Did Basel regulation cause a significant procyclicality? ⋆

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Abstract

This paper examines the procyclical effect of risk-sensitive capital regulation on bank lending. We find evidence that the sensitivity of bank lending to GDP is significantly positive under the internal rating-based approach. Our findings show that the risk-sensitive requirements of the Basel II and III regulations have procyclical effects on bank lending in nine European countries. The introduction of the risk-sensitive capital requirement rule negatively impacts lending in these countries. The policy implication is that regulators should place greater priority on building a buffer in advance, which can be used in times of stress rather than for dampening excess cyclicality.

Keywords:

Basel regulation, business cycle, procyclicality, buffer capital

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JEL classification: G21; G28; G18; G14; G32

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Abstract

This paper examines the procyclical effect of risk-sensitive capital regulation on bank lending. We find evidence that the sensitivity of bank lending to GDP is significantly positive under the internal rating-based approach. Our findings show that the risk-sensitive requirements of the Basel II and III regulations have procyclical effects on bank lending in nine European countries. The introduction of the risk-sensitive capital requirement rule negatively impacts lending in these countries. The policy implication is that regulators should place greater priority on building a buffer in advance, which can be used in times of stress rather than for dampening excess cyclicality.

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1. Introduction

The 2007-2009 global financial crisis indicated the need for a thorough re-examination of risk-sensitive capital requirements in the Basel II framework. Herring (2018) has highlighted the growing complexity of capital regulation and emphasized the decisions made by the Basel Committee on Banking Supervision and Regulation. Recent studies have focused on internal ratings-based (IRB) banks that economize on capital by reporting lower risk, such as credit risk (Abbassi and Schmidt 2018, Berg and Koziol 2017, Behn et al. 2016, Firestone and Rezende 2016) or market risk (Begley et al. 2016). Capital adequacy rules failed to align regulatory capital requirements with the riskiness of bank assets and therefore undermined banks' abilities to respond to adverse shocks.

Kim and Sohn (2017) analyse how the effect of bank capital on lending varies in response to bank liquidity. However, they do not examine how an economy-wide business cycle affects lending through capital requirement regulations. We complement this literature by addressing specific questions along the following lines: If bank capital requirements are associated with the riskiness of loans, do banks lend too much at the top of the business cycle (when loans appear less risky, thereby requiring less reserve capital) and too little at the trough (when loans become riskier)? In particular, is the risk-sensitive capital requirement based on the IRB approach truly too risk-sensitive? How different is the effect of the IRB approach on bank lending relative to the risk-insensitive rule inherited from the Basel I regulation? To address these questions, we re-examine the level of procyclicality in the way bank lending responds to risk-sensitive capital regulation.

We need to re-examine this topic for two reasons. First, in the Basel III revision, the regulators introduce and currently plan for several kinds of new regulations, such as the capital conservation buffer, countercyclical buffer, and increasing capital quality (common equity). The Basel III revisions reflect the reconsideration that the Basel II regulation was too risk insensitive and inadequate for prudent activity by the banks. In the euro area, the Basel regulation was adopted through the Capital Requirements Directives (CRD). The IRB approach for credit risk was first established by Directive 2006/48/EC on June 14, 2006, and replaced by Regulation (EU) No 575/2013 (CRR).[1] In July 2011, the CRDIV legislative package was adopted to replace the CRDII governing deposit-taking activities (Commission 2011a) and a regulation on prudent requirements for credit institutions (Commission 2011b). The directive integrates the two capital buffer elements of the Basel III accord, namely, the capital conservation buffer that must be applied equally by all EU banks and the countercyclical capital buffer to be determined at the national level. Basel III/CRDIV requires banks to hold a Common Equity Tier 1 capital ratio of 4.5%, a Tier 1 capital ratio of 6% and a total capital ratio of 8%. The requirement to maintain a capital conservation buffer of Common Equity Tier 1 capital equal to 2.5% of their total risk exposure amount was implemented in 2019. However, evidence has not been obtained on the effects of risk-sensitive requirements on the relationship between bank capital and *its lending* during the period *Following the Basel II* revision.[2]

Second, although the Basel III revision introduced many concepts to ensure prudence on the part of banks, the basic regulation inherited the Basel II provisions.[3] Basel III inherited not only the risk-sensitive capital requirement introduced by Basel II but also the standardized (STD hereafter) approach of the Basel I regulation. More specifically, the STD approach was introduced in Basel I and included in the 1996 amendment that encompasses market risk (BCBS 1996). In Basel II, the Basel Committee introduced a new paradigm to align the regulation of market risk with banks' own internal risk models (IRB approach) in

[1]The CRR developed technical standards and guidelines to determine more harmonised application of the IRB requirements. Specifically, the CRR forces banks adopting IRB approach to calculate the difference between expected loss amounts and credit adjustments, additional value adjustments and other own-funds reductions for the purpose of their capital recognition, namely, IRB shortfall (EBA, 2015).

