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In good times and in bad: Bank capital ratios and lending rates☆

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ABSTRACT

This paper investigates the relationship between bank capital ratios and lending rates using data from 1998 to 2012 for 13 large banks accounting for 75% of total UK lending. We document a substantial change in the coefficient of the Tier 1 capital ratio in reduced-form regressions for secured household lending rates; the coefficient changes from positive pre-crisis to negative in crisis. Significant changes are also detected in the relationship for unsecured household and corporate lending. Such instability is difficult to reconcile with many well-established theories of financial intermediation but is consistent with the relatively recent theories of bank portfolio decisions emphasising cyclical variation in bank leverage and risk-appetite.

1. Introduction

This paper examines the relationship between bank capital and loan interest rates for a panel of UK banks covering altogether about three quarters of the UK lending market. Our focus is on the cyclicality or state-dependence of this relationship during the period from October 1998 to December 2012, i.e. the possibility that it differs between episodes of rapid credit expansion (when times are 'good', before the global credit crisis) and periods of crisis and moderate credit growth (the 'bad' times, or subsequent years).

There are limits to the conclusions that can be drawn from an exercise of this nature. Bank capital decisions are endogenously determined alongside loan supply and interest rate decisions, and influenced also by loan demand. Our estimated coefficients cannot be reliably interpreted as representing the impact of an exogenous policy change such as an increase in the level of bank regulatory capital requirements. Nonetheless, even though the estimations we report are based on reduced-form models, they do provide some insights into a key question: what theory provides an adequate and consistent account of the portfolio and loan rate decisions of UK banks before and after the crisis?

The reason that even a reduced-form estimation strategy may be informative is that the most well-established theories prior to the crisis share one common feature: they adopt modelling frameworks in which bank portfolio choices are driven by bank specific factors such as capitalisation, liquidity and market power in deposit and lending markets. Cyclicality can appear in these models but only exogenously through changes in various explanatory model variables. Therefore these models predict that, once fully controlling for bank-specific and macroeconomic factors affecting loan supply and loan demand, then one should observe stable relationships between bank capital and the different dimensions of the bank portfolio decision such as the volume of bank loans and bank loan interest rates.

Our estimation results and tests clearly reject this prediction, suggesting instead that the association between bank capital ratios and lending rates alters substantially from the pre-crisis (or 'good times') period to the crisis (or 'bad times') period. For total bank lending, the coefficient on the Tier 1 capital ratio is significantly positive pre-crisis (October 1998–June 2007) and significantly negative in the period comprising the crisis (July 2007–December 2012). The corresponding coefficient in regressions for secured household lending (residential mortgages) is significantly positive prior to the crisis and significantly

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negative in the crisis period. For unsecured household lending we find instead a positive association in both the pre-crisis and crisis sub-periods, but a significant change in magnitude from relatively strong to weak. Finally, for corporate loans we find a significant negative association pre-crisis and no association in the crisis period.

These findings are robust to various specification tests that include: (*i*) formulating the panel model in 'error correction' form to capture the short-run dynamics of loan rates, (*ii*) estimating the panel model using rates on new business lending only, (*iii*) using data sampled at the quarterly rather than monthly frequency, (*iv*) explicitly controlling for bank- and time-varying regulatory capital requirements, and (*v*) allowing not only for bank fixed effects but also time fixed effects so as to ensure that all (observed and unobserved) aggregate common factors influencing bank loan rate decisions are controlled for.

As we have stated, many well-established theories of bank decision-making are not consistent with this finding of pronounced cyclical instability in the relationship between bank capital and lending rates. One example are those models in which bank capital provides banks with the incentive to apply effort to loan screening and monitoring. This theory predicts that banks with higher capital will make greater monitoring effort, lending more and offering lower rates of interest, but provides no obvious explanation for cyclical changes in the relationship between bank capital and loan interest rates. The same is true of the extensive theoretical literature that focuses on bank risk–return decisions. This literature provides a variety of predictions about relationships between bank capital and many dimensions of bank decision-making including lending rates, but, again, it provides no easy explanation for cyclical variation in those relationships.

Our finding of cyclical instability in the relationship between bank capital and lending rates is though consistent with theoretical perspectives on bank decision-making that have emerged since the crisis, exploring endogenous variation in bank leverage and risk appetite. This recent literature offers various rationales for changes in bank's willingness to accept risk exposure, between periods of rapid credit expansion – when, for example, the bank and its investors are optimistic about returns or perceive risks are relatively low – and periods of slow credit expansion or contraction – when they may hold opposite views, becoming pessimistic about returns or perceiving risks as being relatively high.

The paper is structured as follows. Section 2 reviews some of the relevant theoretical and empirical literature. Section 3 describes our data and methodology. Section 4 presents the estimation results and a battery of robustness tests. Section 5 concludes.

2. Prior literature

2.1. Theoretical perspectives

This section reviews theories about the relationship between bank capital and other bank decisions (including lending rates), starting with those theories that allow for a disciplinary role of capital or for the interaction of capital structure and risk–return decisions.[1]

One branch of theory, epitomised by the work of Holmström and Tirole (1997), emphasises the role of capital as a disciplining device ensuring that banks have sufficient 'skin in the game' to put the necessary effort into loan monitoring.[2] It predicts that higher bank capital is associated with higher lending volume and lower lending rates. Other models highlighting the disciplinary role of short-term wholesale funding (e.g., Diamond & Rajan 2000) suggest the contrasting prediction that a substitution of short-term debt funding for bank capital will result in higher lending volume and lower lending rates.

A much larger body of theory incorporates risk and the role of bank capital structure in bank risk–return decisions. The seminal contribution of Merton (1977) shows how deposit insurance provides bank shareholders with a put-option on bank returns. Lower bank capital can increase the magnitude of this put option (as it moves 'into the money') and increase the bank's incentives for risk-taking. This analysis of bank 'moral hazard' can be extended to accommodate bank franchise value or charter value lost in the event of failure (Marcus 1984; Keeley 1990). Under-capitalised banks may then seek to reduce their risk-exposure so as to protect their charter value (if this incentive outweighs the put option offered by the bank safety net).

These models of bank portfolio risk are further developed in the bank capital, competition and risk-taking literature; e.g., in Hellmann, Murdock, and Stiglitz (2000) greater competition in deposit markets can reduce charter value and lead to increased risk-taking. In Boyd and De Nicoló (2005), greater competition lowers the interest rates paid by bank borrowers in turn ameliorating agency costs in loan contracts and reducing bank portfolio risk.

These models of bank risk–return decisions make ambiguous predictions about the relation between risk exposure, the quantity of bank lending and loan interest rates. A bank could increase its risk exposure either by lowering loan interest rates and hence, increasing its lending volume along a standard loan demand; or through a portfolio reallocation towards higher-risk assets that offer higher rates of return. In both scenarios, the bank's overall risk exposure is increased but the promised return, that is, the interest rate, can be either lower (in the first scenario) or higher (in the second scenario).

The common denominator of all these theories is that bank lending and portfolio decisions are determined by a range of bank-specific and aggregate factors. Once these factors are controlled for, one should observe a stable relationship between capital and loan interest rates (and other dimensions of bank portfolio decisions such as bank lending).

This is not the prediction of more recent (since the global financial crisis) contributions to the literature that emphasise the cyclicality of both bank leverage and bank willingness to accept risk ('risk-appetite'). Prominent contributions are those provided by Geanakoplos (2010) (this is per se not an analysis of banking but his models of leverage can be applied to banks), Adrian and Shin (2011) and Borio and Zhu (2012).

Various rationales have been provided for why this cyclical variation might happen; for a review, see Gambacorta and Marquez-Ibañez (2011). The 'leverage cycle' in Geanakoplos (2010) arises from the interaction of heterogeneity in beliefs and constraints on borrowing. In expansionary periods optimistic investors are willing to pay high prices for assets which can generate a positive feedback – rising prices increase the access of these borrowers to funding which further increases asset prices.

A second rationale hinges on asset price volatility, notably in Brunnermeier and Pedersen (2009) where value-at-risk constraints determine access to leverage. This predicts multiple equilibria with the possibility of periods of low volatility, high asset prices and (by implication) high levels of lending; or high volatility, low asset prices and low lending levels.

