require capital above the amount selected privately by the banks' managers.

[18] We assume that maintaining capital resources k above the capital requirement k^* is a necessary regulatory condition for a bank to continue to provide deposits. If a bank has resources less than requirements, the regulator will shut down the bank.

[19] The interest rate that a borrower faces is made up of the spread charged by the bank and the bank rate set by the central bank. Individual banks have no influence over the central bank rate which (in general) affects the level of both lending and deposit rates in the same ratio.

[20] We assume here for convenience that the regulator does not instantaneously adjust requirements such that banks cannot be compliant.

[21] We also consider UK output gap as a proxy of cyclical demand (taken from the NiGEM model, See Barrell et al. 2009). We excluded it from the final model versions because: it may be measured with errors; as a proxy for the economic cycle it may be correlated with unemployment; the model results and characteristic are very similar (lag order, number of cointegrating relationships) not altering our conclusions.

where X_{t-1} is the first lag of a vector that includes the i endogenous variables, ΔX_t is the coincident first difference and ΔX_{t-j} is the j-th lag of the first difference on the same vector. The elements of the coefficient $\boldsymbol{\alpha} = [\alpha_1 \quad \cdots \quad \alpha_i]'$ contains the loading matrix for each of the m cointegrating equations corresponding to endogenous variable i and β' is the cointegrating matrix containing the m cointegrating vectors. The rows of each component α of the loading matrix $\boldsymbol{\alpha}$ represent the speed at which the long-term adjustment is made and can be different for each of the i endogenous variables. The elements of $\boldsymbol{\Phi} = [\Phi_1 \quad \dots \quad \Phi_i]'$ and each $\boldsymbol{\Gamma}_j = [\Gamma_{1j} \quad \cdots \quad \Gamma_{ij}]'$ are the rows of Johansen's coefficient matrices associated with the lags of the n exogenous variables D_t (non-stochastic trends or dummies) and the first difference of the regressors ΔX_{t-j}, respectively. The coefficients of each Γ determine the short term dynamics of the model and can also be different for each of the i endogenous variables. Lastly, the matrix product $\beta' X_{t-1}$ is a vector containing the cointegrating or long-run equations.

2.2.1 Evidence of long-term and short-term adjustments by economic sector

To estimate the VECM system, we expand on the approach taken by Barrell et al (2009) who estimate the relationship between capital regulation and the cost of credit in the economy as part of a UK aggregate banking sector credit supply and demand system[22]. Their approach is to take the amount of credit extended to households and PNFCs separately, linking those amounts to households' disposable income and PNFCs' profits, respectively, and to the cost of credit for each sector (measured by the spread between lending and deposit rates). In turn, they link the cost of credit to bank's loan portfolio risk, cyclical demand factors, aggregated capital ratios and banks' capital surplus. The authors use UK data between 1989 and 2008 to estimate multiple econometric models using the standard single-equation Engle-Granger approach and find that in the long run a one per cent increase in the risk weighted capital ratio increases credit spreads to households by 6.4 basis points and PNFC credit spreads by 19.7 basis points. This represents a 'not insignificant' impact on the cost of finance for the real economy. For example, these coefficients imply a 197 basis points increase in the cost of physical investment funded by banks for around a ten percentage point increase in UK risk based capital ratios (such as those imposed by Basel III[23]). Moreover, according to these models, the cost (in terms of wider credit spreads) for PNFCs *permanently* increases three times more than the cost for households.[24]

3 Data and Empirical findings

In this section we use the VECM system described in equation (1) to estimate a model of banks' adjustments to changes in capital resources. The aim is to achieve three separate statistical inference objectives: (i) overcome drawbacks of the standard Engle-Granger cointegration approach, in particular its inability to deal with multiple cointegrating relationships; (ii) to allow for endogenous changes in the risk based capital ratio ($rbcr$) given that banks make decisions on both credit spreads and equity capital; and (iii) take a flexible approach towards any differences in the long-term relationship between credit spreads for PNFCs and households which the single equation approach does not allow us to do.

The econometric strategy for model selection and testing follows closely that of Hendry and Juselius (2001).[25] In section 3.1 we briefly discuss the main time-series characteristics of the data and present

[22] The equations estimated in Barrell et. al. (2009) became part of subsequent versions of the National Institute of Social and Economic Research (NIESR) model NiGEM. For more details on NIGEM see "Appendix 1: The Structure and Use of the NiGEM Model" of the same study.
[23] Prudential Regulation Authority (2013) estimated that UK deposit-takers would need to increase their total risk-based capital ratio by around ten percentage points between 2009 and 2019. One caveat on the estimate above is that the increase in lending rates (as distinct from net interest margins) may be lower because the central bank can set lower base rates when aggregate demand and inflation have fallen and banks may also reduce deposit rates.
[24] We reproduce the results of Barrell et al (2009) using updated banking sector data. We find that in the long-term when the capital ratio increases by one percentage point, spreads increase by around 13 basis points for households and 17 basis points for corporations.
[25] We undertake all estimation and tests using the time-series econometric software EViews version 9.5 (Enterprise Edition).

stationarity tests for the key variables. Section 3.2 sets out the general model, model selection and test of restrictions and the identification strategy. Section 3.3 presents an innovative approach to the short-term relationship tailored to optimise its use within the large scale macroeconomic model NiGEM.

3.1 Data sources and characteristics

We use a number of official data sources in our estimation, including the Bank of England, UK Office of National Statistics (ONS) and other multilateral institutions. Interest rate data are taken from the UK resident monetary financial institutions' series in the Bank of England Interactive Database. Capital and risk-weighted assets are industry aggregates from the Bank of England database HBRD.[26] Appendix 1 describes the data in more detail including data definitions, sources and availability for each of the model variables.

Figure A1.1 to Figure A1.7 show the evolution of the model variables and suggest that they are all non-stationary. The sample mean, standard deviation and unit root test for each of the main variables are shown in Table 3.1. The variables are integrated of order I(1) according to both the Dickey-Fuller and Phillips-Perron tests.

Table 3.1: Unit root tests and data statistics

	Variable sample mean	Variable standard deviation	Number of Observations	Dickey Fuller t-Statistic[1] (probability)[2]	Phillips Perron t-Statistic (probability)[2]
PNFC credit spread ($corpw$)	2.51	0.26	104	-2.36 (0.157)	-2.05 (0.264)
Households credit spread ($mortw$)	1.75	0.56	189	-1.84 (0.359)	-1.79 (0.386)
Risk based capital ratio ($rbcr$)	12.86	1.55	97	1.92 (1.000)	2.35 (1.000)
Loan concentration (HHI))	0.08	0.03	97	0.06 (0.961)	-0.36 (0.911)
Boone indicator ($boone$)	-4.73	1.86	97	-1.14 (0.698)	-0.36 (0.911)
Company Insolvency ratio ($insolr$)	1.14	0.52	164	-2.60 (0.095)	-1.51 (0.523)
Unemployment (U)	7.16	2.34	177	-2.31 (0.168)	-1.58 (0.492)

Source(s): See appendix 1. Overall data range 1961Q4 to 2013Q4

Note(s):

[1] Augmented Dickey Fuller with lag selection by Schwartz information criterion;

[2] the probability is for rejecting the null hypothesis that a unit root is present.

3.2 The basic unrestricted model

3.2.1 Lags and order of cointegration

In order to determine the lag order of the VECM we start by estimating an unrestricted VAR system. We use two model specifications: one using the Boone indicator, a direct measure of competition and one using loan concentration (HHI) as a proxy for competition. De-Ramon and Straughan (2016) discuss the properties of each of these variables, noting that the Boone indicator is a more direct measure of competition than measures of loan concentration. Most of the lag-order tests (the final prediction error, Akaike, Schwartz and Hannan-Quinn information criteria) suggest two lags (see Table A2.1 in Appendix 2). For the model that includes the Boone indicator the likelihood ratio test suggests a longer lag structure. However, Lütkepohl (1993, section 4.2) discusses the difficulties in determining the significance level of this LR test with a longer lag structure. For that reason we use two lags for the remaining model estimation.

[26] See de-Ramon et al. (2017).

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We then use the unrestricted model with the endogenous variables identified above to determine the number of cointegrating relationships. Table 3.2 shows the results of the Johansen cointegration test rejecting a maximum of one but not rejecting a maximum of two relationships[27].

Table 3.2: Johansen cointegration tests

Hypothesized No. of CE(s)1	Eigenvalue	Trace Statistic	5 percent Critical Value	Probability[2]
Unrestricted Cointegration Rank Test (Trace) using Boone indicator				
None *	0.5043	147.76	95.753	0.0000
At most 1 *	0.3490	85.302	69.819	0.0018
At most 2	0.2389	47.095	47.856	0.0588
At most 3	0.1701	22.803	29.797	0.2559
At most 4	0.0662	6.2072	15.495	0.6710
At most 5	0.0013	0.1136	3.8415	0.7360
Unrestricted Cointegration Rank Test (Trace) using loan concentration				
None *	0.3706	114.78	95.754	0.0013
At most 1 *	0.2594	73.575	69.819	0.0243
At most 2	0.2079	46.846	47.856	0.0620
At most 3	0.1509	26.107	29.797	0.1255
At most 4	0.1147	11.552	15.495	0.1797
At most 5	0.0080	0.7127	3.8415	0.3985

Source(s): Authors' own calculations using EViews version 9.5 (Enterprise edition)
Note(s):
[1] The asterisk (*) denotes rejection of the hypothesis at the five percent level
[2] Presents the MacKinnon-Haug-Michelis (1999) probability values.

As a robustness check, we include a third cointegrating relationship and assess the stationarity of the residuals, as shown in Figure A2.8 in Appendix 2. The graph shows evidence that the third cointegrating relationship is non-stationary as it results in much larger errors than the first and second relationships and drift-off from positive to negative values. From the tests above, we proceed with a model including two cointegrating relationships and two quarterly lags.

3.2.2 Weak exogeneity test

We now look at whether any variables in the system are weakly exogenous in the long-run in order to simplify and reduce the size of the system. This approach improves estimation efficiency[28] in addition to simplifying the discussion of coefficient values. Table 3.3 shows the weak exogeneity tests for individual variables as well as joint tests. The outcome of these tests show that insolvencies, unemployment and competition (as measured alternatively by the Boone indicator and the loan concentration index) are exogenous for the purpose of estimation.[29] The joint weak-exogeneity test for all three variables confirms that we can efficiently estimate the conditional system holding them exogenous. The table suggests that only three variables should be endogenous in the final model: PNFC spreads ($corpw$), household credit spreads ($mortw$) and the risk based capital ratio ($rbcr$).

[27] An alternative test based on maximum eigenvalue finds one cointegrating relationship for the model with loan concentration as a proxy for competition. The maximum eigenvalue and trace tests are equivalent in large samples. We follow the econometric evidence of Lütkepohl who argues these test do not diverge in large samples but finds that on smaller samples trace tests are preferable.
[28] See for example the discussion in Johansen (2006), page 555.
[29] We also test a separate system using the Herfindahl-Hirschman index of loan concentration which is also weakly exogenous.