[2]Shim (2013) analyses sample periods, including that of Basel II, but does not distinguish changes in the framework before and after Basel II.

[3]For example, Basel III introduced the following: (i) higher capital levels, (ii) a stronger definition of capital, (iii) better risk capture in the trading book, (iv) liquidity regulation (a liquidity coverage ratio and a net stable funding ratio), and (v) a leverage ratio.

addition to the STD approach (Herring 2018). The Basel framework allows banks to choose between the STD and IRB approaches for credit risk. For this reason, the effect of risk-sensitive regulation on bank lending is still an open issue. Hereafter, we use the term Basel II/III.

Using bank balance sheet data for nine European countries between 2005 and 2014, we find the following: (i) the sensitivity of bank lending to GDP is significantly positive under the IRB approach; (ii) variations in this sensitivity based on the risk-sensitive capital requirement is remarkably smaller than the figures reported in the existing literature; (iii) risk-sensitive regulation induced higher capital requirements than risk-insensitive regulation; and (iv) the STD approach did not cause a negative influence on bank lending after the Basel II revision.

Results (i) and (ii) imply that lending by banks that adopt IRB approaches (IRB banks hereafter) is indeed procyclical, although this procyclicality is economically small. Our findings differ from that of Maatoug et al. (2019), who show that the cyclicality effect is moderate.[4] Ayuso et al. (2004) argue that a one percent increase in GDP growth might reduce capital buffers by 17%, while our regression analysis indicates that a one percent increase in GDP growth might reduce capital requirements by only 0.1%.

The existing literature has overestimated the amplified effect of risk-sensitive capital regulation, whereas the actual regulation was too risk-insensitive. Results (iii) and (iv) imply that bank lending by IRB banks is slightly lower than that of banks adopting STD approaches (STD banks hereafter). The IRB banks' capital requirements tended to be greater than those of STD banks, and the introduction of Basel II did not have a negative impact on lending under risk-insensitive regulation.

Our study focuses on bank lending because it plays an important role in the transmission

[4] Ayuso et al. (2004) define procyclicality as a positive relationship between the capital buffer (regulatory capital minus minimum capital requirements) and real activity. If capital requirements increase in a recession, building reserves from decreasing profits is difficult and raising fresh capital is likely to be extremely costly. Therefore, banks would have to reduce their lending and the subsequent credit squeeze would add to the downturn.

mechanism for monetary policy (Gambacorta and Mistrulli 2004, Gambacorta 2005, Kishan and Opiela 2006, Altunbas et al. 2009, Borio and Zhu 2012). Gambacorta and Mistrulli (2004) provide evidence that the credit supply of well-capitalized banks is less procyclical and that bank capital influences the way banks react to GDP shocks.

The positive sensitivity of bank lending to GDP means that banks lend more at the top of the business cycle when loans appear less risky and therefore require less capital and lend less at the trough when loans become riskier. We build an econometric model to test this hypothesis following the theoretical literature (Barrios and Blanco 2003, Estrella 2004, Peura and Jokivuolle 2004, Heid 2007, Repullo and Suarez 2012, Repullo 2013, Allen et al. 2015).[5] These studies show how banks optimally hold capital buffer stocks to guard against violating the minimum requirement.

Our econometric model primarily follows the theoretical model of Heid (2007) that captures the procyclical effect of capital requirements. Capital regulation simply states that bank capital should be greater than the minimum required capital. Required capital is calculated as the amount of risky assets multiplied by a certain required ratio. Based on a division between lower middle-income and low-income countries, Kanga et al. (2020) find a positive co-movement between the capital position and the business cycle. However, this required ratio is procyclical to risk in the IRB approach because an internal risk model is used (Herring 2018). Hence, different from Kanga et al. (2020), we consider the adopted approach to be more important than income at country level. To keep capital above the minimum, the bank has the option to either reduce the amount of risky assets or to increase total capital. Therefore, lending by IRB banks is likely to be more procyclical to GDP when the bank chooses the first option.

Our work contributes to the capital regulation literature in the following ways. As previously mentioned, our analysis first examines the cyclicality issue for bank lending during the

[5] See also Wall and Peterson (1987), Froot and Stein (1998), Furfine (2001), and Peura and Keppo (2006).

post-Basel II period. Valencia and Bolanos (2018) find that buffers became more counter-cyclical after the crisis but ignore the importance of the gradual implementation of Basel II during the post-crisis period. Although Vallascas and Hagendorff (2013) also evaluate the risk sensitivity of capital requirements, they do not analyse the cyclicality issue. Behn et al. (2016) also argue that the counter-cyclicality of capital charges based on individual asset risk has a significant procyclical effect on the lending behaviours of banks. Our focus on the post-Basel II period incorporates the work of Behn et al. (2016).