A third rationale is behavioural, with reference to potential investor and intermediary irrationality. Periods of low interest rates and rapid growth may lead investors and bankers to underestimate risks. In

[1] For brevity, we focus on theoretical perspectives that provide relatively fully worked out models of the relationship between bank capital and bank lending volumes and/or interest rates. These are just one part of the broader literature exploring the reasons for departure from the Modigliani–Miller propositions for banks; for comprehensive reviews, see Miller (1995), and Berger, Herring, and Szegö (1995). Nor do we attempt any review of the theory on the 'bank lending channel' initiated by Bernanke and Blinder (1988, 1992), in which better capitalised banks are predicted to respond less to changes in central bank reserves because they can substitute alternative market funding for reserved deposits.

[2] This approach incorporates bank capital into the extensive earlier literature on bank monitoring and screening, originating with Leland and Pyle (1977) and Diamond (1984).

Borio and Zhu (2012), during periods of low perceived risk and credit expansion (such as the 'great moderation' that preceded the global financial crisis), banks see less need to hold much capital against risk; more aggressive banks may operate with lower capital and more portfolio risk. This cyclicality may be reinforced by increased credit demand, a key mechanism in the Minsky (1986) model of financial instability, or by rises in the market value of bank capital (Borio, Furfine, & Lowe 2001). Another explanation offered by Gambacorta and Marquez-Ibañez (2011) is that cyclical fluctuations in bank lending may be driven by incentive arrangements that focus excessively on short-term performance.

This literature on cyclical leverage and risk-appetite is new and relatively immature. It again offers a range of predictions. Some versions – for example, those emphasising the role of asset price volatility and value-at-risk constraints – suggest that the relationship between bank capital and loan interest rates while varying cyclically might still be explained by aggregate market- or economy-wide factors. Other versions of these newer theories (for example, those emphasising variation across banks in their optimism about future asset returns or perceptions of risk) explicitly introduce time-varying heterogeneity in bank behaviour, in which case the cyclical relationship between bank capital and loan interest rates cannot be empirically modelled by the inclusion of aggregate factors.

2.2. Empirical literature

Given the wide range of theoretical predictions, it is important to let the data speak on the relationship between bank capital and lending decisions (and other bank portfolio decisions). Empirical studies yield a range of findings.[3] Various papers assess the impact of bank capital in the US 'credit crunch' of the late 1980s and early 1990s (see Sharpe (1995), for a review). Some findings suggest that declines in bank capital reduce loan supply (e.g., Bernanke & Lown 1991; Hancock & Wilcox 1993; Peek & Rosengren 1995). Several recent studies have examined the relationship between bank capital and other dimensions of bank decision-making during and following the global financial crisis. Banks with relatively illiquid asset portfolios were forced to deleverage (Cornett, McNutt, Strahan, & Tehranian 2011). Better capitalised banks increased balance sheet assets relative to other banks (Berger & Bouwman 2013). Closest to our own findings are those of Košak, Li, Lončarski, and Marinč (2015) who analysing a sample of annual bank data examine the impact of bank capital on loan growth both pre-crisis and during the crisis. Their findings indicate that higher levels of capital and retail deposits are both associated with higher loan growth rates, and that the impact of Tier 1 bank capital on loan growth is very much higher during the crisis period.

Some empirical studies, like ours, assess the relationship between bank capital and loan interest rates. Most take a 'static' approach in which this relationship is assumed to be constant over time (Saunders & Schumacher 2000; Demirgüç-Kunt & Huizinga 1999; Carbó-Valverde & Rodríguez-Fernández 2007; Hubbard, Kuttner, & Palia 2002; Santos & Winton 2010). But others report cyclical variation in the relationship between lending rates (or interest margins) and capital even before the global financial crisis. Analysing UK syndicated loan data, Steffen and Wahrenburg (2008) find that undercapitalised banks during the 1996–2005 period charge higher interest rates during four episodes identified as recessionary. Fischer et al. (2012) study US syndicated loans and find that loan margins and the lender's capital ratio are negatively linked from 1988 to 1992 when both regulatory changes and market pressure force bank capital ratios upwards, and positively linked during 1993–2007 when banks operated in more benign conditions.

3. Data description and methodology

3.1. Institutional features of UK bank lending markets

We briefly describe some institutional features of the UK bank lending market. First, unlike in the US, there is relatively little fixed interest rate lending. Most mortgage lending is variable rate, either linked to wholesale lending rates such as the Bank of England base rate (the monetary policy rate), LIBOR or even more commonly at variable rates set at the discretion of lenders. Fixed rate residential mortgage lending is relatively uncommon and typically rates are fixed for only three to five years.

Second, also in comparison to other countries, the amount of UK corporate lending is relatively small. UK corporate lending (excluding commercial property mortgages) is only around 15% of total sterling bank lending and total UK corporate lending including commercial property represents only around 30% of sterling total bank lending.

Third, the level of competition varies considerably from one lending market to another. For residential mortgages and credit cards (the most important form of unsecured household lending) there are many competing providers. For corporate lending, especially SME borrowers, there are relatively few lenders.

UK banks, like those in other countries, were affected by the 2007–2009 global financial crisis (GFC). This arose in part because of UK bank holdings of US dollar sub-prime and other structured credit securities. But the main culprit was the extensive reliance of UK banks on wholesale funding and on securitisation (the closure of these markets was, for example, the reason for the failure of Northern Rock in September 2007).

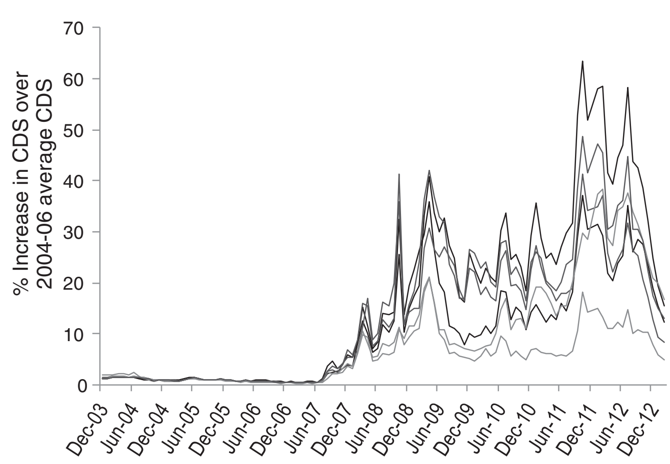

Fig. 1. Bank CDS prices. Bank CDS prices are obtained by averaging the prices of 1 year senior, 1 year subordinated, 5 year senior and 5 year subordinated CDS contracts from *Credit Market Analysis* (CMA) and *Thomson Reuters*. The resulting bank CDS prices are expressed as ratios (in percentage) over the corresponding average of the bank CDS price from December 2003 to December 2006. The figure shows the ratios for 6 of the 13 sampled banks on which data is available over the entire sample period.

[3] Due to space constraints, we do not review in detail the empirical literature on the 'bank lending channel' and the role of bank capital in response to changes of monetary policy rates; e.g., Kashyap and Stein (2000); Angeloni, Kashyap, and Mojon (2003); Ashcraft (2006) and Jiménez, Ongena, Peydró, and Saurina (2012). But we can note some parallels to our own findings, despite the notable differences in modelling approach. Gambacorta and Marquez-Ibañez (2011) report cyclical variation in the bank lending channel while Jiménez, Ongena, Peydró, and Saurina (2014) and Ioannidou, Ongena, and Peydró (2015) report increased risk-taking in response to cuts in monetary policy rates (but do not assess cyclical variation).

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The behaviour of end-of-month CDS prices for each UK bank based on 1- and 5-year senior and subordinated debt contracts are indicative of the impact of the crisis. Fig. 1 plots the resulting composite CDS price as a percentage of its average pre-crisis 2004–06 value for each bank. CDS prices rise sharply from July 2007, coinciding with public concerns about the valuation of structured products and a drying up of the market for structured securities and for short-term asset-backed commercial paper (Brunnermeier 2009).