Table 3.3: Weak exogeneity tests[1]

	Chi-square	Probability[2]
PNFC spreads ($corpw$)	30.82	0.00**
Household spreads ($mortw$)	19.31	0.00**
Risk based capital ratio ($rbcr$)	6.24	0.04*
Company insolvency ratio ($insolr$)	1.91	0.38
Unemployment (U)	3.43	0.18
Competition – Boone indicator ($boone$)	2.19	0.33
Concentration (HHI)	0.17	0.92
Joint test[3]: $insolr$, U , $boone$	11.44	0.08
Joint test[4]: $insolr$, U ,HHI	8.58	0.20

Source(s): Authors' own calculations using EViews Enterprise edition version 9.5.
Note(s):
[1] The null hypothesis is that the variable is weakly exogenous
[2] * indicates that the we reject the null hypothesis at the 5% level, ** at the 1% level
[3] Test is estimated from a VECM consisting of $corpw$, $mortw$, $rbcr$, U, $insolr$ and $boone$
[4] Test is estimated from a VECM consisting of $corpw$, $mortw$, $rbcr$, U, $insolr$ and HHI

We interpret the weak exogeneity results for insolvencies, unemployment and competition as an indication that they influence the long-run level of the endogenous variables, but not vice-versa. That said, this result does not preclude that short-run movements in the endogenous variables may influence the weakly-exogenous variables. The intuition behind this result is that long-run macroeconomic risks and market competition are stochastic trends whose levels are determined by other factors not included in the model. Following Hendry and Juselius (2001) we proceed with a reduced model including the PNFC credit spreads, household credit spreads and the risk-based capital ratio as endogenous variables.[30]

We partition the model, separating the endogenous variables from the weakly-exogenous ones by defining $X_t = [X_t^e \quad X_t^w]'$ and re-specifying the model[31] as:

$$\Delta X_t^e = (\boldsymbol{\alpha_1}.\beta')X_{t-1} + \sum_{j=0}^{k-1} \boldsymbol{\Gamma}_j \Delta X_{t-j} + \boldsymbol{\Phi} D_t + \boldsymbol{\upsilon}_t \quad (2)$$

where $\boldsymbol{\alpha_1}$ corresponds to the rows of the endogenous variables. We can efficiently estimate β from the partial model and test the long-run properties by imposing restrictions on the components of β.[32]

3.2.3 The unrestricted models

In this section we use the VECM described in equation (1) to estimate an unrestricted model taking into account the lag length, number of cointegrating equations and weak exogeneity of variables as set out above. Table A2.2 of Appendix 2 presents the full regression results for the models using the Boone indicator and loan concentration index as a proxy for competition and market concentration respectively. De-Ramon and Straughan (2016) show that in the UK for the period under study these two

[30] Hendry and Juselius (2001) argue that this reduces the need for including structural breaks and dummies in the model estimation as many of the shocks affecting the banking sector are present in the weakly exogenous variables as common stochastic trends.
[31] See equation 32 in Hendry and Juselius (2001)
[32] One alternative we explored was to isolate the 3 endogenous variables and investigate whether they were cointegrated when excluding the weakly exogenous factors (competition, insolvencies and unemployment). For this reduced set of variables we found that there are 2 cointegrating relationships between the endogenous variables and that the long-term parameters have similar characteristics to our preferred model. We do not use this reduced model as: (i) it lacks risk factors that we know influence bank spreads; and (ii) it limits the way the model interacts with the wider NiGEM model.

measures are correlated, particularly over the long term. Therefore, it is not surprising the two models have similar estimated coefficients.

We normalise the estimated cointegrating equations such that the coefficients on PNFC and household spreads are equal to one and zero respectively in the first cointegrating equation and minus one and one respectively in the second cointegrating equation. The first cointegrating equation therefore explains the long-run adjustment of PNFC spreads to the capital ratio while the second cointegrating equation explains the adjustment of household spreads to the capital ratio. The estimated cointegrating equations from Table A2.2 for the model including the Boone indicator[33] are shown below in equations (3) and (4).

$$corpw_t = 0.9986 + 0.1147 rbcr_t \quad (3)$$

$$mortw_t = corpw_t + 0.1511 - 0.0820 rbcr_t$$

$$= 1.1497 + 0.0327 rbcr_t \quad (4)$$

The coefficient on $rbcr_t$ in equation (3) is significant at the one percent level and indicates that when the capital ratio increases by one percentage point, the PNFC spread increases by around 11½ basis points (or just under 12 basis points in the model using loan concentration). The final coefficient on $rbcr_t$ in equation (4) shows that the long-run influence of the capital ratio on household spreads is 3 basis points, although this coefficient is not significantly different from the coefficient in equation (3).[34]

The two models indicate that there is strong feedback from the cointegrating relationships to the short term movement in the spreads and capital. In particular, the loading parameters on the first cointegrating relationship are large and significant. The model using the Boone indicator has a coefficient of -0.66 for corporate lending and -0.41 on household lending which suggests a relatively quick adjustment from disequilibrium, particularly on corporate spreads. There is a degree of positive persistence (through the lagged dependent variable coefficients) which is strongest for corporate spreads.

3.2.4 Long run impact on spreads – the restricted model

In this section we test the hypothesis noted in section 2.1.4 of whether differences in the impact of capital ratios on PNFC and household credit spreads are transitory or permanent. That is, we test whether the level of PNFC and household credit spreads with respect to the risk-based capital ratio are the same in the long run when other factors are held constant. We test this hypothesis by placing additional restrictions on the cointegrating matrix β in equation (1). For the vector of endogenous variables $X_t^e = [corpw_t \quad mortw_t \quad rbcr_t]'$, the normalised cointegrating matrix used for the unrestricted model above is:

$$\beta' = \begin{bmatrix} -1 & 0 & \lambda \\ -1 & 1 & \mu \end{bmatrix} \quad (5)$$

where the second column contains the normalised coefficients on $mortw$ discussed above and λ and μ are the coefficients on $rbcr$ for each cointegrating equation.[35] We can impose the restriction that credit

[33] We exclude the parameters associated with the weakly exogenous variables from these expressions for simplicity. They can be found at the bottom of Table A2.2 of Appendix 2.
[34] The coefficient on $rbcr_t$ in the second cointegrating equation before substituting for $corpw_t$ from the first equation is not significantly different from zero.
[35] The normalisation of the coefficients in β' helps to visualise the effects but does not disturb the statistical properties of the model

spreads respond equally to changes in the capital ratio *ceteris paribus* directly in the second cointegrating equation by setting $\mu = 0$ such that:

$$\beta' = \begin{bmatrix} -1 & 0 & \lambda \\ -1 & 1 & 0 \end{bmatrix} \tag{6}$$

In other words, we restrict the cointegrating equations such that the behaviour of credit spreads for PNFCs and households with respect to the risk based capital ratio is determined as:

$$corpw_t = \lambda\, rbcr_t \tag{7}$$

$$mortw_t = corpw_t \tag{8}$$

and test the validity of this restriction.

Table A2.3 of Appendix 2 presents the results for the model after imposing the restriction. The results of the likelihood ratio test show that the restrictions to the cointegrating equations cannot be rejected using either of the two competition proxies. The implication is that, in the long run, the final change in the PNFC and household spreads that can be attributed to a change in the capital ratio must be the same, and of the order of 9 basis points for a one percentage point increase in the capital ratio. However, the speed of adjustment may be different due to difference in other coefficients, for example, due to persistence and the relatively smaller loading factor that affect household spreads compared to PNFC spreads.

Table A2.3 shows the short-term adjustment coefficients estimated using this approach. PNFC credit spreads ($\Delta corpw$ in the table) adjust quickly to a shock in the first cointegrating equation (with a coefficient equal to -0.66) but less quickly to disequilibrium in the second cointegrating relationship (with coefficient -0.17). Household credit spreads ($\Delta mortw$) adjust much more slowly to the first cointegrating vector (with coefficient -0.40 but with a similar response to the second cointegrating equation, as with PNFC credit spreads. These coefficients suggest that, in response to an increase in the risk-based capital ratio, it would take the PNFC credit spread three quarters to achieve 95% of the adjustment, while it will take household credit spreads 1½ years to adjust by the same amount.[36] This suggests 'leader-follower' behaviour as in Hendry & Juselius (2001), where shocks to capital ratio affect PNFC credit spreads first.

3.2.5 *Crisis period and coefficient stability*

De-Ramon et al. (2016), which investigated the effect of individual bank capital requirements on balance sheet growth found that the empirical relationship changed following the 2008-09 UK financial crisis. The authors found that banks reduced loan growth in response to an increase in individual capital requirements, but that the reduction in loan growth became less prominent after the crisis, as banks complied with capital requirement by issuing or retaining more capital. In this section, we estimate additional regressions to investigate if the price setting process changed in recent periods with respect to earlier periods.

Table 3.4 presents additional results for the restricted model using the two different competition proxies estimated over different periods or including dummy variables for the crisis period. Columns (1) and (2) of the table present the two model versions estimated for the period 1991 to 2005. The year 2006 marks a significant regulatory milestone in the UK with the announcement of the introduction of Basel II.

[36] Different model normalisation ($mortw$ adjusting to $rbcr$ in the first long term-relationship) results in the same short-term adjustment.

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Subsequent years saw the implementation of new rules on capital quality, risk measurement and further prudential regulation changes with the introduction of European Directives CRD III and CRD IV.[37] Estimating the model using data from the early period results in similar inferences about the long-term effect of the capital ratio on spreads (see test of long-term equality of the capital ratio coefficient). However, the long-term effect of a one percentage point change in the capital ratio is about twice as large (around 22bps) compared to the model that includes more recent data.[38] These results are consistent with de-Ramon et al (2016) and suggest that banks modified their behaviour with respect to capital requirements in recent years and loan supply changes are less prominent than in the past.[39]

Columns (3) and (4) present results for the overall period after including period dummies to account for higher volatility during the crisis period. The long-term capital ratio coefficient increases by between one and three basis points suggesting that data volatility may be dampening the coefficient to some extent. Most of the variables show a significant increase in model adjustment (R-square) the latter also true for models (1) and (2) that also exclude the crisis period.

Table 3.4: Summary results on coefficient stability[1]

	(1)	(2)	(3)	(4)
Competition proxy	**Boone**	**Loan concentration**	**Boone[2]**	**Loan concentration[2]**
$rbcr_{t-1}$	-0.226**	-0.224**	-0.105**	-0.122**
	(0.037)	(0.051)	(0.020)	(0.017)
Test of long-term equality of the capital ratio coefficient:				
LR Chi-Sq(1) value	1.935	0.190	0.000	0.988
Probability	0.164	0.663	0.989	0.320
Sample Period	1991Q4-2005Q4	1991Q4-2005Q4	1991Q4-2013Q4	1991Q4-2013Q4
$\Delta corpw_t$				
R-squared	0.455	0.450	0.547	0.537
Adj. R-squared	0.321	0.315	0.447	0.434
$\Delta mortw_t$				
R-squared	0.500	0.484	0.174	0.218
Adj. R-squared	0.378	0.358	-0.010	0.045
$\Delta rbcr_t$				
R-squared	0.314	0.313	0.510	0.518
Adj. R-squared	0.147	0.145	0.401	0.411

Source(s): Authors' own calculations using EViews Enterprise edition version 9.5.
Notes:
[1] ** indicates significance at one percent level.
[2] Dummies included for 2007Q4, 2008Q1, 2008Q2, 2008Q3 and 2008Q4.