As documented in Cohen and Scatigna (2016), the loan growth rate became negative in European countries during the 2009-2012 period. Our analysis also sheds light on how capital regulation influenced this decline. In this regard, we provide additional evidence to the bank capital literature (Ayuso et al. 2004, Estrella 2004, Peura and Jokivuolle 2004, Heid 2007, Jokipii and Milne 2008, Stolz and Wedow 2011, Francis and Osborne 2012, Repullo and Suarez 2012, Adrian and Shin 2013, and Shim 2013) that buffer capital is more procyclical to business cycles under risk-sensitive requirements than under risk-insensitive requirements. However, so far there has been no evidence on the effect of the risk-sensitive requirements on the relationship between bank capital and *its lending* during the period *after the Basel II* revision. Our work also identifies an amplified effect from risk-sensitive requirements and warns of shrinking outcomes on business cycles.

Bitar et al. (2018) find that risk-based capital ratios fail to decrease bank risk, and this finding casts doubt on the Basel risk-weighting methodology. They argue that the adoption of the new Basel III capital standards exacerbates the ineffectiveness of risk-based capital ratios in terms of bank risk. We stipulate that the sensitivity of bank lending to the GDP is significantly positive under the IRB approach. Ovi et al. (2020) find that ASEAN banks have anticyclical behaviour in adjusting their credit risk and capital buffer. Different from the ASEAN region, in Europe, the effort of the Basel Committee on Banking Supervision (BCBS) was followed by a reform plan to create a European Systemic Risks Board that includes a

European Banking Authority to provide new macroeconomic policies to stabilize the system (Bitar et al. 2018). Therefore, the doubts about the Basel risk-weighting methodology should be highlighted in the European Systemic Risks Board and the on-going discussions of Basel III capital guidelines.

Finally, we stress more important policy implications on the comparison between European Banking Authority (EBA) and non-EBA banks. In a recent study on this topic, Montes et al. (2018) show that the use of the IRB approach of EBA banks is related to lower equity capital, lower liquidity and larger bank size. EBA banks tend to strategically manipulate risk-weighted assets to reduce capital requirement, and we add new evidence showing that EBA banks tend to be negatively impacted by risk-sensitive capital requirements on bank lending. Therefore, Basel III should incorporate a higher buffer requirement to serve as a backstop against the failing of internal models inside those EBA banks.

The remainder of this study is organized as follows. Section 2 provides an econometric model of bank lending and capital and explains the identification strategy, data, variables and calibration results. Section 3 provides the empirical results using the GMM instrumental variable method and the counterfactual approach. Section 4 concludes the study.

2. Econometric model of bank lending and capital

2.1. Econometric model

This section introduces an econometric model of bank lending and capital.[6] To derive the estimable moment conditions, we simply replicate the idea that a bank chooses to either raise capital or contract lending practices to maintain the minimum requirement.[7]

Consider a bank that has a simple portfolio that includes loans L_t and bonds D_t at period t. The bank has regulatory capital K_{t-1} at the end of the period $t-1$. At the end of period

[6] Our theoretical logic is similar to that in the existing literature (Heid 2007).

[7] By lending contraction, we mean that banks slow their lending growth.

t, the bank capital becomes $K_t = K_{t-1} + u_t + I_t$, where u_t is a random shock to the capital and I_t is the raised capital.[8] We assume the shock u_t follows an MA(1) process:

$$u_t = \lambda\epsilon_{t-1} + \sigma\epsilon_t, \tag{1}$$

where ϵ_t follows an independent and identically distributed (i.i.d.) standard normal distribution whose distribution function is denoted by Φ. The coefficients of each ϵ are denoted by λ and σ.

Following Heid (2007), the bonds' risk weights are assumed to be zero. Here, we consider only sovereign bonds issued by the country where the bank is located and ignore corporate bonds and sovereign bonds from other countries.[9] A bank loan consists of a single risk class of loans that can be regarded as the average risk class of the loan portfolio.

The required capital per unit of the loan is denoted by c_t. Then, the minimum requirement regulation is represented as the inequality $K_t \geq c_t L_t$, where the total amount of required capital is $c_t L_t$. In the STD approach, the risk-weighted assets (RWAs) are calculated as wL_t, the exposure of assets multiplied by the risk weight w. Using this risk weight, the minimum regulation is represented as $K \geq 0.08wL_t$. Hence, the required capital is translated into $c_t = 0.08w$. Since the risk weight does not depend on the time-varying risk, the requirement c_t is constant over time.