3.2. Key variables: lending rates and capital ratios

We use confidential data submitted by banks to the Bank of England (BoE) and Financial Services Authority (FSA).[4] During the sample period, banks authorised in the UK submitted detailed data to the FSA on a quarterly basis on their balance sheets and capital adequacy. Large commercial banks also submitted data that enables the calculation of effective interest rates (defined below) to the BoE on a monthly basis, largely for the purpose of monitoring the pass-through of monetary policy decisions into market interest rates.

Differences between the BoE and FSA forms limit the scope of our sample. Whereas the FSA database covers every bank authorised in the UK, the effective rates collected by the BoE pertain to a small number of large retail banks which are the most active in the UK lending market. Unlike the BoE database, the FSA database does not include branches of foreign banks or building societies (since primary responsibility for their prudential supervision lies with the home regulator). Our final sample is necessarily limited to 13 large and UK-authorised banks that report in both datasets. These 13 banks account for around 75% of the UK lending market over the 1998–2012 sample period under study.

The sample banks are observed over two contrasting periods; one of exuberant credit conditions and benign macroeconomic performance up to 2007, and another of financial market stress and economic recession thereafter until the end of the sample in 2012. The main two variables, lending interest rates and capital ratios, are described next.

3.2.1. Effective lending rate

Banks submit to the FSA and BoE the average loan balances and interest accrued each month, from which *the annualised effective lending rate*

$$l_{it} = \frac{\text{interest accrued during month}}{\text{average loan balances during month}} \cdot \frac{\text{no.of days in year}}{\text{no.of days in month}} \tag{1}$$

is calculated monthly from 1998 to 2012 for all loans, corporate loans, household secured loans and household unsecured loans. From 2004 to 2012, we can also calculate the interest accrued on new loans agreed during the month which allows for a better measure of the immediate response to changing funding conditions (*new business* lending rates).

We opted for the effective rate after considering two alternative sources of lending rates employed in extant studies. One is quoted interest rates representing the interest rates advertised for new business, which were used by Fuertes and Heffernan (2009) and Fuertes, Heffernan, and Kalotychou (2010). These data have two main disadvantages: they do not include rates for large corporations which are generally not advertised; and they are quoted rather than agreed rates, which means they do not reflect the lending rates actually offered to borrowers (e.g., riskier borrowers may have to pay higher interest rates). Others use agreed rates on syndicated loans, e.g. Hubbard, Kuttner, and Palia (2002) and Santos and Winton (2010) in the US market, and Steffen and Wahrenburg (2008) in the UK market. While these represent interest rates agreed by syndicates of banks, they only include loans to large corporations and hence, do not include lending to households or to smaller businesses.

3.2.2. Capital ratio

The measure of bank capital ratio chosen for our empirical analysis is

$$k_{it} = \frac{\text{Tier 1 capital}}{\text{Total assets}} \tag{2}$$

instead of the ratio of Tier 1 capital to the regulatory measure of risk-weighted assets. The main reason for this choice is that the risk-weighted assets calculation has undergone major changes during the sample period, specifically in 2007 when Basel II allows banks to use their own internal models to determine credit risk weights, and in 2011 when the so-called “Basel 2.5” increased risk weights in the trading book and tightened eligibility criteria for regulatory capital. In addition, risk-weighted ratios have been much criticised post-crisis since banks were able to increase leverage substantially while maintaining healthy regulatory risk-weighted capital ratios (Turner 2009). We also prefer Tier 1 capital (common equity, reserves and certain hybrid equity-like securities) to the Tier 1 plus Tier 2 capital. This is because Tier 2 capital (subordinated debt and some hybrid instruments) was revealed by the crisis not to be truly loss-absorbing on a going concern basis.

3.3. Panel regression model and control variables

Our main reduced-form model, aimed at estimating the long-run association between bank lending rates (l_{it}) and bank capital ratios (k_{it}), can be formalised as follows.

$$l_{it} = A_i + Kk_{it} + Rr_{it} + Pp_{it} + Cc_{it} + Ww_{it} + Ss_{it} + Mm_{it} + Dd_{it} + Bb_t + Ff_t + Gg_t + u_{it} \tag{3}$$

This is a panel regression with bank fixed effects (A_i) and various controls to mitigate endogeneity arising from factors that simultaneously influence the lending interest rate and capital ratios; $i = 1, 2, \ldots, N$ are banks and $t = 1, \ldots, T_i$ are months (the panel is unbalanced with a maximum T_i of 148 months per bank, and an average T_i of 97 months). The fixed effects are aimed at capturing unobserved bank-specific heterogeneity such as the business model. The estimation method is pooled ordinary least squares (OLS).

The overall motivation for the control variables is to mitigate endogeneity (omitted variable) bias in the coefficient of interest K. The controls $(r_{it}, p_{it}, w_{it}, c_{it}, s_{it}, m_{it}, d_{it})'$ are *bank-specific* variables.[5] The first four are measures of bank portfolio risk that, according to the theories outlined in Section 2 above, can be expected to be correlated both with lending rates and capital ratios. These are the ratio of risk-weighted assets to total assets (r_{it}), ratio of provisions to total loans and other debt instruments (p_{it}), ratio of write-offs to total loans (w_{it}), and ratio of corporate loans to total loans (c_{it}).[6]

For the same reason, we also include each bank's total assets (s_{it}, expressed in £ billions) and measures of each bank's competitive position, the share of loans (m_{it}) and the share of total deposits (d_{it}).[7] These are standard controls in empirical banking.[8]

[4] The prudential functions of the FSA moved into the Prudential Regulatory Authority (PRA) in 2013.

[5] In an additional exercise we include the average CDS price on 5-year debt of banks in our models as a market measure of bank risk. The variable is significantly positively linked with lending rates. However, CDS prices reflect banks' capital ratios as well as the portfolio risk of the banks, so we do not report these results.

[6] The provisions data (Bank of England form PL) used to construct p_{it} include debt investments as well as loans, as provisions data exclusively for loans are not available over our entire sample period. To derive appropriate scalars for these variables we have constructed series for the stock of loans and investments which broadly match the provisions data (using the Bank of England forms BT and BE).

[7] The denominator is the total lending and deposits for all UK banks, not just those in our sample, from the Bank of England http://www.bankofengland.co.uk/statistics/Pages/bankstats/.

[8] Bank size is known to be correlated with capital ratios, and for this reason is used in most empirical studies of bank capital, e.g. Francis and Osborne (2012) and Jokipii and Milne (2008) and especially important in the context of lending rates where large banks may have lower funding costs (see Berger and Turk-Ariss 2015).

The remaining control variables $(b_t, f_t, g_t)'$ are *macroeconomic* indicators aimed at controlling for business-cycle endogeneity arising from common shocks that influence both the lending rate and the capital ratio. The most obvious candidate is the BoE base rate that is the target interest rate for UK monetary policy (b_t, expressed as a monthly average). In practice, interest rates for interbank lending can diverge from the BoE base rate due to expectations of losses which increase in periods of stress, together with term structure risk or the premium associated with lending at longer maturities. This motivates as control variable the spread of 1-year LIBOR over the BoE base rate (f_t, also as a monthly average). Our third macroeconomic control is the output gap (g_t) defined as the deviation of actual real GDP from "potential" or trend real GDP to control for loan demand.[9]

We begin by estimating the long-run panel model (3) using total lending rates (l_{it}) as the dependent variable. Then we re-estimate the model for household secured loans (l_{it}^{hsec}), household unsecured loans (l_{it}^{hunsec}) and lending rates on corporate loans (l_{it}^{corp}). Accordingly, we redefine the ratio of write-offs to loans in each of these sectoral models as w_{it}^{hsec}, w_{it}^{hunsec} and w_{it}^{corp} respectively, to reflect the specific risks in each loan category. We also redefine the loan market share variables as m_{it}^{hsec}, m_{it}^{hunsec} and m_{it}^{corp} to reflect the bank's competitive position in each of these loan sub-markets. The sampling frequency is monthly for all variables except capital ratios (k_{it}), output gap (g_t) and write-offs (w_{it}) which are only available quarterly. We convert them to monthly by linear interpolation.