3.2.6 Impulse responses

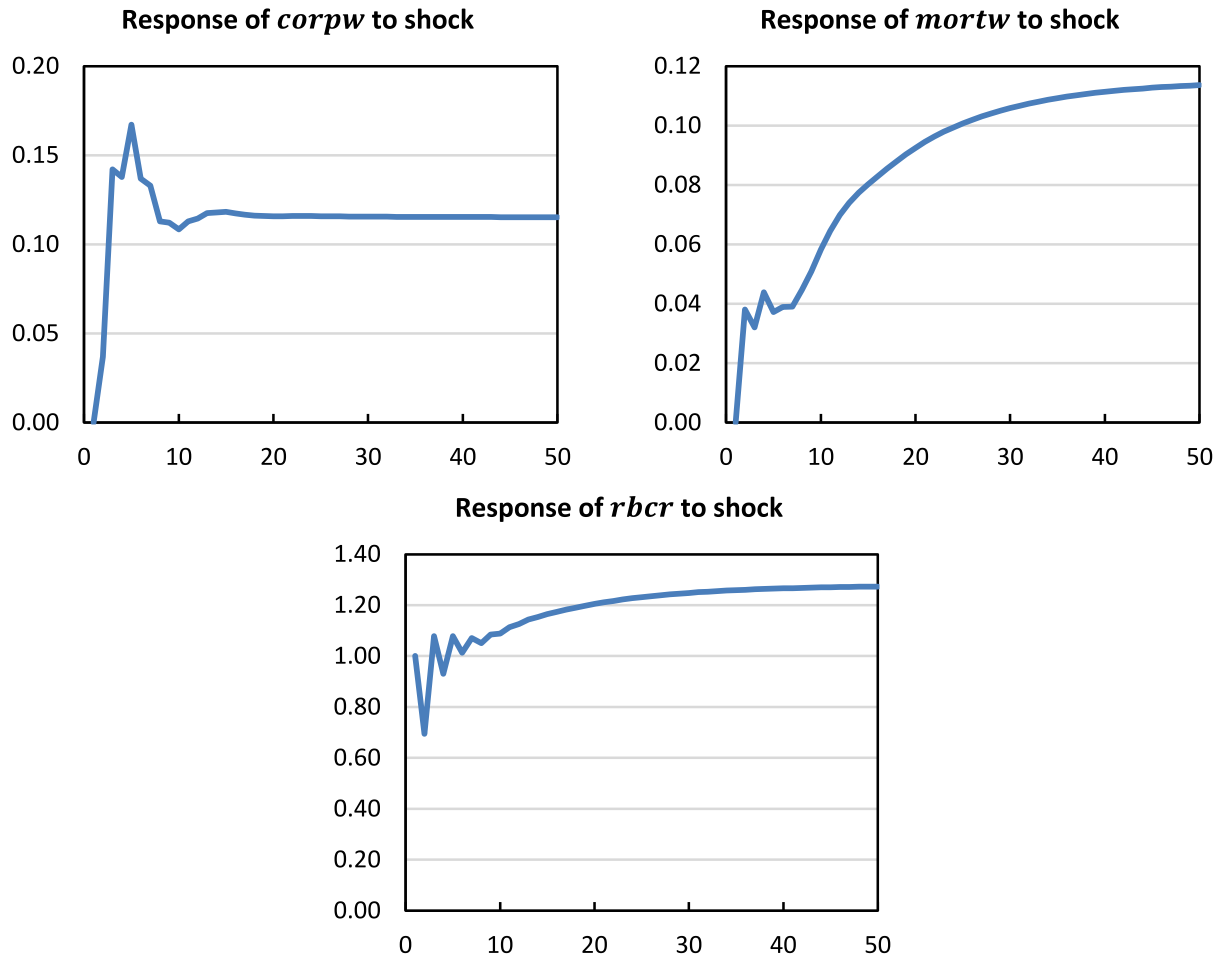
In this section we discuss impulse responses to a shock in the model variables. In particular, we are interested effects of prudential policy shocks (in the form of higher capital requirements) on the sectoral spreads. We use a shock identification strategy following recent literature (e.g. Berrospide and

[37] Including also the periods immediately before the crisis 2006 and 2007 results on similar estimates but not long-run equality of the capital ratio effects.
[38] Additional regressions using even earlier data or including the pre-crisis years confirm this 22bps result.
[39] We estimate the model using post-2005 data only and crisis period dummies. The capital ratio estimate is around 6bps with a standard deviation of 2½bps. However, this estimate is over a relatively short period data (8 years) for an accurate long-run estimate and crisis period data may be dampening the coefficients as discussed below.

Edge (2010)) where shocks from the credit sector do not alter spending, production and overall price determination immediately. The weak exogeneity tests shown in section 3.2.2 support this assumption. In addition, we assume that a capital requirement shock will affect capital resources immediately but will not affect the spread of loans to deposits until later. This assumption is consistent with evidence from US banks studied by Hancock, Laing, and Wilcox (1995). These authors show that delays in arranging new loans and loan price stickiness mean that capital adjusts much more quickly than loan volumes. The impulse response uses our preferred model estimated from 1991 to 2013 and using the Boone indicator as a proxy for competition.

Figure 3.1 below shows the impulse response functions of $corpw$, $mortw$ and the $rbcr$ to a one percentage point shock on $rcbr$. The graphs show that a widening of $rbcr$ by 1.3 percentage points corresponds to an increase of 1.2 basis points on both PNFC and household credit spreads in the long run.

Figure 3.1: Impulse responses for the basic model



Source(s): Authors' own calculations using EViews version 9.5 (Enterprise edition).

The adjustment coefficient on the error correction relationships explains the dynamic characteristics of these impulse responses, in particular: the fast response of PNFC credit spreads to changes in capital ratio; and the slow but similarly paced response of both credit spreads to a disparity between them. This is consistent with the idea that banks adjust credit spreads for higher risk and more price elastic sectors more acutely than for lower risk / less price elastic sectors in order to move more quickly towards new capital ratios. PNFC credit spreads overshoot initially, while household credit spreads respond more slowly, rising steadily to the long-run outcome. In the first few quarters, PNFC credit spreads increase by as much as 17 basis points while the risk-based capital ratio increases by around 1 percentage point. Over time the difference between PNFC and household credit spreads disappears converging to an identical long-run response for both sectors.[40]

3.3 Second stage estimation: short-run model for NiGEM

In this section we estimate the short-term equations that will be incorporated into the NiGEM model. The objective is to improve the short-term dynamics of the restricted model estimated in section 3.2.4 and to eliminate irrelevant effects for use it within the larger macroeconomic model (NiGEM). These improved models can give further insights on short-term responses to changes in bank capital requirements, competition and risk. Our approach allows us to include all the relevant short-term dynamic effects and do a stepwise model selection.

3.3.1 Methodology

In the Johansen estimation method the short-run equations are for the one-period difference of the model endogenous variables (e.g. $\Delta corpw$ in Table A2.3). These models include the error correction terms from the long-term equation residuals and several lags of the endogenous variables. We modify this approach using a two-step estimation method for the short-term equations including a broader set of one-period difference variables on the right hand side. We implement a stepwise model selection to eliminate non-significant factors, thereby improving model accuracy.

We ensure that our estimates are unbiased and efficient through a battery of tests on the model variables, residuals and on the cointegrating relationship residuals. Johansen (1988) discusses the properties of the long-term coefficient estimates from VECM systems. In particular, the error correction terms are consistent in probability which allows us to introduce them in a standard OLS regression estimation of a system of first-difference variables which are all stationary. Table A2.4 shows the characteristics of the cointegrating vectors for the models above. In general, these terms are distributed close to normal[41] indicating that the long-term equation residuals are well behaved and are close to the true error correction terms. We use the residuals from our preferred long-run model (from Table A2.3 for the model using the Boone indicator), labelled as Cointeq11 and Cointeq12. We implement an efficient OLS estimation and perform stepwise model selection from the same set of variables in all the short-term models.

3.3.2 Results

Table 3.5 presents the results for two versions of the short-term dynamic model. The first version (Model 1 in columns (1) and (2)) includes just the dynamic structure of the differences in credit spreads and capital requirements (the endogenous variables). The second version (Model 2 in columns (3) and (4)) adds a broader set of variables, including lagged values of all the variables of the long-term equation, namely: insolvencies, competition and unemployment. Table 3.5 shows the final models chosen from a stepwise model selection procedure. In general, the post-estimation tests perform better in the augmented models. This means that the inferences from Model 2 are likely to be more accurate. The models seem adequate except for the presence of heavy tails (shown by the large kurtosis) in the household spread equation (2).

[40] This model uses the Boone indicator, a measure of competition. We also estimated an alternative model using a measure of loan concentration. The insights above remain the same so our model is robust to using competition or concentration. Full results have been omitted for the sake of brevity but can be made available on request.
[41] There is some evidence of excess kurtosis but that is a lesser concern for consistency of estimators, as discussed in Hendry and Juselius (2001).

Table 3.5: Short term credit spread equations

	Model 1		Model 2	
	PNFC spread ($corpw$) (1)	**Household spread ($mortw$) (2)**	**PNFC spread ($corpw$) (3)**	**Household spread ($mortw$) (4)**
Error correction terms:				
$CointEq11_{t-1}$	-0.681	-0.287	-0.547	-0.508
	(0.095)	(0.125)	(0.087)	(0.127)
$CointEq12_{t-1}$	-0.171	-0.182	-0.125	-0.251
	(0.033)	(0.047)	(0.036)	(0.049)
PNFC credit spreads:				
$\Delta corpw_{t-1}$	0.240		0.223	0.205
	(0.085)		(0.080)	(0.117)
$\Delta corpw_{t-2}$	0.163			
	(0.087)			
$\Delta corpw_{t-3}$	0.178			
	(0.088)			
Household credit spreads:				
$\Delta mortw_{t-2}$	0.134		0.160	
	(0.068)		(0.059)	
$\Delta mortw_{t-3}$		-0.306		-0.277
		(0.087)		(0.084)
Risk based capital ratio:				
$\Delta rbcr_{t-2}$	0.082		0.071	
	(0.027)		(0.026)	
Boone indicator:				
$\Delta boone_{t-1}$				0.055
				(0.022)
$\Delta boone_{t-3}$			-0.063	
			(0.015)	
Corporate insolvencies:				
$\Delta insolr_{t-2}$				-0.845
				(0.281)
$\Delta nsolr_{t-3}$			0.400	
			(0.169)	
Unemployment:				
Δu_{t-3}				0.171
				(0.071)
R-squared	0.543	0.273	0.583	0.463
(Adjusted)	(0.497)	(0.246)	(0.534)	(0.387)
Log likelihood	95.66	62.866	103.52	74.22
F-statistic (prob)	(0.000)	(0.000)	(0.000)	(0.000)
Sample	92Q1 13Q4	91Q2-13Q4	91Q3 13Q4	91Q3 13Q4
Observations	88	91	90	90
Number of search regressors	10	16	18	23
Normality				
Jarque-Bera (prob)	(0.141)	(0.000)	(0.424)	(0.007)
Skewness	0.356	0.765	0.297	0.621
Kurtosis	3.75	4.84	3.32	4.07
Serial Correlation				
(Breusch-Godfrey LM test)	(0.078)	(0.818)	(0.187)	(0.248)
Durbin-Watson stat	2.104	2.10	2.242	2.131
Heteroskedasticity				
(Breusch-Pagan-Godfrey)	(0.615)	(0.275)	(0.054)	(0.216)

Source(s): Authors' own calculations using EViews version 9.5 (Enterprise edition).
Note(s): The models also include some binary dummy variables for the crisis period.

Table 3.5 re-iterates the result from the earlier models that PNFC credit spreads adjust much faster than household credit spreads[42]. The strength of the lagged value of the dependent variable in the PNFC credit spread equations indicates that there is also a degree of stickiness; banks tend to apply these changes over two to three quarters. Similarly, PNFC and household credit spreads continue to indicate a degree of leader-follower behaviour.[43] This is suggested by two features of the coefficients: first, PNFC credit spreads adjust quickly to changes in the risk based capital ratio $rbcr$ while household spread adjust more slowly. Second, household credit spreads adjust more quickly to a differential with PNFC credit spreads compared the corresponding adjustment of PNFC to a differential with household credit spreads. These characteristics are present in both the basic and the augmented model specifications.

Competition affects credit spreads in the short-run. The short-run coefficients on household spreads indicate that an increase in competition leads to a reduction in spreads. According to our estimates, the maximum absolute one-quarter change in the Boone indicator is just over one[44]. Therefore, the estimated coefficients imply that if the Boone indicator moves by minus one (indicating more intense competition) in one quarter, household credit spreads would see a short-term fall of 15 basis points. In contrast, the short-run coefficient on corporate spreads has the opposite effect. A negative change in the Boone indicator by one unit will lead to a 4 basis points increase in corporate spreads. This outcome suggests that, in the short-term, banks cross-subsidise activities across their balance sheets by reducing costs for corporate borrowers relative to households as competition intensity decreases[45]. Finally, insolvencies affect household credit spreads in the short-run, with higher insolvencies leading to higher credit spreads.

4 Application: an evaluation of the impact of CRD IV on the UK

In this section we use the NiGEM model in combination with the long-term and short-term equations estimated in sections 3.2.4 and 3.3.2 respectively to simulate the impact on the UK economy of the estimated increase in the aggregate risk based capital ratio required under CRD IV[46]. The estimates reflect regulatory capital changes and economic conditions as at the end of 2012 and are based on the analysis undertaken for the introduction of CRD IV published in Chapter 15 of Prudential Regulation Authority (PRA) (2013).