In the IRB approach, we assume that the log of the GDP x_t affects c_t, which follows the AR(1) process and is generated by a common shock ϵ_t as follows:

$$x_t = \kappa x_{t-1} + \gamma\epsilon_t, \tag{2}$$

[8] Capital is an accounting residual between assets and (fixed) liabilities. Shock to capital is considered in our model for balance sheet management. In this regard, shock to asset values may increase or decrease capital, which in turn affects bank lending.

[9] In the empirical analysis below, we consider risky assets in addition to loans.

where κ and γ are positive coefficients. A negative shock ϵ_t lowers GDP growth and simultaneously damages capital through u_t as the materialization of credit risk. Following Heid (2007), we avoid the Basel formula's complexity and consider the following:

$$c_t = c_1 - \eta x_t \tag{3}$$

where c_1 and η are positive constants. The coefficient η measures the sensitivity of capital requirements to the current GDP. [10]

We consider a particular behaviour by the bank facing the minimum requirement as follows:

$$I_t = \max\left(c_t L_t - K_{t-1} - u_t, 0\right) \tag{4}$$

In other words, the bank raises capital only when a capital shortfall occurs, i.e., $K_{t-1} + u_t < c_t L_t$. In addition, the bank raises enough capital to cover only the amount of the deficiency $I_t = c_t L_t - K_{t-1} - u_t$. Otherwise, the bank does not raise capital ($I_t = 0$). Raising capital means issuing or selling shares, reducing dividend payouts, or revaluing assets. The capital shortfall probability is

$$\Pr(c_t L_t > K_{t-1} + u_t) \tag{5}$$

Using (1), a capital shortfall occurs if

$$c_t L_t > K_{t-1} + \lambda \epsilon_{t-1} + \sigma \epsilon_t \tag{6}$$

[10] The Basel formula has a more sophisticated and complex nature regarding the effect of the business cycle because it affects the required capital through both the probability of default (PD) and the loss-given default (LGD). It is important here to capture that the requirement ratio increases in a recession because the credit risk rises as x_t declines.

Further substituting (2) and (3),

$$\epsilon_t < (c_1 - \eta\kappa x_{t-1})L_t - K_{t-1} - \lambda\epsilon_{t-1})/(\eta\gamma L_t + \sigma) \equiv A_t \tag{7}$$

where A_t is the threshold of the capital shortfall. The capital shortfall probability for IRB banks becomes $\Phi(A_t)$. [Appendix shows the derivation of Eq. (7)]

Therefore, banks need to raise capital when their capital falls short of the minimum requirement. The shortfall probability depends on the threshold A_t, which includes the existing capital K_{t-1}, loan amount L_t, and capital requirement $c_t = c_1 - \eta\kappa x_{t-1}$. GDP ($x_{t-1}$) affects lending through the capital requirement.

2.2. Identification strategy

We use the above equation to identify the sensitivity of lending on the GDP.[11] Rearranging eq. (7), we have

$$(c_1 - \eta\kappa x_{t-1} - \eta\gamma A_t)L_t - K_{t-1} - \sigma A_t = \lambda\epsilon_{t-1} \tag{8}$$

Considering expectations, we have moment conditions for bank i:

$$E\left(z_{it}\left(\left(c_1 - \beta_1 x_{s,t-1} - \beta_2 A_t\right)L_{it} - K_{i,t-1} - \beta_3 A_t - \sum_{k=4} \beta_k f_{k,i,t-1}\right)\right) = 0, \tag{9}$$

because the conditional expectation of ϵ is assumed to be zero conditional on several covariates $f_{k,i,t-1}$s. We use the coefficients β_k for the convenience of exposition, which is defined below. This moment condition can be estimated using nonlinear GMM with instruments denoted by z_{it}.[12] We apply nonlinear GMM with instruments in our main regression and other robustness checks.

[11] Although the above model does not incorporate a bank's objective function, it is easy to obtain the following results by assuming a reasonable objective function. The previous version of this paper, which includes a more theoretical argument, can be provided by the authors upon request.

[12] Our GMM estimation is not a dynamic panel GMM but rather a nonlinear generalized method of moments with instruments. Technically, to identify the model, one may define a new error term $\nu_t = \lambda\epsilon_{t-1}$ by regarding just the previous error term (multiplied by λ) as a new error term that we cannot observe. In addition, we should note that $cov(x_{t-1}, \epsilon_{t-1}) \neq 0$ because x_{t-1} is generated by ϵ_{t-1} in Eq. (2). However, since ϵ is i.i.d.,

Our primary concern is the sensitivity of capital requirements on the GDP, which is denoted by $\beta_1 = \eta\kappa$ hereafter. The coefficient κ appears because we take one lag to avoid the simultaneous determination of the GDP and loans. When estimating the above moment condition, it is important to include the capital shortfall threshold A_t to obtain consistent parameter estimates. Since we do not observe this threshold A_t, we make use of the relative frequency $\widehat{\Phi}_t = m_t/n_t$ by country as the estimate of $\Phi(A_t)$, where the number of banks in a country during the period t is denoted by n_t and the number of banks raising capital is denoted by m_t.[13] The variable A_t in Eq. (9) is replaced by $\widehat{A}_t = \Phi^{-1}(\widehat{\Phi}_t)$.