We estimate the model using the entire sample together with a crisis dummy interacted with all the variables (including the bank fixed effects) to accommodate changes from the 'good times' period to the 'bad times' period in all the model parameters. Such a model produces identical results to estimating separate models for the two subperiods, but has the advantage that it enables standard tests for the significance of parameter changes. The crisis dummy takes value 0 from the beginning of the sample on October 1998 until June 2007 (the 'good times' period), and 1 from July 2007 until the sample end on December 2012 (the 'bad times' period). The choice of July 2007 as the cut-off point is grounded empirically on the evolution of the banks' CDS prices since these are likely to reflect investor sentiment about each bank (Fig. 1). The reason for including all months up to December 2012 in the 'bad times' period is that, although the acute liquidity crisis was essentially resolved by early 2009, the banking sector continued to be distressed due to low capital levels and the risk of losses stemming from the European sovereign debt crisis. As shown in Fig. 1, the CDS indices remain at a higher level through 2009–2012.

3.4. Robustness tests

In order to assess the robustness of the results, we carry out various robustness checks. We begin by embedding the long-run model (3) in lagged form, rewritten as $l_{i,t-j} = l_{i,t-j}^* + u_{t-j}$, into a dynamic error correction model (ECM) which can be formalised as.

$$\Delta l_{it} = c_i + \sum_{h=1}^{H} \beta_h^L \Delta l_{i,t-h} + \sum_{h=0}^{H} \boldsymbol{\beta_h}' \Delta \boldsymbol{Z_{i,t-h}} + \delta\left(l_{i,t-j} - l_{i,t-j}^*\right) + e_{it}. \tag{4a}$$

Model (4a) is more general in that it nests model (3) and additionally captures the short-run dynamics of lending rates; the vector $Z_{it} \equiv (k_{it}, r_{it}, p_{it}, w_{it}, c_{it}, s_{it}, m_{it}, d_{it}, b_t, f_t, g_t)'$ gathers all the control variables. An ECM is previously used, for instance, by Fuertes and Heffernan (2009) and Fuertes, Heffernan, and Kalotychou (2010) to analyse the long-run relationship between UK retail bank interest rates and the BoE base rate while simultaneously capturing their short-run behaviour. In this formulation, the lending rate changes (Δl_{it}) in response to deviations of the current lending rate l_{it-j} from its long-run path l_{it-j}^* which is often referred to as the cointegration path; the economic intuition behind the concept of cointegration is that l_{it}^* acts as an attractor for the interest rate l_{it} over the long run so that the deviation $(l_{it-j} - l_{it-j}^*)$ can be conceptualised as a zero-mean stationary process. Hence, the term $\delta(l_{i,t-j} - l_{i,t-j}^*)$ has the interpretation of an error correction or catch-up mechanism that pulls the loan rate towards its long run path l_{it}^* in the wake of exogenous shocks.[10]

Accordingly, the above ECM can be conveniently re-parameterised as follows.

$$\Delta l_{it} = \pi_i + \sum_{h=1}^{H} \beta_h^L \Delta l_{i,t-h} + \sum_{h=0}^{H} \boldsymbol{\beta_h}' \Delta \boldsymbol{Z_{i,t-h}} + \delta^L l_{t-j} + \boldsymbol{\delta Z_{t-j}} + e_{it} \tag{4b}$$

where δ^L and $\boldsymbol{\delta} \equiv (\delta^K, \delta^R, \delta^P, \delta^W, \delta^C, \delta^S, \delta^M, \delta^D, \delta^B, \delta^F, \delta^G)'$ are long-run parameters. Therefore, the long-run effect of the capital ratio on the lending rate can now be obtained as $K = -\delta^K/\delta^L$. Similarly, the long-run effects of the controls gathered in $\boldsymbol{Z}_{it}$ are given by the corresponding coefficient in the vector $\boldsymbol{\delta}$ multiplied by $-1/\delta^L$. The crucial short-run effect, according to the goal of this paper, is the coefficient that measures the association between the capital ratio and lending rate which is given by $\beta^K = \sum_{h=0}^{H} \beta_h^K$. Model (4b) also includes bank-specific fixed effects and is estimated by OLS.

The appropriate lag parameter j in the long-run component of the model, that is, the "error correction" mechanism that drives the lending rate towards its long-run path, is identified using the Akaike Information Criterion (AIC). This lag length reflects rigidities in the lending rate (e.g., difficulties in renegotiating contractual terms) that may prevent changes in the key variables driving the long run path, l_{it}^*, from immediately materializing as changes in the lending rate, Δl_{it}. For this identification purpose, we begin by estimating a baseline ECM with no additional lags of the first-differenced variables ($H = 0$) but considering different values for the lag parameter j (from 1 to 6 months) in $\delta^L l_{t-j}$ and in the different variables $\boldsymbol{Z}_{t-j}$ that drive the long-run path. We select the lag that minimises the AIC. This lag length identification process is conducted for each (overall and sectoral loans) model, since loans in each sector may have different maturity profiles or contractual features which influence the mechanism of "catch-up" towards the long-run path. Once the appropriate lag length j is identified, we augment the equation with as many short-term lags $h = 1, 2, \ldots, H$ as required to absorb the residual autocorrelation.

The lagged dependent variable ($\Delta l_{i,t-h}$) can induce a bias in dynamic panel regression although any lagged-dependent-variable bias is likely to be small in our ECM estimation given the large T dimension (about 150 months) relative to the cross-section dimension ($N = 13$ banks) of our sample. The most common method of dealing with this bias is to adopt the General Method of Moments (GMM) estimation; however, this is precluded in our context because of the small N. Alternatively, one can estimate the ECM using the Corrected Least Squares Dummy Variable estimator of Bun and Kiviet (2003) and Bruno (2005) which is appropriate for small N; hence, we take this route. The bias-corrected coefficients are very close to those obtained by standard pooled OLS and so we only report the latter below.

9 The source of the output gap data is the OECD Economic Outlook.

10 We deployed the panel Augmented Dickey Fuller (ADF) test on each of the variables in (2) in the pre-crisis and crisis periods and in the majority of cases (including our key variables of interest, the lending interest rate and the capital ratio) the null hypothesis of a unit root cannot easily be rejected.