4.1 The NiGEM model

The macroeconomic model NiGEM is a large scale model[47] that includes detailed modules of 60 countries, including the UK, and economic interactions between them. The model has New Keynesian foundations with forward-looking agents and nominal rigidities so that the economy adjusts dynamically to external shocks. The model equations' coefficients are estimated using historical data. The theoretical background for the factor demand equations is derived from the aggregated constant-returns-to-scale CES production function as follows:

$$Y = \theta[(1-\delta)K^{-\rho} + \delta L^{-\rho}]^{-1/\rho} \tag{9}$$

[42] This is in line with the empirical results from the cointegrated VAR of section 3.2.3.
[43] See Hendry and Juselius (2001)
[44] From the sample, the first and third quartiles of the quarterly changes in the Boone indicator are -1.3 and 1.3 respectively. In addition, 2 standard deviations from the mean of the quarterly changes is 1.1.
[45] The long-run impact of competition on PNFC and household lending spreads is more complicated and requires disentangling the role of competition within the set of weakly-exogenous stochastic trends and the capital ratio, but is not the focus of this paper.
[46] CRD IV is a package of European Union legislation that consists of changes to the Capital Requirements Directive (CRD) and the introduction of the Capital Requirements Regulation (CRR). The CRD IV package implements the internationally agreed Basel III regulatory framework in the EU.
[47] The model includes more than 5,000 relationships and many more variables.

Here Y is real output, K is the total capital stock and L is total hours worked (corrected by technical progress). The elasticity of substitution is estimated from the labour demand equation (roughly around 0.5) and is used in the calibration of the other coefficients of the production function.

The factor demand models embody the outcomes of firms' profit maximisation subject to given input costs of investment and labour through the production function above.

$$\max_{L,K} \prod (p, c, w) = \{pY - cK - wL\} \tag{10}$$

Here p, c, and w are the price of output, capital and labour, respectively. The model maximisation result on factor demand equations as follows.

$$L^q = f\left(Y, \frac{w}{p}\right) \tag{11}$$

$$K^q = g(Y, c) \tag{12}$$

The last expression links explicitly the demand for physical capital with the user cost of capital c. The user cost of capital in turn is linked to cost of bank credit and the latter is linked to bank capital through NiGEM's UK banking sector module[48]. An increase in banking sector funding generally increases the cost of investment for non-financial firms when other factors are held constant. In particular, a change in regulation that forces banks to replace debt with more costly capital or that increases their fixed costs will find its way through the model to push up the cost of physical investment. This will ultimately reduce the amount of physical investment and physical capital accumulation reducing the sustainable level of output.

However, the impact of banking finance on the cost of capital depends on both leakages to other types of finance as well as the effect of central bank policy (either offsetting or exacerbating the impact) on base interest rates. Barrell et al (2009) discusses in more detail the model approach to leakages.

A secondary impact of higher costs of finance acts through households' savings and consumption decisions. Households experience an increased cost of financial intermediation, reducing the return on their deposits and increasing the cost of mortgages and other types of credit. Because of these additional costs, households increase savings over the long term which leads to a reduction in their total liabilities and hence interest rate costs. This effect reduces the impact of higher cost of credit on household consumption in the long term.

4.2 The macro model exercise

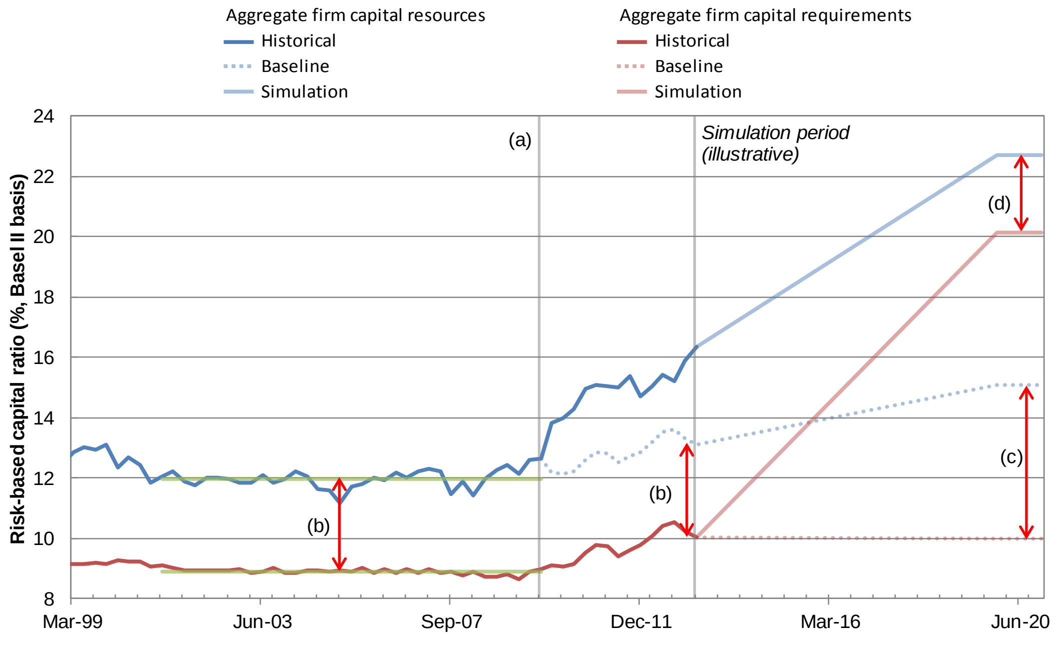
We used the framework above to estimate the incremental opportunity costs[49] to the UK economy of the CRD IV capital measures, using a baseline scenario in which the CRD IV reforms are not enacted and levels of bank capital largely reflect the pre-CRD IV policy stance. These impacts are reproduced from the PRA's cost-benefit analysis of CRD IV based on data available to end 2012 (see PRA (2013)). In summary, the CRD IV measures considered in this analysis include (i) changes to the definition of capital;

[48] As described in de-Ramon et al. (2012) we also modified NiGEM's banking sector equations in other ways. In particular we enhanced equations dealing with the impact of regulation on the housing market and international linkages.
[49] We ignore in this analysis the benefits to the UK economy of higher capital requirements, which arise from reducing the probability that a systemic financial crisis occurs. See de-Ramon et al. (2012) and PRA (2013) for discussion of benefits.

(ii) changes to the risk coverage on banks' balance sheets; (iii) changes to minimum capital ratios; and (iv) the introduction of the capital conservation and counter-cyclical buffers[50].

Figure 4.1, reproduced from PRA (2013), shows the assumed path for the industry's total capital requirements and resources in both scenarios. The vertical axis in Figure 4.1 reflects pre-CRD IV (i.e. Basel II / CRD II) definitions of capital and risk-weighted assets. Consequently it is not possible to directly compare the risk-weighted assets ratios in the figure with headline CRD IV capital requirements[51]. Point (a) of Figure 4.1 indicates the introduction of the FSA Enhanced Supervisory programme at the end of 2008, which partly pre-empted the higher regulatory capital requirements of the Basel III / CRD IV package (and is assumed to remain in place in our baseline scenario[52]). The distance (b) represents the size of banks' pre-crisis capital surplus. In the baseline scenario, the distance (c) shows the assumption that, in addition to their pre-crisis level of their capital surplus, banks would face an additional regulatory 'capital planning buffer' in the absence of CRD IV.

Figure 4.1: Baseline and CRD IV scenarios[53]



(a) September quarter 2009. The FSA Enhanced Supervisory programme was introduced in the December quarter 2008
(b) size of the average, pre-crisis capital surplus, defined as the difference between banks' capital requirements and resources
(c) size of the average capital surplus in the baseline, calculated as the average across banks of the larger of either individual banks' voluntary buffer or the capital planning buffer (calculation is illustrative)
(d) size of the average capital surplus in the simulation, assumed to be half the average capital surplus in the baseline

Source(s): Bank of England

The CRD IV scenario presented assumes that deposit-takers' capital resources increase in a linear fashion to reach compliance with the final requirements by 2020. The distance (d) in Figure 4.1 reflects the

[50] Importantly, this analysis does not include policy initiatives finalised subsequent to the CRD IV, such as the leverage ratio, the Global Systemically Important Bank ('G-SIB') buffer, recovery and resolution policy or the introduction of total loss-absorbing capacity ('TLAC'). See PRA (2013) for more details on the wider modelling exercise on the UK implementation of the CRD IV package from which these scenarios are taken.
[51] See de-Ramon et al (2012) and Chapter 15 of PRA (2013) for discussion.
[52] The FSA Supervisory Enhancement programme was introduced in response to the failure of Northern Rock. While the programme did not explicitly introduce higher capital requirements, the move to more close and continuous supervision, particularly of larger firms, saw banks hold more capital than in the period prior to the 2008 financial crisis.
[53] Figure 4.1 is a reproduction of Chart 15.1 from PRA (2013) which shows the path for the aggregate total capital ratio calculated as part of the cost-benefit analysis of the CRD IV.

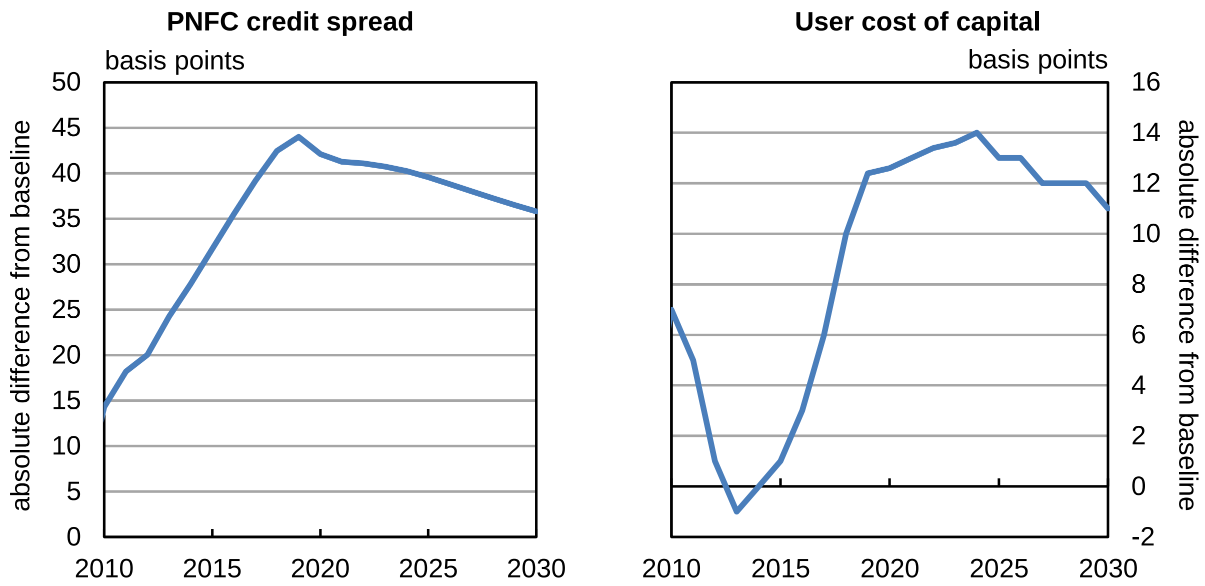
assumption that banks reduce their voluntary capital surplus compared to the baseline, and that the reduction is linear over the implementation period. This assumption reflects: (i) the introduction of new regulatory buffers that effectively reduce the need for deposit-takers to hold the same pre-crisis voluntary surplus; and (ii) an assumed reduction in the volatility of banks' capital resources given more constrained bank risk-taking behaviour and improved transparency under CRD IV.

We use the standard NiGEM model under these assumptions modified to include the model set out in section 3.3.2 to measure the impacts of prudential policy on aggregate lending margins, total credit and the overall economy. The model reflects the intuition that deposit-takers recover the costs of raising capital ratios by increasing the credit spreads between lending and deposit rates. The model also reflects differences in the recovery of costs over time and across types of borrower.