In Eq. (9), the threshold A_t appears twice. The coefficient $\beta_2 = \eta\gamma$ measures the effect of a decline in the shortfall threshold due to a higher GDP through the change in capital requirements. As the threshold is higher, the bank can expand loans ($\beta_2 > 0$) because the lower capital requirement is less likely to cause a capital shortfall. The second coefficient $\beta_3 = \sigma$ measures the effect of a reduced threshold due to a higher GDP through the loss of bank capital. As the threshold is higher, the bank can expand loans ($\beta_3 > 0$) because capital stock is less likely to cause a capital shortfall. Our first hypothesis is as follows:

Hypothesis 1: IRB banks tend to expand (contract) their loan levels during a boom (recession) through changes in capital requirements.

In other words, the loan sensitivity to GDP (β_1) is predicted to be positive. As Eq. (9) indicates, a higher GDP (x_{t-1}) allows more lending (L_{it}) if β_1 is positive.[14] This hypothesis is in accordance with but not equivalent to those in the cyclicality literature mentioned in the introduction. Our hypothesis differs from the existing literature because it formally relates GDP to bank lending through a channel of capital requirements.

we have $cov(x_{t-\tau}, \epsilon_{t-1}) = 0$ for $\tau = 2, 3, \ldots$. In other words, the GDP is weakly exogenous in our model. GDP lags satisfy the general condition for good instruments in our model.

[13]We define the dummy variable q_{it} that takes 1 if the bank i raises the capital during the period t and $m_t = \sum_{i=1,\ldots,n_t} q_{it}$.

[14]Keeping the expectation in Eq. (9) equal to zero, the bank can increase loans as GDP increases.

Comparison between the IRB and STD approaches

Next, we are interested in how differently banks behave depending on their measurement approach. In the STD approach, all asset classes have fixed risk weights that do not directly depend on the business cycle. To capture this feature of the STD approach, we assume $\eta = 0$ in eq. (3) for the STD approach. Instead, the risk-insensitive capital requirement in the STD approach is denoted by a constant c_0. Combining these, the capital requirement is represented as

$$\begin{cases} c_t = c_0 & \text{for STD} \\ c_t = c_1 - \beta_1 x_{t-1} & \text{for IRB} \end{cases} \tag{10}$$

Now, we introduce the dummy variable d_{it}, which equals 1 if a bank adopts the STD approach and 0 if it adopts the IRB approach. Note that d_{it} necessarily takes a value of 1 before the Basel II revision. The moment condition is replaced by

$$\begin{aligned} E\Big(z_{it}\big((1-d_{it})\left(c_1 - \beta_1 x_{t-1} - \beta_2 A_t\right) L_{it} + d_{it} c_0 L_{it} \\ -K_{i,t-1} - \beta_3 A_t - \sum_{k=4} \beta_k f_{k,i,t-1}\big)\Big) = 0. \end{aligned} \tag{11}$$

We simply add the term $d_{it} c_0 L_{it}$ to eq. (9) and multiply the corresponding term for IRB banks by $(1 - d_{it})$.

Recently, Behn et al. (2016) analysed how IRB banks adjust their loans relative to STD banks in response to credit shock using loan-level data. Unfortunately, since our data set is aggregated at the bank level, our study cannot address issues around lending decisions for each loan. In our story, lending by IRB banks is procyclical because the capital requirement is countercyclical. Endogeneity issues arise when demands for IRB banks are procyclical in nature while those of STD banks are not. However, our GMM instrumental variable method overcomes such endogeneity issue with the choice of either the IRB or the STD approach.

Our second prediction is hypothesized formally as follows:

Hypothesis 2: On average, IRB banks face higher capital requirement than STD banks.

Since GDP varies over time, we test this hypothesis using the mean and several percentiles of GDP. When we use a sample GDP mean ($\overline{x}$), the hypothesis is represented as $c_0 < c_1 - \beta_1 \overline{x}$. This hypothesis implies that IRB banks have lower loan levels than STD banks, as indicated by eq. (11). If $c_0 < c_1 - \beta_1 \overline{x}$ holds, lending by IRB banks cannot exceed that of STD banks when the average GDP is attained. Under a high GDP, the capital requirement for IRB is more likely to be higher than that of STD because the requirement for IRB is countercyclical, and vice versa. Our interest lies in whether the capital requirement for IRB is actually lower than that of STD in a boom and higher than that of STD in a bust. In the existing literature, Gordy and Howells (2006) emphasize that Basel II assigns higher capital compared with Basel I; however, Vallascas and Hagendorff (2013) find that STD banks do not experience an increase in the risk sensitivity of capital requirements. Therefore, this hypothesis is a meaningfully testable hypothesis.