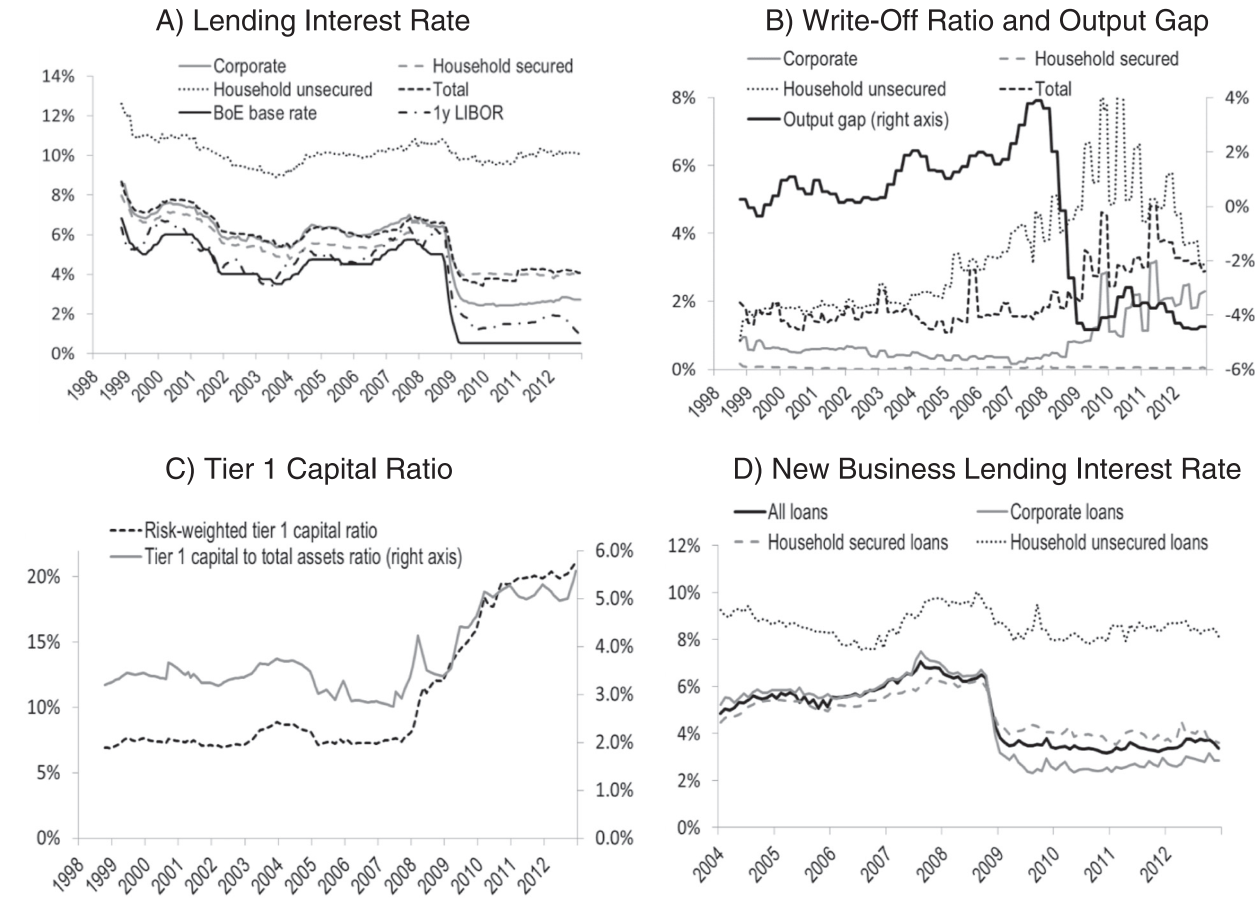

Fig. 2. Lending rates, write-offs and Tier 1 capital. Panels A to C plot average (across banks) loan interest rates, write-offs ratios alongside the output gap, and Tier 1 capital over the sample period October 1998 to December 2012. Panel D shows the average (across the 13 banks in the sample) interest rate on new loans granted each month from January 2004 to December 2012. These new loan rates are not strictly comparable to those graphed in Panel A as the new business rates cover slightly different categories of loans. See http://www.bankofengland.co.uk/statistics/Documents/reporters/defs/def_er2014.pdf.

We then present a range of further robustness checks. The first of these robustness checks is re-estimation of the long-run panel model, Eq. (3), with quarterly data to address concerns that observing the capital ratios, write-offs and output gap quarterly and then interpolating them to monthly observations might have contaminated our earlier findings.

The second robustness check is the inclusion of the capital requirement set by the FSA (denoted kr_{it}) as additional control variable in Eq. (3) to mitigate another potential source of endogeneity bias for the coefficient of interest K in model (3). Capital requirements can influence a bank's capital ratios and at the same time correlate with a bank's lending strategy and hence, influence the pricing and/or risk of loans; e.g., a bank pursuing a risky expansionary business strategy may be subject to higher capital requirements by the regulator.[11] Capital requirements also changed substantially over the sample period.[12]

The additional control variable kr_{it} included in Eq. (3) for these purposes is the regulatory capital requirement set by the FSA until April 2008 as the ratio of Tier 1 capital to risk-weighted assets multiplied by the ratio of risk-weighted assets to total assets. From April 2008 onwards, we replace this capital requirement variable with a flat 8% ratio of Tier 1 capital to risk-weighted assets multiplied by the bank's ratio of risk-weighted assets to total assets wherever this exceeds the bank- and time-specific FSA capital requirement.

A third robustness check as regards estimation of Eq. (3) includes monthly time fixed-effects instead of the macroeconomic control variables $(b_t, f_t, g_t)'$. The purpose is to ensure that our earlier results are not biased due to omission of other aggregate effects.

A final robustness check is an estimation of the long-run model (3) for total and sectoral lending using monthly data on *new business loans* defined as new loans or renegotiated outstanding loans during the month. This re-estimation is rather limited on two accounts. The first limitation is that data are available only for the period 2004–2012. The second limitation is that the portfolio-risk control variables $(r_{it}, p_{it}, w_{it}, c_{it})$ and the loan market share variable (m_{it}) refer to existing business lending not to new business lending.

4. Empirical results

4.1. Preliminary data analysis

The dynamics of monthly bank lending rates (l_{it}), write-offs to total loans (w_{it}) and Tier 1 capital ratio (k_{it}) during the entire sample period – October 1998 to December 2012 – is illustrated in Fig. 2. The graphs show means across all the $i = 1,\ldots,N$ banks ($N = 13$).

Panel A shows the average monthly lending rate for all loans, household secured loans, household unsecured loans and corporate loans

[11] Francis and Osborne (2012) and Aiyar, Calomiris, and Wieladek (2014) provide evidence of these links for the UK market. See also the literature cited in Section 2.2 on the US 'credit crunch' in the late 1980s and early 1990s.

[12] The pre-crisis capital requirements were set at the level of the regulatory risk-weighted total capital ratio and varied across banks and over time according to FSA judgements (see Francis and Osborne 2012). From 2008, Tier 1 capital ratios rose substantially as the FSA set higher benchmark expectations for firms in the context of the government support package for major banks, including a minimum Tier 1 capital ratio of 8%.

Table 1
Descriptive statistics for lending rates, capital ratios and controls.

	Full sample		Pre-crisis period		Crisis period	
	Mean	StDev	Mean	StDev	Mean	StDev
I. Bank-specific variables						
Lending rate (l_{it})	6.02	1.51	6.51	1.24	4.73	1.40
Household secured lending rate l_{it}^{hsec}	5.46	1.38	5.91	0.83	4.63	1.76
Household unsecured lending rate l_{it}^{hunsec}	10.14	1.89	10.15	2.15	10.09	1.07
Corporate lending rate l_{it}^{corp}	5.69	1.87	6.43	1.17	3.72	1.94
Tier 1 capital ratio (k_{it})	3.61	1.55	3.29	1.29	4.46	1.84
Capital requirement (kr_{it})	2.03	0.80	1.99	0.80	2.14	0.81
Risk-weighted assets to total assets ratio (r_{it})	40.80	17.30	44.63	17.63	30.68	11.32
Provisions to loans and investments ratio ρ_{it}	0.77	0.58	0.83	0.58	0.59	0.53
Corporate loans to total loans ratio (c_{it})	20.44	15.56	20.09	1.67	21.35	13.30
Write-offs to loans ratio (w_{it})	1.95	1.86	1.61	16.33	2.87	2.02
Household secured write-offs to loans ratio w_{it}^{hsec}	0.04	0.06	0.03	0.05	0.05	0.08
Household unsecured write-offs to loans ratio w_{it}^{hunsec}	3.10	2.92	2.29	2.18	5.00	3.49
Corporate write-offs to loans ratio w_{it}^{corp}	0.74	1.31	0.48	0.69	1.41	2.09
Total assets, £bn (s_{it})	258	258	156	151	526	289
Share of total loans (m_{it})	0.08	0.05	0.06	0.04	0.12	0.05
Share of household unsecured loans (m_{it}^{unsec})	0.06	0.04	0.05	0.04	0.09	0.04
Share of household secured loans (m_{it}^{sec})	0.07	0.05	0.07	0.05	0.09	0.06
Share of corporate loans (m_{it}^{corp})	0.06	0.05	0.05	0.05	0.08	0.04
Share of deposits (d_{it})	0.06	0.04	0.05	0.04	0.08	0.03
II. Macroeconomic variables						
BoE base rate (b_t)	3.99	1.86	4.81	0.80	1.84	2.11
1y LIBOR spread to BoE base rate (f_t)	0.50	0.48	0.33	0.40	0.97	0.35
Output gap (g_t)	0.10	2.26	1.02	0.78	−2.31	2.98