4.3 Simulation results

Figure 4.2 to Figure 4.5 show the simulation results in terms of the difference in the levels of the model variables over time (either in absolute or percentage terms) between the baseline and CRD IV scenarios reflecting regulatory capital changes and economic conditions as at the end of 2012 and based on the analysis undertaken for the introduction of CRD IV. As discussed in Sections 4.1 and 4.2, the effects of prudential policy in the model filter down from the banking sector to the price of production factors and, in particular, the user cost of capital. CRD IV increases the cost of credit to business by up to 45 basis points but this falls towards 35 basis points over the long run.

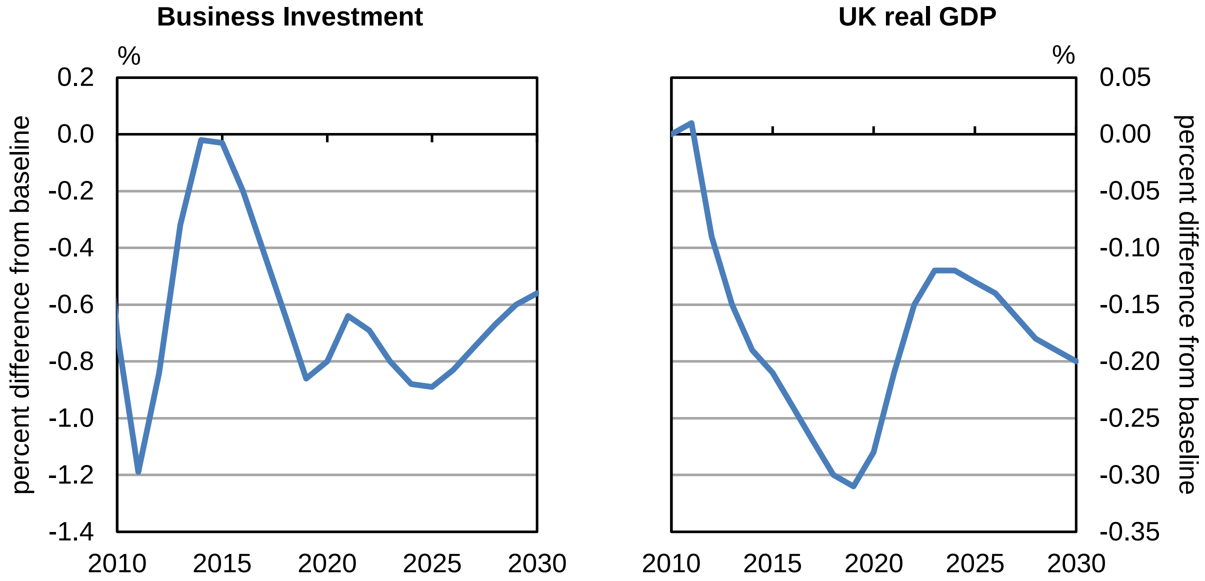
Figure 4.2: Cost of credit and business investment



Source: Bank of England calculations

Figure 4.2 shows that the user cost of capital increases in line with that change by around 14 basis points at the peak. The impact on user cost of capital depends on three additional sets of model coefficients: the proportion of private sector credit channelled through the banks; the international linkages of UK price with world prices through trade; and the central bank response to lower inflation and nominal GDP. The former two are estimated using historical averages of private sector debt share of banks and international trade matrices. The latter is based on a central bank response function econometrically estimated on UK historical data which is included in NiGEM[54].

Figure 4.3: Impact on business investment and long-term GDP



Source: Bank of England calculations

Figure 4.3 shows that business investment demand falls as a result of the increase in its cost as shown in Figure 4.2; this effect will be permanent unless there are other changes over the long-run (e.g. changes in UK and international regulation or technology). The investment fluctuations over the simulation period are the result of a number of elements: first, as aggregate demand is reduced central bank base rates stay lower under the CRD IV than would the case in the baseline. This has a softening effect on overall credit interest rates[55] helping to sustain aggregate investment demand under CRD IV. This effect emerges slowly over time.

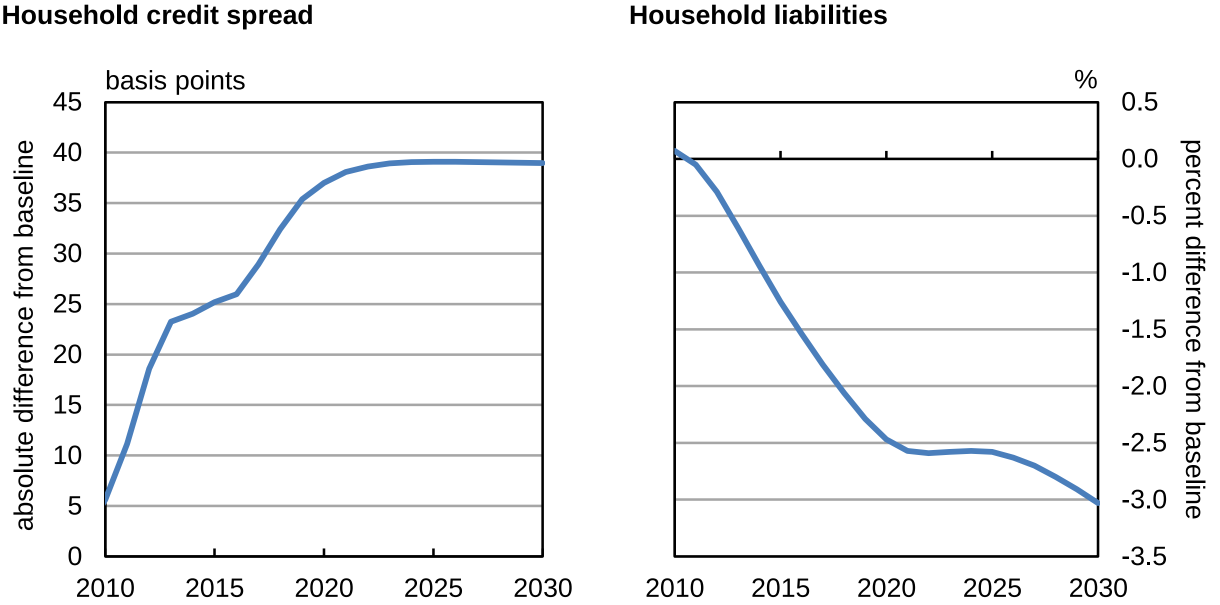
Second, as shown by the impulse responses in Section 3.2.6, PNFC credit spreads fall back over time after a stronger reaction in the initial periods. This occurs in the simulation after 2020 when the capital ratio has fully adjusted to the higher CRD IV requirements. The user cost of capital falls back increasing investment demand slightly.

Figure 4.3 also shows the path of real GDP over time. Because of the offsetting effects discussed above, real GDP bounces back slightly from around 2020 after banks fully adjust to the higher prudential levels. Figure 4.4 shows the impact on households credit spreads and liabilities. As expected these variables move in opposite directions: household spreads rise by just over 35 basis points and household liabilities fall in the long run by 3%.

[54] In our model the central bank response can, to some extent, reduce PNFCs' total cost of credit and its impact on private sector investment. UK aggregate balance sheet data shows that PNFCs' are less affected by a reduction in income from their deposits with banks. See Barrell and Dury (2000) for more information on the NiGEM's central bank response.

[55] But not on savings (deposit) rates.

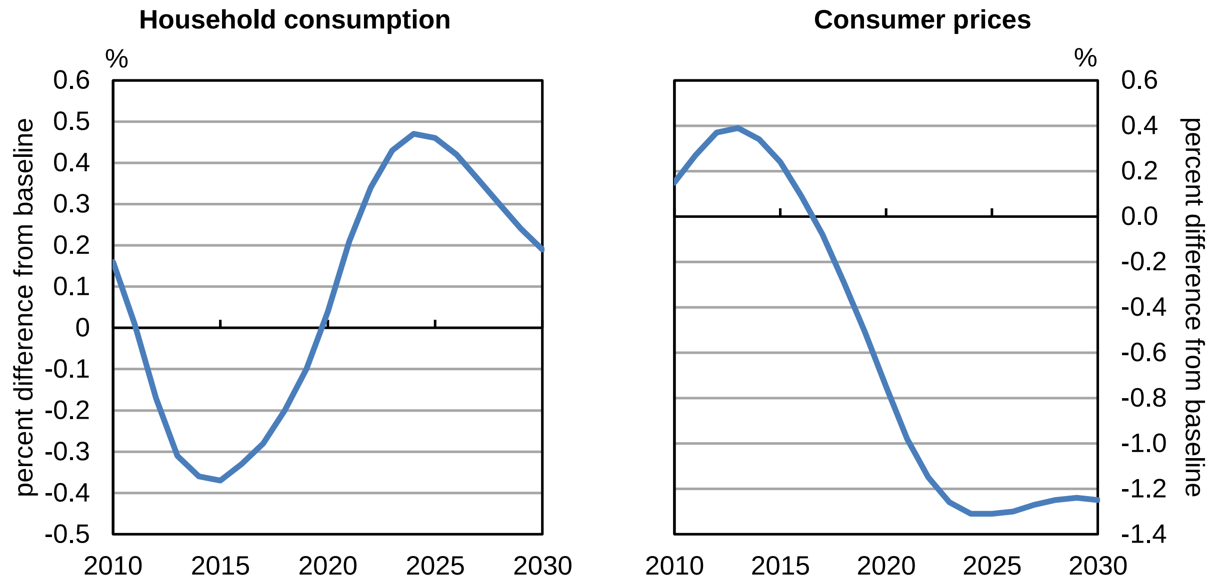
Figure 4.4: Impact on households credit spreads and liabilities



Source: Bank of England calculations

Finally, Figure 4.5 shows the resulting reduction in consumer expenditure and inflation. Consumer expenditure falls initially but recovers after 2020. This is driven by the same offsets that help business investment demand. However, households benefit as well from a significant reduction in total liabilities and face lower interest payments in the long run. This effect, on top of the effect from lower consumer prices, improves households' purchasing power and supports real consumption over the long run.

Figure 4.5: Real consumer expenditure and consumer prices.



Source: Bank of England calculations

5 Conclusion

The Basel III/CRD IV reforms to the banking system following the financial crisis of 2008–09 requires banks in the UK to raise significantly both the quality and quantity of capital they need to have on their balance sheets. This econometric study looks for evidence of the long and short-term implications of capital regulation at the macroeconomic level to help measure the overall impact on UK economic activity. The literature notes a number of possible mechanisms by which capital ratios may affect lending in the economy (and the level of economic activity), departing from the Modigliani-Miller value-invariance proposition. The literature suggests that these mechanisms can affect the supply of loans to the economy as banks pass through increased funding costs to borrowers, increasing the price of credit. The extent to which this pass through occurs may also be influenced by the intensity of competition in the banking sector.

We develop a simple dynamic model to describe how banks adjust their capital ratios by adjusting their capital levels, level of risk and loans (assets) through time. The estimated model shows that, in response to higher capital levels, banks increase credit spreads to PNFCs more than credit spreads for households in the short term. In effect, banks exploit the higher demand elasticity of the PNFC sector to reduce average risk-weights most efficiently and thereby improve capital ratios more quickly as their capital requirements increase. Over the longer term, the difference we find between PNFC credit spreads and household spreads are smaller than in the short run. We find that after the Basel II reforms and the 2008-09 financial crisis, banks have changed the way they increase spreads in the long-run in response to regulatory capital increases. Using pre Basel II data we find that the spread increases were more prominent in those earlier periods than after the crisis.

We find some empirical evidence that the intensity of competition in the banking sector can affect the extent to which banks pass-through their increased funding costs to borrowers. However, the model cannot disentangle the impact on bank credit spreads arising from the intensity of competition from the impact of bank risk taking, preventing us from drawing any direct conclusions on the relative size of the pass-through. We leave disentangling these effects for future research.

We demonstrate in a simulation using the final estimated model that increases in aggregate capital ratios in the UK economy slow economic activity, but the impact on household demand is different from the impact on business investment. There is also a more pronounced impact on activity in the short-term than over the long run. Both of these outcomes are the consequence of the dynamics of our model arising from a greater overall reduction in lending to the more risky PNFC sector than the less risky household sector. We find that monetary policy can alleviate to some extent the impact on activity, but does not completely unwind the effect of higher aggregate capital requirements.