Requirement changes before and after the Basel II revision

The Basel II/III revisions introduced refined risk-weights for a given external assessment of credit risk and strengthened the role of both supervision in pillar II and market discipline in pillar III (BCBS 2006). Compared with Basel I, Basel II/III focus on making minimum capital requirements more sensitive to the underlying risk of bank activities (Andersen 2011). In particular, the risk weights for obligors rated below BB$-$ became higher than those of Basel I, whereas the weights fell for obligors rated above A$-$ (Saunders and Allen 2010, p278).[15] Therefore, the capital requirement increased when the bank had more high-risk assets. Since the actual effect depends on the composition of assets, we formally state our next hypothesis as follows:

Hypothesis 3: The introduction of Basel II/III negatively affected bank lending through

[15] In addition, Basel II/III introduced new regulations, such as credit risk mitigation in pillar I, differentiation of sovereign credit risk within OECD countries, the framework of pillar II and III, and market and operational risk.

higher regulatory capital requirements for STD banks.

To empirically examine this hypothesis, we consider that the capital requirement for STD banks is

$$\begin{cases} c_t = c_0 & \text{before Basel II} \\ c_t = c_0 + \Delta c & \text{after Basel II,} \end{cases} \tag{12}$$

where Δc denotes an increase in the requirement after Basel II. We define ψ as the dummy, which takes 1 during the Basel II/III period and 0 during the pre-Basel II period. The moment condition becomes

$$E\Big(z_{it}\big((c_0 + \psi\Delta c)L_{it} - K_{i,t-1} - \beta_3 A_t - \sum_{k=4} \beta_k f_{k,i,t-1}\big)\Big) = 0. \tag{13}$$

We estimate $\psi\Delta c$, which is predicted to be positive if hypothesis 3 is true. Eq. (13) implies that positive $\psi\Delta c$ does not allow banks to extend more loans after Basel II/III than before.

2.3. Data set

Our sample banks are from nine countries, namely, Belgium, France, Germany, Italy, Luxembourg, the Netherlands, Spain, Sweden and the United Kingdom (UK), and data are obtained from 2005 to 2014.[16] We manually collected data for IRB banks in nine European member states because of the limited data access and information on which banks file their IRA approach with the regulatory body. The data obtained for the nine European countries in the BCBS (2014) report represent the authorsâ€™ best efforts in terms of manual data collection. The BCBS (2014) report indicates that within the EU, the nine countries examined in this study account for 86% of the total assets of all EU banks and the 14 banking groups classified by the Basel Committee as globally important banks in the EU provide for

[16]Banks include commercial banks, saving banks, cooperative banks, real estate and mortgage banks, investment banks and bank holding companies. The reason why our analysis ends in 2014 is because we mainly focus on the BCBS (2014) and EBA (2014) to collect our sample. We want to maintain the sensitivity of bank balance sheet and income statement variables to the business cycle and regulatory condition in these two regulatory reports.

fairly comprehensive coverage in Europe.[17] Yearly and quarterly bank data were retrieved from Bankscope by International Bank Credit Analysis Ltd. (IBCA) and the Bureau van Dijk. We conducted web searches on 233 banks in nine countries between 2007 and 2014. Our research timeframe starts in 2007 because the euro area began to adopt Basel II after the end of 2006 (Financial Stability Institute, 2004). Among those banks, 116 banks are members of the European Banking Authority (EBA) and 117 are non-member banks, according to the world ranking by assets provided by Bankscope. The quarterly country-level data were obtained from the Eurostat database, whereas the yearly data were accessed from the World Bank database. All banks that reported missing values for dependent variables or for bank-specific and country-control variables are excluded. The sample observations that showed M&A during the sample period are also excluded. Our data are winsorized at the 1st and 99th percentiles to prevent the effects of outliers.

Table 1 provides the frequency distribution of the sample banks by year and country.[18] The distribution for the quarterly data is similar to that for the yearly data and omitted to conserve space.[19]

Table 1

2.4. Variables

Appendix Table A1 provides the list of variable definitions. In our analysis, the nominal amount of loans (L_{it}) is regarded as a dependent variable. In addition, we employ risky

[17]Sehgal et al. (2017) classify Belgium, France, Germany, Italy, the Netherlands, and Spain as large Economic and Monetary Union (EMU) countries and find that large EMU countries show strong stock market integration. Olszak and Pipien (2016) suggest that the sensitivity of bank balance sheet and income statement variables to business cycles is subject to the increasing integration of financial markets.

[18]Years 2005 through 2008 have only 11, 50, 36, and 57 banks, and then the numbers increase later in the sample. This pattern is observed in the available data from Bankscope.