Notes: The table reports the mean and standard deviation of all variables pooled across banks and months in pre-crisis (October 1998–June 2007) and crisis (July 2007–December 2012) periods. L_{it} is the lending rate as defined in (1) measured for all loans and, separately, for household (un)secured loans and corporate loans. K_{it} is the ratio of Tier 1 capital to total (unweighted) assets. Kr_{it} is the capital requirement set by the FSA regulator as explained in Section 2.4 of the main text. R_{it} is the ratio of risk-weighted to total assets. P_{it} is the ratio of provisions to total loans and debt investments. C_{it} is the ratio of corporate loans to total loans. W_{it} is the ratio of write-offs to total loans measured separately for household (un)secured and corporate loans. S_{it} is the total assets of each bank expressed in £ billions. M_{it} is each bank's share of loans which is measured separately for household (un)secured and corporate loans. D_{it} is each bank's share of total deposits. b_t is the target overnight interest rate set by the BoE. f_t is the spread of the 1 year LIBOR rate over the bank rate. g_t is the OECD estimate of the UK output gap.

alongside the BoE base rate. During the pre-crisis period, all rates tracked the BoE base rate fairly closely with a spread of between 50 and 150 basis points (bp) for household secured loans and corporate loans and 400–700 bp for household unsecured loans, reflecting a notably larger credit risk premium for the latter. In 2008 there is a profound shift as the BoE base rate fell to an historic low of 50 bp and the spread between lending rates and BoE base rate widened considerably to 300 bp for household secured and corporate loans and to 800 bp for household unsecured loans. The wider spread is likely to reflect both heightened loan credit risk premia and increases in banks' cost of funding due to investors' concerns about bank creditworthiness, as demonstrated by the CDS dynamics shown in Fig. 1 and the spread between the BoE base rate and the 1-year LIBOR rate shown in Fig. 2 (Panel A).

Panel B of Fig. 2 shows the average write-offs over total loans for household secured lending, household unsecured lending and corporate lending. Again there is a clear contrast between the pre-crisis period and the crisis period. Household unsecured loans have a write-offs ratio of 1–2% in the pre-crisis period which doubles to around 5–8% in the crisis period, after which it broadly returns to pre-crisis levels. Corporate loan write-offs are between 0.3% and 0.7% in the pre-crisis period but rise to between 2% and 4% in the crisis period. Household secured write-offs are 0.01–0.03% pre-crisis and increase to around 0.08–0.13% during crisis period, before declining to 0.04–0.05% thereafter.

Panel C of Fig. 2 shows the average of bank Tier 1 capital ratios and their risk-weighted version. Both fell between 2004 and 2007 and then rose notably thereafter. Finally, the new business loan rates are shown in Panel D of Fig. 2. As one would expect, new business rates are more volatile than existing rates. Nonetheless, despite significant spreads opening up in particular months of both positive and negative sign, there is no visual evidence that these spreads persist for any length of time.

The sample distribution of each variable (data pooled across banks and months) is summarised in Table 1 over the entire 1998–2012 period, the 'good times' or pre-crisis period (up to June 2007) and the 'bad times' or crisis period (from July 2007 onwards).

The capital ratio, write-offs to total loans ratio and LIBOR spread are much lower pre-crisis than in crisis. The BoE base rate, lending rates and output gap are also much lower in crisis. The risk-weighted assets to total assets ratio is lower in the crisis period. Lending rates are the highest for unsecured lending, and fall little in the crisis period. The household secured and corporate loan rates are generally lower, and fall more notably in the crisis period.

4.2. Estimation results

Table 2 reports the estimation results for the baseline model, Eq. (3), adding interaction variables (i.e., the crisis dummy variable interacted with all other variables) so as to allow for full parameter heterogeneity from 'good times' to 'bad times'. We focus our discussion primarily on the main parameter of interest, the coefficient K on the Tier 1 capital ratio, and we report Wald tests for the change in this parameter only, for space constraints.[13]

In the all-loans regression, the model parameter K is significantly positive during the pre-crisis period and becomes significantly negative during the crisis period. Turning to the different sub-categories of lending, there is a similarly large change, economically and statistically, in the coefficient K for both household secured (residential mortgage) and household unsecured lending. While for both household secured and unsecured loans the capital ratios versus lending rates association

[13] Similar unreported Wald tests for the significance of changes in each of the other model parameters revealed that the change from pre-crisis to crisis is not just confined to the Tier 1 capital ratio coefficient.

Table 2
Estimation results for long-run model of lending rates.

Variable (coefficient)	All loans		Household secured		Household unsecured		Corporate	
	Pre-crisis	Crisis	Pre-crisis	Crisis	Pre-crisis	Crisis	Pre-crisis	Crisis
Tier 1 capital ratio (K)	0.048***	−0.084***	0.077***	−0.065***	0.181***	0.051**	−0.223***	−0.016
	(0.016)	(0.014)	(0.013)	(0.014)	(0.042)	(0.021)	(0.029)	(0.016)
Wald test statistic (prob), Ho: $K^{pre\text{-}crisis} = K^{crisis}$	37.28 [0.000]		57.53 [0.000]		6.52 [0.011]		27.45 [0.000]	
Risk-weighted assets to total assets ratio (R)	−0.004**	−0.009***	−0.008***	−0.009***	−0.031***	−0.022***	0.007**	−0.009***
	(0.002)	(0.003)	(0.002)	(0.003)	(0.005)	(0.004)	(0.003)	(0.003)
Provisions to loans and investments ratio (P)	0.017	−0.021	−0.149***	0.043	0.021	−0.581***	0.093	0.064
	(0.035)	(0.069)	(0.040)	(0.068)	(0.099)	(0.100)	(0.065)	(0.076)
Corporate loans to total loans ratio (C)	0.003	0.044***	0.006**	0.016***	0.003	0.013***	0.029***	0.008**
	(0.002)	(0.003)	(0.003)	(0.002)	(0.007)	(0.003)	(0.003)	(0.003)
Write-offs to loans ratio (W)	0.049***	0.007	0.012*	0.053***	−0.005	−0.058***	−0.041**	0.004
	(0.009)	(0.010)	(0.007)	(0.010)	(0.024)	(0.016)	(0.016)	(0.017)
Total assets (S)	−0.000***	−0.001**	−0.001***	0.001***	−0.001***	0.002***	−0.001**	−0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Share of total deposits (D)	−1.521*	−4.850***	−4.090***	3.497***	9.704***	−1.044	11.820***	0.164
	(0.780)	(0.742)	(0.507)	(0.694)	(1.615)	(0.833)	(1.258)	(0.637)
Share of total loans (M)	−2.514***	−3.030***						
	(0.804)	(1.096)						
Household secured								
Write-offs to loans ratio (W^{hsec})			−0.616***	0.569***				
			(0.173)	(0.199)				
Share of loans (M^{hsec})			−2.469***	1.350*				
			(0.681)	(0.794)				
Household unsecured								
Write-offs to loans ratio (W^{hunsec})					0.053**	0.007		
					(0.024)	(0.008)		
Share of loans (M^{hunsec})					5.418*	−4.524***		
					(2.841)	(1.709)		
Corporate								
Write-offs to loans ratio (W^{corp})							0.234***	−0.016
							(0.035)	(0.016)
Share of loans (M^{corp})							−18.703***	4.159***
							(1.347)	(1.604)
BoE base rate (B)	0.864***	0.637***	0.849***	0.584***	0.859***	0.242***	0.816***	0.961***
	(0.011)	(0.025)	(0.010)	(0.024)	(0.030)	(0.035)	(0.021)	(0.027)
1y LIBOR spread to BoE base rate (F)	0.032	−0.030	0.051***	−0.009	0.188***	−0.094	0.013	0.019
	(0.023)	(0.053)	(0.020)	(0.051)	(0.060)	(0.075)	(0.042)	(0.059)
Output gap (G)	−0.246***	−0.050***	−0.266***	−0.026	−0.574***	−0.010	−0.107***	−0.077***
	(0.016)	(0.018)	(0.015)	(0.017)	(0.045)	(0.026)	(0.031)	(0.020)
No. of observations (T'N)	1715		1309		1556		1707	
No. of banks (N)	13		10		12		12	
Adjusted-R^2	0.962		0.971		0.877		0.929	

Notes: The table reports OLS estimates of the long-run Eq. (3) for lending rates with fixed bank effects. The data are monthly from October 1998 to June 2007 (pre-crisis period) and from July 2007 to December 2012 (crisis period) for *N* banks. See note to Table 1 for variable definitions. The numbers in parentheses are Newey–West h.a.c. standard errors. The numbers in square brackets are *p*-values.

is significantly positive in the 'good times' it becomes much smaller (unsecured loans) or changes sign (secured loans) in the 'bad times'.