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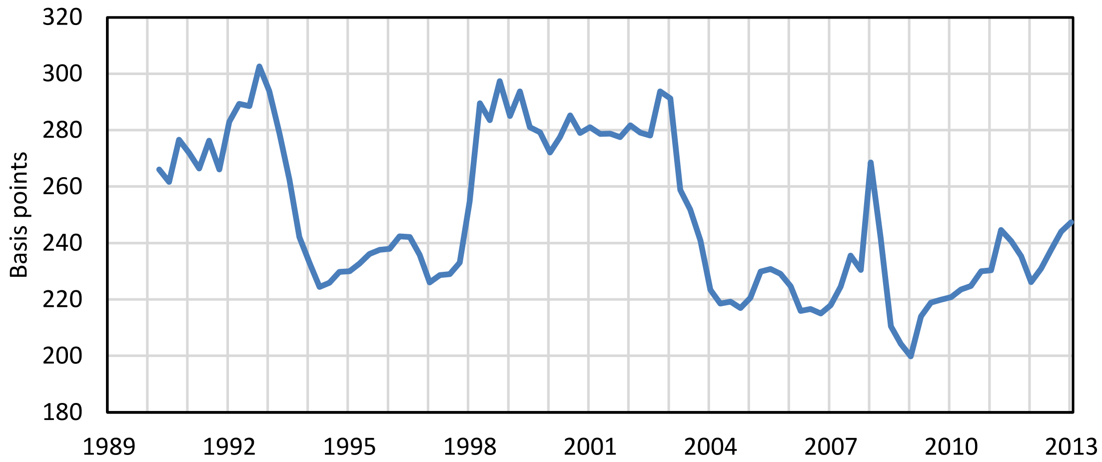
Appendix 1: Database details and sources

Table A1.1: Data sources and alternative measures

Variable		Source	Alternative proxies and data sources
Household lending margin	$mortw$	1999-2013 Bank of England sectoral interest rates 1989-1998 Building Societies' spreads	– 2004-2013 Bank of England Effective interest rates (ER) return – 1995-2003 Bank of England Interest Rates and/or Flows for Sterling Business by Sector (RIR) return – 1989-1994 Building Societies' spreads – lending margin for credit cards or unsecured lending
PNFC lending margin	$corpw$	1999-2013 Bank of England sectoral interest rates 1989-1998 NIESR	– 2004-2013 Bank of England ER return – 1995-2003 Bank of England RIR return – 1989-1994 NIESR
Risk based capital ratio	$rbcr$	2008-2013 FSA regulatory returns 1998-2007 BSD3 Capital Adequacy Return 1996-1998 BSD2 Capital Adequacy Return 1989-1995 BSD1 Capital Adequacy Return	– Create a proxy for Tier 1 capital – Incorporate building societies and other smaller banks
Loan concentration index	$hhil$	2008-2013 FSA regulatory returns 1998-2007 BSD3 Capital Adequacy Return 1996-1998 BSD2 Capital Adequacy Return 1989-1995 BSD1 Capital Adequacy Return	– Other indices: deposit, assets – Incorporate building societies and other smaller banks
Business sector risk	$insolr$	2001-2013 The Insolvency Service, Companies House 1989-2000 NIESR	– IMF financial stress index
Mortgage market risk	$arrear6$	1999-2013 Council of mortgage lenders (CML) 1989-1998 CML estimated from annual ratio	– IMF financial stress index – 12 months or more arrears index
Household sector risk	U	Office of National Statistics	– GDP growth
Excess demand	$ygap$	Office of National Statistics, NIESR calculations	– GDP growth – Growth of new lending to GDP ratio – Employment compensation to nominal GDP ratio

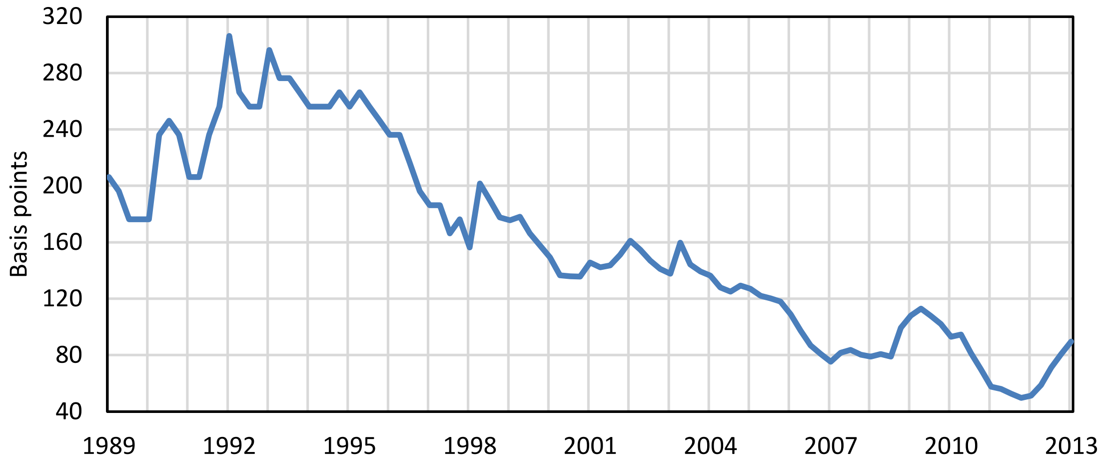
Source: Bank of England

Figure A1.1: UK average PNFC loan spread over deposits (%)



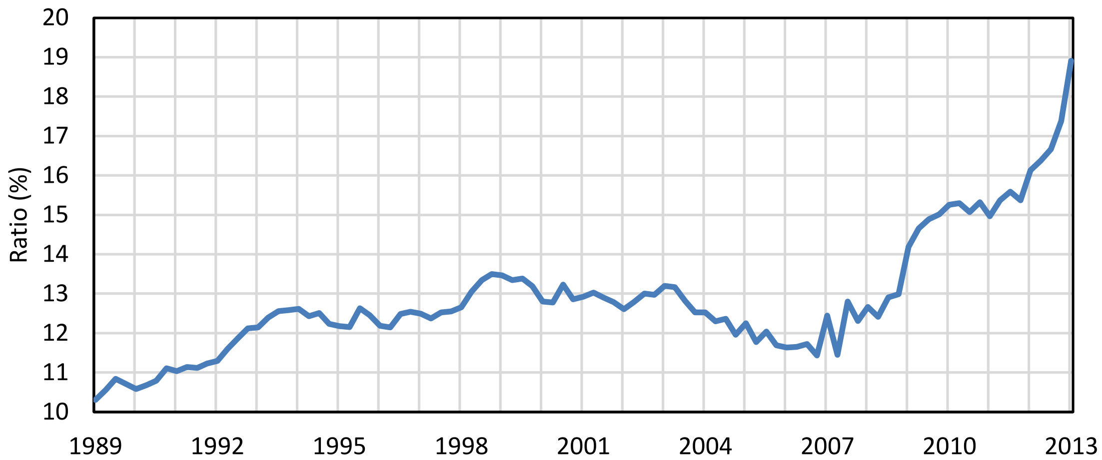
Source(s): Bank of England.

Figure A1.2: UK average household loan spread over deposits (%)



Source(s): Bank of England.

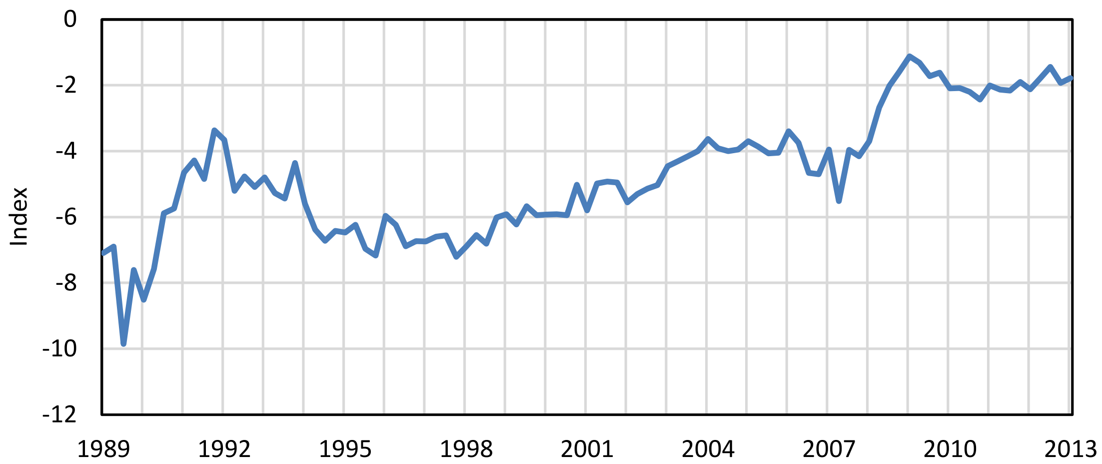
Figure A1.3: UK average risk based capital ratio (%)



Source(s): Bank of England.

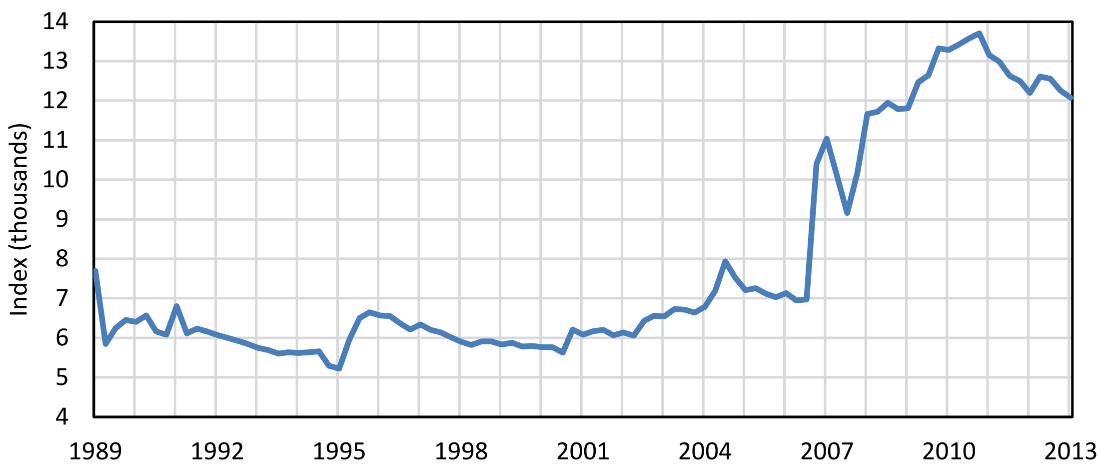
Notes(s): Average of all UK banks and building societies weighted by total risk weighted assets.

Figure A1.4: Boone indicator; UK banks and building societies (index)



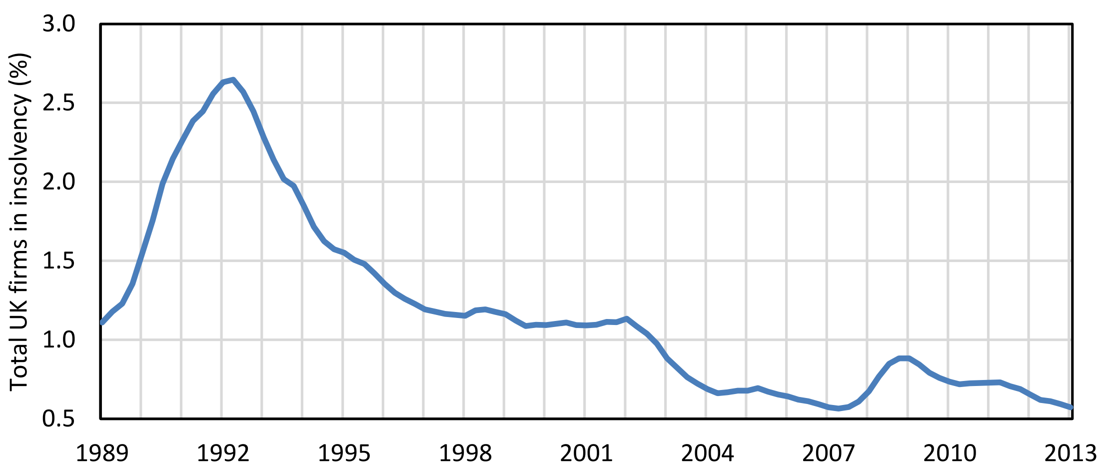
Source(s): Bank of England.