[19]The table for the quarterly data is available upon request.

assets, which are calculated as total assets minus government bonds.[20] For the capital level ($K_{i,t-1}$), we use total regulatory capital, tier 1 capital and core tier 1 capital. [21]

Although previous studies (Jokipii and Milne 2008, Shim 2013) simply employed GDP growth to indicate the business cycle, we follow the macroeconomics study of Rotemberg and Woodford (1999) to obtain the Hodrick-Prescott (HP)-filtered GDP growth (GDP growth hereafter) (Hodrick and Prescott 1997) as the business cycle variable x_{t-1}.

The set of bank-specific control variables includes the bank size, liquidity, non-performing loans (NPLs), revenue diversification and return on assets (ROA). All bank-specific variables are lagged by one year and treated as exogenous variables. Bank size represents the total assets, which is a common proxy in banking studies. According to Francis and Osborne (2012), larger banks tend to maintain a smaller capital buffer above the minimum required capital ratio. Stolz and Wedow (2011) reason that large banks have a lower likelihood of experiencing a large negative shock to their capital. Therefore, we expect that larger banks will be less likely to alter their loan amounts in response to changes in the buffer stocks of regulatory capital under GDP-sensitive requirement regulations. Regarding liquidity, Stolz and Wedow (2011) state that liquid assets have a non-zero risk-weight and provide the bank with insurance against a minimum capital requirement violation. Banks can liquidate their liquid assets to increase their capital buffer. Therefore, it is predicted that a bank with higher liquidity will be less likely to reduce its lending.

Barseghyan (2010) argues that NPLs result in a reduction in loanable funds; however, banks are not willing to disclose their NPLs. Thus, NPLs can have an unpredictable impact on bank lending behaviours. According to Stiroh (2004), revenue diversification is the ratio of non-interest incomes to gross revenues. Stiroh (2004) argues that banks with a higher non-interest income are able to reduce cyclical variation in bank profits. Bank capital is

[20] This approach is similar to that used in Shimizu (2015).
[21] We do not use common equity due to the data availability.

perceived as an on-balance-sheet item in terms of the propagation of shocks to lending if the market is imperfect for banks to raise funds (Gambacorta and Mistrulli 2004), which implies that bank-lending behaviour is less likely to result in the procyclical amplification of financial shocks if banks have a higher degree of non-interest income and consequently higher predicted retained earnings. We expect to find a negative relationship between ROA and loans because ROA increases the capital buffer, thereby reducing a bank's incentive to contract loans.

Country instrumental variables include credit/GDP gap, inflation and GDP per capita, usually with three lags. Following BIS (2011), we employ the credit/GDP gap, which displays deviations in the credit/GDP ratio from the long-term trend to reflect the sensitivity of this ratio to structural changes. Table 2 reports the descriptive statistics for our sample.

Table 2

2.5. Calibration results

Now, we demonstrate the properties of bank lending behaviour by calibrating the model in Eq. (9). Since few of these analyses have been performed, we use the following ad hoc but reasonable parameters: $c_1 = 0.5$, $\eta = 0.5$, $R = 3$, $\delta = 0.95$, $r = 0.01$, $\kappa = 0.5$, $\gamma = 0.5$, $\lambda = 0.5$, and $\sigma = 0.5$. [22]

Figure 1 displays the model calibration results, which indicate the bank capital channel. Three effects are distinguished in this calibration. First, the positive shock in ϵ_t increases both GDP growth and bank capital. Second, the requirement ratio is negatively correlated with the shock. Third, the loan amount is endogenous and impacted by the previous bank

[22] In addition, to exclude the requirement that is negative and is over one, we assume that there exists a lower bound $c^- = 0.3$ and an upper bound $c^+ = 0.9$ in c_t. We truncate the distribution at these two values when the requirement reaches these bounds. Eq. (3) is rewritten as follows: $c_t = \min(\max(c^-, c_1 - \eta x_t), c^+)$.

capital and previous GDP.

Figure 1

Figure 1(A) presents a comparison of the impulse responses to a positive shock under the GDP-sensitive capital requirements with those under insensitive requirements. The shock has an amplified effect under the former requirements in the sense that the level of loans overshoots once before diminishing. In contrast, loans increase and remain constant afterward under the latter requirements. The former makes the buffer diminish slowly, thus reflecting a gradual increase in the capital ratio.

Figure 1(B) presents a comparison of the impulse response to a negative shock. We provide a shock greater than that depicted in Figure 1(A) in terms of absolute values to invoke the capital shortfall when the shock occurs. The level of loans declines dramatically and then slightly recovers afterward under a GDP-sensitive capital requirement. This level also declines under an insensitive requirement, although the magnitude is smaller than otherwise. The different effects between these requirements are due to the sensitive requirement being higher in a recession compared with the insensitive requirement.