The results for corporate lending also reveal a significant change in *K* from the 'good times' to the 'bad times'. This change is, however, in the opposite direction to that detected for the two categories of household lending. Pre-crisis, the capital ratios versus loan rates association is significantly negative whereas during the crisis period the corresponding coefficient becomes essentially zero suggesting no association. As revealed by the Wald test statistics in Table 2, all of these changes in the coefficient *K* are highly significant.

We briefly comment on the estimates of the coefficients pertaining to the control variables in Table 2. The share of corporate loans (c_{it}) is consistently positive and larger during the crisis (with the exception of corporate lending where the coefficient falls during the crisis). Bank size and loan and deposit market share are negative and highly significant in the total loan model. For individual loan sectors, these variables are also highly significant, though there is a mixture of positive and negative coefficients.

The coefficient of the BoE base rate (b_t) is positive and significant throughout, unsurprisingly. The coefficient of the output gap (g_t) is consistently negative, but lower in the crisis period than pre-crisis, and while always significant pre-crisis it becomes insignificant during the crisis period for both categories of household lending.

We interpret the significant changes reported in Table 2 for the coefficient *K* on the capital ratio in our loan rate regressions as evidence of a cyclical change in risk appetite of the kind discussed in the newer literature on cyclical bank leverage and risk appetite. Note that this interpretation can explain our finding of a significant change in sign of the coefficient *K* that is of the opposite direction for corporate lending and for household lending. This is a consequence of the theoretical ambiguity about the relationship between risk appetite and lending rates discussed above in Section 2. Risk may be reduced in the crisis either by raising loan rates along a loan demand function for one category of lending (this might be the case for the household secured lending) while at the same time changing the composition of lending from relatively high risk loans offering higher rates of interest to relatively low risk loans offering lower interest rates for another category of lending (this might be the case for the corporate lending).

Turning to the robustness tests, the estimation results for the ECM specification (4b) that captures long- and short-term mechanisms are shown in Table 3. To preserve space, we report the long-run parameters

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Table 3
Estimation results for error correction model of lending rates.

Variable (coefficient)	All loans		Household secured		Household unsecured		Corporate	
	Pre-crisis	Crisis	Pre-crisis	Crisis	Pre-crisis	Crisis	Pre-crisis	Crisis
A. Long-run effects								
Tier 1 capital ratio (K)	0.068*	−0.004	0.120	−0.180	0.283**	0.099	−0.265***	0.132
	(0.040)	(0.041)	(0.103)	(0.121)	(0.135)	(0.068)	(0.086)	(0.107)
Wald test statistic (prob), Ho: $K^{pre\text{-}crisis} = K^{crisis}$	1.59 [0.207]		3.53 [0.060]		1.48 [0.224]		8.32 [0.004]	
Risk-weighted assets to total assets ratio (R)	−0.009**	−0.016**	0.010	0.010	−0.040***	−0.020*	0.014	−0.038*
	(0.004)	(0.007)	(0.016)	(0.020)	(0.014)	(0.012)	(0.009)	(0.020)
Provisions to loans and investments ratio (P)	0.097	0.211	−0.506	0.217	0.044	−0.276	0.058	0.438
	(0.088)	(0.188)	(0.332)	(0.466)	(0.312)	(0.312)	(0.190)	(0.465)
Corporate loans to total loans ratio (C)	−0.001	0.047***	−0.013	0.012	0.003	0.017	0.032***	−0.001
	(0.005)	(0.008)	(0.020)	(0.017)	(0.022)	(0.011)	(0.009)	(0.020)
Write-offs to loans ratio (W)	0.070***	0.137***	−0.014	−0.033	0.018	0.019	−0.032	−0.073
	(0.023)	(0.049)	(0.052)	(0.120)	(0.080)	(0.083)	(0.050)	(0.118)
Total assets (S)	−0.001*	−0.001**	0.001	−0.000	−0.002*	0.002**	−0.000	−0.002
	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
Share of total deposits (D)	−0.242	−4.692**	−3.462	6.445	18.015***	−0.772	11.911***	0.097
	(1.983)	(1.970)	(3.948)	(4.593)	(5.164)	(2.600)	(3.726)	(3.833)
Share of total loans (M)	−2.509	−5.895**						
	(2.061)	(2.968)						
Household secured								
Write-offs to loans ratio (W^{hsec})			−1.500	−9.325				
			(1.368)	(25.892)				
Share of loans (M^{hsec})			−11.460*	−2.401				
			(6.056)	(5.109)				
Household unsecured								
Write-offs to loans ratio (W^{hunsec})					0.046	−0.058		
					(0.078)	(0.104)		
Share of loans (M^{hunsec})					3.922	−7.124		
					(9.060)	(5.270)		
Corporate								
Write-offs to loans ratio (W^{corp})							0.333***	2.381
							(0.104)	(4.330)
Share of loans (M^{corp})							−16.428***	14.652
							(3.957)	(10.009)
BoE base rate (B)	0.855***	0.623***	0.691***	−0.252	0.904***	0.229*	0.839***	0.929***
	(0.030)	(0.080)	(0.096)	(0.350)	(0.098)	(0.130)	(0.065)	(0.197)
1y LIBOR spread to BoE base rate (F)	0.424***	−0.127	0.859***	1.284**	0.542**	0.115	0.214	0.125
	(0.076)	(0.157)	(0.264)	(0.584)	(0.243)	(0.261)	(0.155)	(0.394)
Output gap (G)	−0.190***	−0.015	−0.331**	0.504**	−0.423***	0.021	−0.024	0.037
	(0.042)	(0.058)	(0.131)	(0.231)	(0.148)	(0.096)	(0.093)	(0.147)
B. Short-run effect								
Tier 1 capital ratio (b^K)	0.014	0.010	0.066*	−0.009	0.081	0.073	−0.078	0.049
	(0.039)	(0.037)	(0.036)	(0.029)	(0.076)	(0.069)	(0.061)	(0.057)
No. of observations (T'N)	1702		1269		1544		1695	
No. of banks (N)	13		10		12		12	
Adjusted-R^2	0.374		0.315		0.111		0.222	

Notes: The table reports OLS estimates of the Error Correction Model for lending rates with fixed bank-specific effects, Eq. (4b), with enough short-term lags (H) to absorb all residual autocorrelation. The data are monthly from October 1998 to June 2007 (pre-crisis period) and from July 2007 to December 2012 (crisis period) for N banks. The long-run effect of the capital ratio (k_{it}) on the lending rate (l_{it}) is measured by the composite parameter $K = -\delta^K/\delta^L$ as shown in the table; likewise, for all the other variables. The short-run effect of the capital ratio on the lending rate is measured by the composite parameter $\beta^K = \sum_{h=0}^{H} \beta_h^K$. See note to Table 1 for variable definitions. The numbers in parentheses are Newey–West h.a.c. standard errors. The numbers in square brackets are p-values.

for all variables as in Table 2, but regarding the short-run effects we focus on the parameter of interest (β^K) concerning the capital ratio.

The results on the long-run association between bank capital ratios and lending rates obtained from the ECM are broadly consistent with those from the long-run model (3). In particular, the Wald test statistics still reveal a significant change from pre-crisis to crisis for household secured and corporate loans. For household secured rates and corporate rates, the change observed in the short-run coefficient β^K from pre-crisis to crisis is aligned with the direction of the change in the long-run coefficient K, which emphasises the evidence.

All the remaining robustness tests concerning the long-run model (3) are gathered in Table 4. We report only the coefficient of interest K and the corresponding Wald test statistic for the significance of change from the pre-crisis to crisis periods. The unreported coefficients on the control variables (the same controls as those used in our baseline analysis summarised in Table 2) do not change much from one robustness check to another; the full set of estimation results are available from the authors upon request.