Figure A1.5: UK banking industry loan concentration (Herfindahl-Hirschman index)



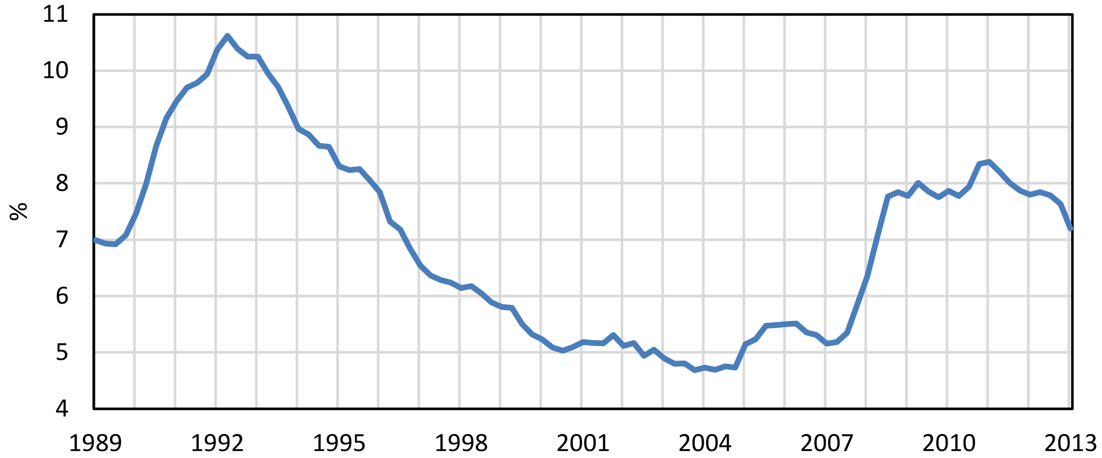
Source(s): Bank of England.

Figure A1.6: UK corporate insolvency ratio (% of UK total firms)



Source(s): UK, The Insolvency Service, Companies House, NIESR.

Figure A1.7: UK Unemployment rate (%)



Source(s): UK Office of National Statistics.

Appendix 2: Detailed Econometric Results

Table A2.1: Lag length test for basic models with the Boone indicator (BOONE) and loan concentration (HHIL)

Endogenous variables: CORPW MORTW RBCR U INSOLR BOONE
Exogenous variables: C
Sample: 1961Q1 2013Q4
Included observations: 87

Lag	LogL	Sequential modified LR test statistic	Final prediction error	Akaike information criterion	Schwarz information criterion	Hannan-Quinn information criterion
1	238.5577	NA	4.04E-10	-4.60358	-3.59013	-4.19529
2	324.0208	147.618	1.32e-10*	-5.72775*	-3.70083*	-4.91115*
3	354.1613	47.9508	1.55E-10	-5.59457	-2.55421	-4.36969
4	395.5233	60.1630*	1.44E-10	-5.71644	-1.66262	-4.08326

Endogenous variables: CORPW MORTW RBCR U INSOLR HHIL
Exogenous variables: C
Sample: 1961Q1 2013Q4
Included observations: 88

Lag	LogL	Sequential modified LR test statistic	Final prediction error	Akaike information criterion	Schwarz information criterion	Hannan-Quinn information criterion
1	645.8909	NA	3.85e-14	-13.86116	-12.84770*	-13.45286
2	718.1639	124.8350*	1.71e-14*	-14.68554*	-12.65863	-13.86895*
3	743.7391	40.68787	2.22e-14	-14.44862	-11.40825	-13.22373
4	774.8562	45.26126	2.60e-14	-14.33764	-10.28382	-12.70446

Source(s): Authors' own calculations using EViews version 9.5 (Enterprise edition)
Note(s): * indicates lag order selected by the criterion

Table A2.2: Unrestricted estimate of the basic model with two competition proxies

Sample period:	1991Q4 2013Q4; 89 observations.			1991Q4 2013Q4; 89 observations.		
Cointegrating Equation:	**Equation 1**	**Equation 2**		**Equation 1**	**Equation 2**	
$corpw_{t-1}$	1.0000	-1.0000		1.0000	-1.0000	
$mortw_{t-1}$	0.0000	1.0000		0.0000	1.0000	
$rbcr_{t-1}$	-0.1147	0.0820		-0.1194	0.0905	
	(0.040)	(0.122)		(0.032)	(0.093)	
Constant	-0.9986	-0.1511		-0.9383	-0.2623	
Error Correction:	$\boldsymbol{\Delta corpw_t}$	$\boldsymbol{\Delta mortw_t}$	$\boldsymbol{\Delta rbcr_t}$	$\boldsymbol{\Delta corpw_t}$	$\boldsymbol{\Delta mortw_t}$	$\boldsymbol{\Delta rbcr_t}$
Cointegrating Eq. 1	-0.6625	-0.4063	-0.4079	-0.6190	-0.4694	-0.3537
	(0.099)	(0.148)	(0.364)	(0.104)	(0.149)	(0.374)
Cointegrating Eq. 2	-0.1708	-0.2207	-0.3206	-0.1313	-0.2772	-0.2717
	(0.045)	(0.067)	(0.165)	(0.050)	(0.071)	(0.179)
$\Delta corpw_{t-1}$	0.2393	-0.0148	0.2106	0.3203	0.0369	0.3667
	(0.097)	(0.145)	(0.356)	(0.095)	(0.137)	(0.343)
$\Delta corpw_{t-2}$	0.1880	0.0107	-0.0404	0.2396	0.0401	0.0585
	(0.096)	(0.144)	(0.356)	(0.097)	(0.139)	(0.351)
$\Delta mortw_{t-1}$	0.0754	0.0207	0.6987	0.0085	0.0252	0.5862
	(0.079)	(0.117)	(0.289)	(0.075)	(0.107)	(0.269)
$\Delta mortw_{t-2}$	0.1342	0.0496	0.5874	0.0880	0.0524	0.5095
	(0.075)	(0.113)	(0.278)	(0.075)	(0.107)	(0.269)
$\Delta rbcr_{t-1}$	-0.0247	0.0077	-0.3293	-0.0274	0.0089	-0.3305
	(0.033)	(0.050)	(0.123)	(0.035)	(0.049)	(0.124)
$\Delta rbcr_{t-2}$	0.0688	-0.0129	0.2416	0.0754	-0.0006	0.2587
	(0.033)	(0.049)	(0.121)	(0.034)	(0.049)	(0.123)
Constant	-0.1430	-0.2390	-0.8211	0.1445	-0.0675	-0.2765
	(0.118)	(0.176)	(0.434)	(0.061)	(0.087)	(0.219)
U_{t-1}	-0.0830	-0.0441	0.0893	-0.0815	-0.0103	0.1041
	(0.018)	(0.027)	(0.066)	(0.024)	(0.035)	(0.088)
$insolr_{t-1}$	0.4980	0.4085	0.0531	0.4549	0.3269	-0.0533
	(0.085)	(0.127)	(0.313)	(0.094)	(0.134)	(0.337)
$boone_{t-1}$	-0.0309	-0.0124	-0.0572			
	(0.013)	(0.019)	(0.047)			
HHI_{t-1}				-1.3828	-3.2384	-3.4028
				(1.393)	(1.994)	(5.015)
R-squared	0.4377	0.1949	0.3556	0.4034	0.2173	0.3472
Adj. R-squared	0.3574	0.0799	0.2635	0.3182	0.1055	0.2540
F-statistic	5.4489	1.6944	3.8621	4.7328	1.9438	3.7232
Log likelihood	95.747	59.910	-20.345	93.111	61.169	-20.918
Akaike AIC	-1.8820	-1.0766	0.7269	-1.8227	-1.1049	0.7397
Schwarz SC	-1.5464	-0.7411	1.0624	-1.4872	-0.7694	1.0753

Source(s): Authors' own calculations using EViews version 9.5 (Enterprise edition)

Table A2.3: Results for the basic model with long-term restriction

Sample period:	1991Q4 2013Q4; 89 observations.			1991Q4 2013Q4; 89 observations.		
LR test: $\chi^2(1)$ (Probability)	0.4294 (0.512)			0.9054 (0.341)		
Cointegrating Equation:	**Equation 1**	**Equation 2**		**Equation 1**	**Equation 2**	
$corpw_{t-1}$	1.0000	-1.0000		1.0000	-1.0000	1.0000
$mortw_{t-1}$	0.0000	1.0000		0.0000	1.0000	0.0000
$rbcr_{t-1}$	-0.0901	0.0000		-0.0929	0.0000	-0.0901
	(0.015)			(0.016)		(0.015)
Constant	-1.3186	0.9114		-1.2812	0.9114	-1.3186
Error Correction:	$\Delta corpw_t$	$\Delta mortw_t$	$\Delta rbcr_t$	$\Delta corpw_t$	$\Delta mortw_t$	$\Delta rbcr_t$
Cointegrating Eq. 1	-0.6631	-0.4043	-0.4041	-0.6212	-0.4630	-0.3483
	(0.099)	(0.148)	(0.364)	(0.104)	(0.149)	(0.373)
Cointegrating Eq. 2	-0.1738	-0.2101	-0.3028	0.1375	0.2593	0.2577
	(0.043)	(0.064)	(0.159)	(0.047)	(0.068)	(0.171)
$\Delta corpw_{t-1}$	0.2372	-0.0071	0.2226	0.3198	0.0381	0.3670
	(0.096)	(0.144)	(0.354)	(0.095)	(0.137)	(0.343)
$\Delta corpw_{t-2}$	0.1862	0.0171	-0.0309	0.2386	0.0431	0.0593
	(0.096)	(0.144)	(0.354)	(0.097)	(0.140)	(0.351)
$\Delta mortw_{t-1}$	0.0777	0.0127	0.6849	0.0112	0.0176	0.5790
	(0.078)	(0.117)	(0.288)	(0.074)	(0.107)	(0.268)
$\Delta mortw_{t-2}$	0.1358	0.0438	0.5774	0.0899	0.0467	0.5043
	(0.075)	(0.113)	(0.277)	(0.075)	(0.107)	(0.268)
$\Delta rbcr_{t-1}$	-0.0229	0.0016	-0.3420	-0.0241	-0.0005	-0.3425
	(0.034)	(0.050)	(0.124)	(0.035)	(0.050)	(0.125)
$\Delta rbcr_{t-2}$	0.0697	-0.0159	0.2351	0.0776	-0.0067	0.2513
	(0.033)	(0.049)	(0.122)	(0.034)	(0.049)	(0.123)
Constant	-0.1520	-0.2070	-0.7662	0.1393	-0.0528	-0.2583
	(0.112)	(0.168)	(0.412)	(0.061)	(0.087)	(0.219)
U_{t-1}	0.4935	0.4237	0.0838	0.4438	0.3582	-0.0201
	(0.085)	(0.127)	(0.313)	(0.092)	(0.132)	(0.330)
$insolr_{t-1}$	-0.0813	-0.0498	0.0786	-0.0776	-0.0214	0.0936
	(0.017)	(0.026)	(0.063)	(0.023)	(0.033)	(0.082)
$boone_{t-1}$	-0.0315	-0.0103	-0.0538			
	(0.013)	(0.019)	(0.046)			
HHI (loans)$_{t-1}$				-1.5002	-2.8981	-3.1811
				(1.361)	(1.954)	(4.895)
R-squared	0.4374	0.1922	0.3550	0.4022	0.2111	0.3472
Adj. R-squared	0.3570	0.0768	0.2628	0.3168	0.0984	0.2540
F-statistic	5.4419	1.6655	3.8520	4.7102	1.8730	3.7236
Log likelihood	95.722	59.762	-20.386	93.025	60.815	-20.916
Akaike AIC	-1.8814	-1.0733	0.7278	-1.8208	-1.0970	0.7397
Schwarz SC	-1.5459	-0.7378	1.0633	-1.4852	-0.7614	1.0752