Panel I of Table 4 reproduces our baseline estimates of K from Table 2 for comparison. Panel II reports the same coefficient estimates using quarterly data. Panel III reports the coefficient estimates when including capital requirements as an additional control. In both of these panels the reported coefficient estimates and the Wald test statistic for the null hypothesis of no-change in K are almost unchanged from the baseline results in Panel I.

Panel IV reports the coefficient estimates K and corresponding Wald tests when replacing the three macroeconomic controls with time fixed-effects. The coefficient estimates for all loans and household secured lending are little changed. For household unsecured lending K now switches from significantly positive pre-crisis to significantly

Table 4
Robustness tests for long-run model of lending rates.

Variable (coefficient)	All loans Pre-crisis	All loans Crisis	Household secured Pre-crisis	Household secured Crisis	Household unsecured Pre-crisis	Household unsecured Crisis	Corporate Pre-crisis	Corporate Crisis
I. Baseline estimates (from Table 2)								
Tier 1 capital ratio (K)	0.048***	−0.084***	0.077***	−0.065***	0.181***	0.051**	−0.223***	−0.016
	(0.016)	(0.014)	(0.013)	(0.014)	(0.042)	(0.021)	(0.029)	(0.016)
Wald test statistic (prob), Ho: $K^{pre\text{-}crisis} = K^{crisis}$	37.28 [0.000]		57.53 [0.000]		6.52 [0.011]		27.45 [0.000]	
II. Quarterly observations								
Tier 1 capital ratio (K)	0.048*	−0.065**	0.070***	−0.075***	0.170**	0.068*	−0.196***	−0.012
	(0.026)	(0.025)	(0.020)	(0.023)	(0.070)	(0.036)	(0.053)	(0.028)
Wald test statistic (prob), Ho: $K^{pre\text{-}crisis} = K^{crisis}$	10.73 [0.001]		23.65 [0.000]		1.24 [0.265]		6.24 [0.013]	
III. Controlling for capital requirements								
Tier 1 capital ratio (K)	0.054***	−0.083***	0.077***	−0.065***	0.174***	0.051**	−0.195***	−0.016
	(0.016)	(0.014)	(0.013)	(0.014)	(0.040)	(0.021)	(0.028)	(0.016)
Wald test statistic (prob), Ho: $K^{pre\text{-}crisis} = K^{crisis}$	41.04 [0.000]		56.53 [0.000]		6.53 [0.012]		24.69 [0.000]	
IV. Time fixed-effects								
Tier 1 capital ratio (K)	0.037**	−0.100***	0.083***	−0.099***	0.199***	−0.176***	−0.278***	0.315***
	(0.016)	(0.025)	(0.014)	(0.020)	(0.039)	(0.059)	(0.028)	(0.043)
Wald test statistic (prob), Ho: $K^{pre\text{-}crisis} = K^{crisis}$	16.03 [0.000]		23.73 [0.000]		8.86 [0.003]		53.69 [0.000]	
V. New business lending rates								
Tier 1 capital ratio (K)	−0.012	−0.050**	−0.134***	−0.065***	−0.532***	−0.043	−0.025	−0.006
	(0.063)	(0.022)	(0.042)	(0.024)	(0.103)	(0.070)	(0.037)	(0.028)
Wald test statistic (prob), Ho: $K^{pre\text{-}crisis} = K^{crisis}$	0.38 [0.539]		1.24 [0.265]		9.69 [0.002]		0.11 [0.740]	

Notes: The table reports OLS estimates of the coefficient of Tier 1 capital ratio in model (3) for lending rates. Panel I reproduces the estimates obtained in Table 2 for comparison. Panel II pertains to the estimation based on quarterly data. Panel III pertains to model (3) with capital requirements as additional control. Panel IV reports results for model (3) with time fixed effects instead of the macroeconomic variables. Panel V reports results for new business lending rates. In all cases, the data are monthly from October 1998 to June 2007 (pre-crisis) and from July 2007 to December 2012 (crisis) except for Panel V where the pre-crisis period is shorter from January 2004 to June 2007 due to data constraints on new business lending rates. See note to Table 1 for variable definitions. The numbers in parentheses are Newey–West h.a.c. standard errors. The numbers in square brackets are *p*-values.

negative in crisis. For corporate lending K now switches from significantly negative pre-crisis to significantly positive in crisis. The Wald test statistic now rejects the no-change null hypothesis in the coefficient K for all three sub-categories of lending as well as all-loans.

Finally Panel V reports the re-estimation of K in the long-run model, Eq. (3), once again with the crisis dummy interacted with all variables but now using *new business* lending rates as the dependent variable. Here, not surprisingly since we are losing two thirds of our pre-crisis sample (the estimation period is 2004–2012, as noted in Section 3.4) there is a substantial change in the pre-crisis coefficient estimates for K. Reassuringly, the coefficient estimates for the crisis period are relatively little changed. The coefficient K on the capital ratio is now negative in all cases, both pre-crisis and during the crisis-period. This final robustness test suggests the possibility of further instability in the capital ratio versus lending rate relationship of interest within the pre-crisis period. These estimation results should be interpreted with caution however since, as noted earlier, the available portfolio-risk control variables and loan market share all refer to existing business lending.

5. Conclusions

This paper reports estimates of the relationship between bank capital and bank lending rates over the period 1998–2012 using data on the 13 largest UK banks that account for around 75% of UK lending. For household secured loans we find a positive long-run relationship between capitalisation and loan interest rates in the pre-2007 period ('good times') and a negative relationship during the subsequent period ('bad times'). For unsecured household lending we find instead a positive association in both sub-periods but with a substantial and significant change in magnitude from pre-crisis to crisis (from relatively strong to weak, respectively). Finally, for corporate loans we find a negative association pre-crisis and no association during the sample period that includes the crisis.

This finding of pronounced cyclical instability in the relationship between bank capital and lending rates is difficult to reconcile with many well-established theories of bank decision-making. We have reviewed theories in which bank capital is needed to provide banks with the incentive to apply effort to screening and monitoring of loans and also models of the impact of bank capitalisation on bank choices about portfolio risk and return. These analyses offer a variety of predictions about the relationship between bank capital and lending rates, but they all suggest that this relationship should be stable over time once fully controlling for aggregate macroeconomic and bank-specific factors.

Our reported coefficient instability might reflect shifts in the distribution of loan demand and therefore be consistent with these well-established theories of banking. For example, the instability may be a consequence of a pre-crisis shift in the distribution of the demand for lending across banks according to their particular regional or sectoral customer exposure that was subsequently reversed. Despite controlling for aggregate determinants of bank loan demand by including macroeconomic variables in our regressions (and replacing these with time-specific effects in a robustness check), we cannot definitively rule out the possibility of such a compositional shift in demand.

Still a plausible interpretation of our finding of instability in the parameter measuring the association between bank capital ratios and lending rates is that it is a consequence of cyclical mechanisms highlighted in the newer theoretical perspectives on bank decision-making that have emerged since the crisis. This recent literature suggests a variety of reasons for why the bank willingness to accept risk exposure may vary between periods of rapid credit expansion and periods of slow credit expansion or even contraction.

The precise mechanisms involved merit exploration. For example, some banks may have been more optimistic than others about future returns during the pre-crisis period and, as a result, operated with comparatively low levels of capital and accepted relatively high portfolio risk. Then, with the onset of the crisis, these same banks may have found themselves over-extended and needed to reduce portfolio risk. Further research is required on a wider range of bank decisions, and for other countries and time periods, to establish which variants of these newer theories of cyclical changes of bank leverage and risk-appetite offer the best explanations of observed bank portfolio and loan decisions. Work is also warranted on the

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impact of minimum regulatory capital requirements and of the newly introduced regulatory capital buffers, for example, the 'capital conservation buffer' in Basel III, both in expansionary and contractionary phases of the credit cycle.[14]

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[14] Also, in relation to the literature on the 'bank-lending channel' discussed in previous footnotes, more research is warranted on cyclical variation in the response of bank loan volumes and bank risk-taking to changes in monetary policy rates.

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