Source(s): Authors' own calculations using EViews version 9.5 (Enterprise edition)

Table A2.4: Descriptive statistics and normality tests

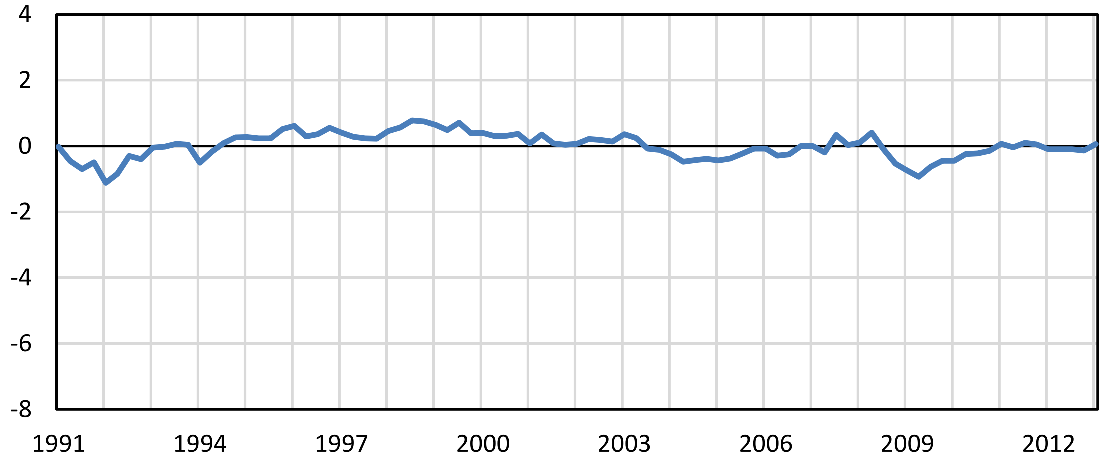
	Mean	Median	Maxi-mum	Mini-mum	Std. Dev	Skew-ness	Excess Kurtosis	Jarque-Bera (Prob)	Observa-tions
$corpw$	2.49	2.41	3.03	2.00	0.273	0.323	1.714	7.851(0.020)	104
$mortw$	1.58	1.44	3.06	0.50	0.698	0.355	1.974	5.901(0.052)	189
$rbcr$	13.01	12.60	18.91	10.79	1.489	1.496	5.449	56.67(0.000)	97
$\Delta corp$	-0.002	0.003	0.381	-0.325	0.111	0.208	5.481	24.00(0.000)	103
$\Delta mortw$	-0.016	-0.030	0.500	-0.400	0.138	1.142	6.435	64.52(0.000)	188
$\Delta rbcr$	0.091	0.063	1.539	-1.000	0.378	1.119	6.480	64.89(0.000)	96
CointEq11	0.000	0.008	0.424	-0.402	0.194	-0.036	2.541	0.817(0.665)	92
CointEq12	0.000	-0.052	0.993	-1.147	0.519	-0.056	2.503	0.984(0.611)	92

Source(s): See Appendix 1 and authors' own calculations.

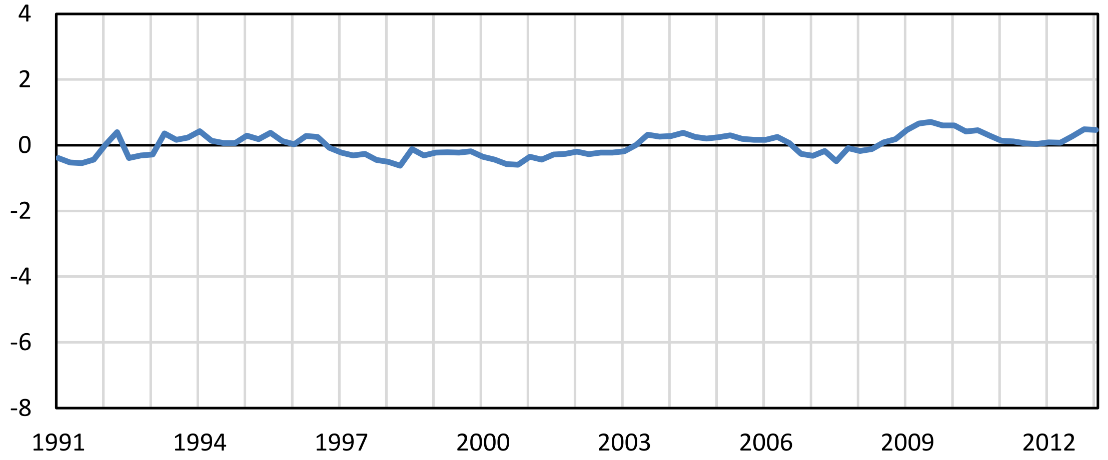
Note(s): CointEq11 and CointEq12 are the first and second error correction terms for the reduced models of section 3.2.4 using the Boone indicator as a proxy for competition.

Figure A2.8: Cointegration graphs (model with Boone indicator)

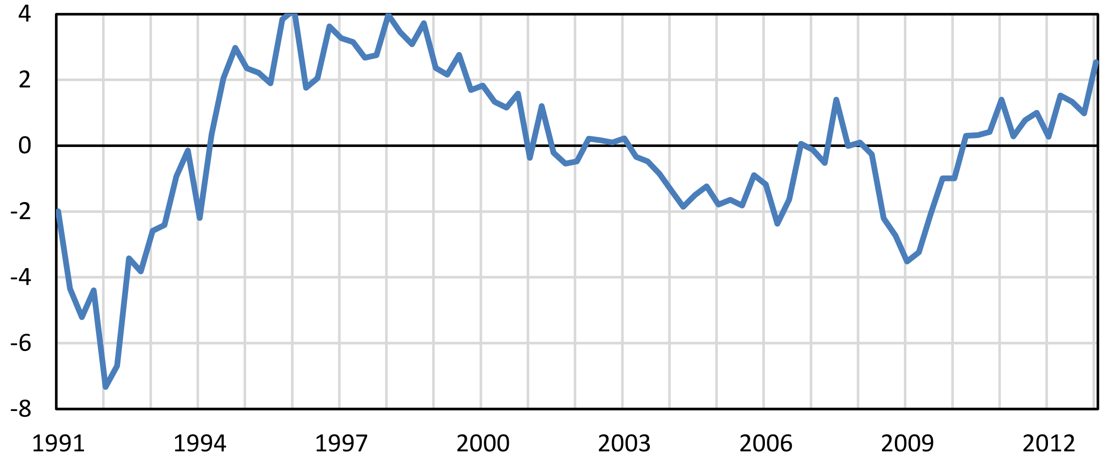
Cointegration relation 1



Cointegration relation 2



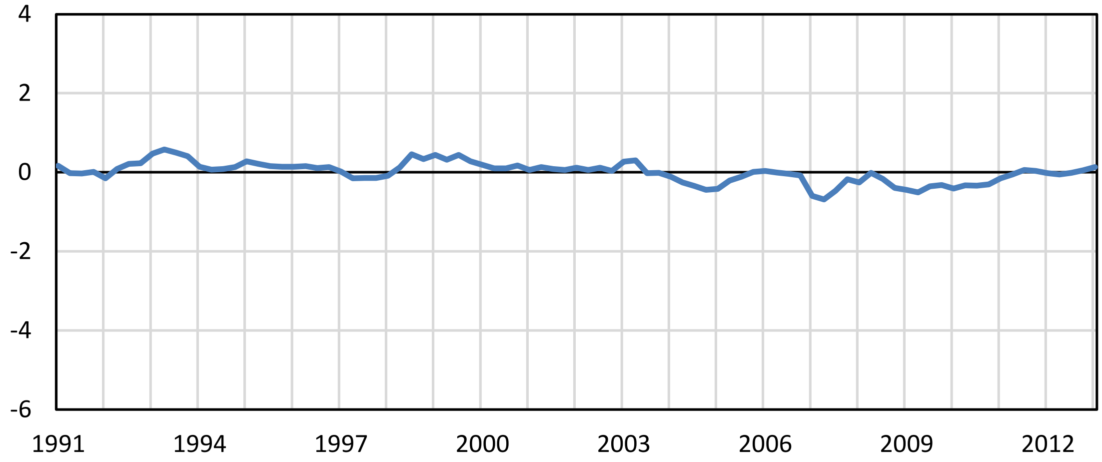
Cointegration relation 3



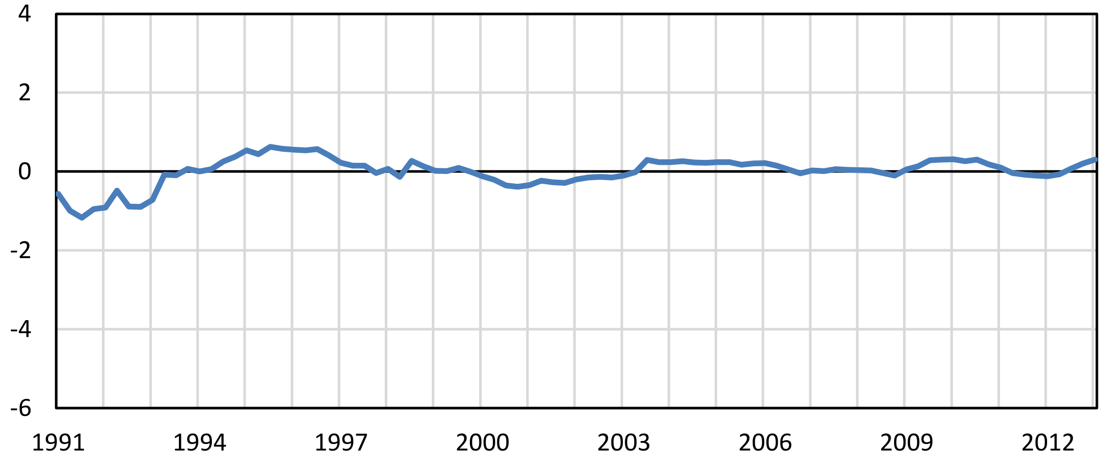
Source(s): Authors' own calculations using EViews version 9.5 (Enterprise edition)

Figure A2.9: Cointegration graphs (model with loan concentration)

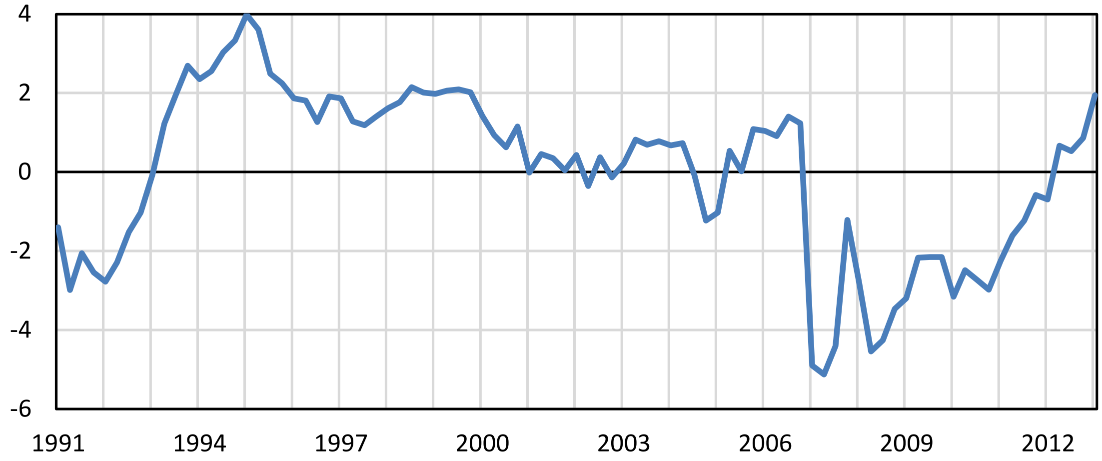
Cointegration relation 1



Cointegration relation 2



Cointegration relation 3



Source(s): Authors' own calculations using EViews version 9.5 (Enterprise edition)