3. Empirical evidence

3.1. Time series correlations of aggregate loans and GDP

Although studies have analysed the procyclical behaviour of banks (Ayuso et al. 2004, Jokipii and Milne 2008), the degree and persistence of this behaviour are unclear. Other fields of macroeconomics have researched cyclical behaviour in great depth, with studies focusing on the cyclicality of mark-ups, labour share, productivity, and profits.[23] Figure 2

[23]See Table 1 or 2 of Rotemberg and Woodford (1999).

depicts the yearly HP-filtered GDP by country in the euro area. We confirm that a few peaks and bottoms appear during our sample in each country. Hence, our sample period is suitable for analysing the transitory component of business cycles. Importantly, the global financial crisis erupted only one year after Basel II was introduced in 2007. Hence, it is likely that any potential cyclical effects of Basel II are mingled with the effects of the crisis. However, as Figure 2 indicates, the HP-filtered GDP growth does not exhibit the expected substantial decline.[24] Therefore, this scenario allows us to perfectly establish the causal effect of introducing an IRB approach on bank lending.

Figure 2

Table 3

Table 3 displays the autocorrelation of the yearly and quarterly GDP and their cross-correlations with aggregate loans. First, although the one-year lag is positively correlated, the coefficient is very small. However, the two-year lag of GDP has relatively high negative correlations with the current GDP, whereas other lags have small correlations. The yearly current loan level is relatively highly correlated with the current GDP. The one-year lag and lead of loans are also correlated with the current GDP. For the quarterly data, the current GDP is highly correlated with one-year and two-year lags. The cross correlations are positive but somewhat smaller than those of the yearly series. These results show that our yearly and

[24]It is easy to check the influences of the global financial crisis and sovereign debt crisis on GDP in the euro area using this figure. Even if we de-trend the series, enormous plunges may be found for the UK and Sweden. However, we do not observe such a plunge for countries that have been described as having serious economic crises, such as Spain and Italy. In this sense, our filtered series has less of an influence and yields reliable results. Another reason for the absence of a crisis effect is that banks had limited ability to react to the financial crisis by changing to an IRB approach since the banks submitted their IRB implementation plans before the crisis (Behn et al. 2016).

quarterly data are sufficient for examining the above hypotheses.[25]

3.2. Estimating the effect of GDP on bank lending through capital requirements

Table 4 reports selected results from our estimation. Specifically, Models 1, 2, 5 and 6 present the results for the sample of IRB banks. The coefficients displayed in these models are relative to Eq. (9). As indicated in columns (1) and (2), IRB banks in the euro area react procyclically to the business cycle, which is in accordance with our first hypothesis. The sensitivity to the lagged GDP, β_1, is approximately 0.1, which is significantly positive and consistent with our model. An increase in x by one standard deviation results in the requirement dropping by $0.048 \times 0.1 = 0.005$. The coefficient β_2 is significantly positive and approximately 0.0025. This coefficient measures the influence on the shortfall threshold of the capital requirement. It is very small relative to that of the lagged GDP, with a magnitude of one-fortieth. Another effect of the capital threshold, which is measured by β_3, is significantly positive, consistent with the model. Its magnitude is large relative to β_2. Through these two effects, the amount of loans is positively related to the higher threshold because an increase in lending is more likely to cause a capital shortfall.

Table 4

In column (2), similar results persist when bank-specific variables are added to the model. We find that larger banks are more likely to alter their lending levels in response to changes in regulatory capital requirements under GDP-sensitive regulations because large banks are less likely to experience a large negative shock to their capital (Stolz and Wedow 2011). We

[25]According to autocorrelations in GDP, quarterly data are more suitable than yearly data because of the high correlation of the one-year lag. According to cross-correlations in GDP, quarterly data have the advantage of a relatively higher correlation. However, our quarterly database has many missing values for the earlier time period. Therefore, we mainly use yearly data.

find that banks with a higher proportion of NPLs, revenue diversification, and ROA tend to reduce their lending levels. In columns (5) and (6), we use risky assets as the dependent variable. The coefficients are relatively smaller than those of loans but mostly similar.

Next, we empirically distinguish between bank lending by IRB and STD banks in response to the business cycle. Models 3, 4, 7 and 8 compare IRB banks and STD banks. The coefficients in these models are from Eq. (11). The coefficients for IRB banks (c_1, β_1, β_2) in this extended sample do not differ greatly from those in the previous results. Furthermore, the threshold effect in β_3, which is common across IRB and STD banks, remains positive. As previously mentioned, the coefficient c_0 is the risk weight multiplied by 0.08 for STD banks. Therefore, according to the estimates of 0.098 in model 3 and 0.061 in model 4, the estimated risk weights are 1.225 and 0.7625, respectively, which are relatively higher than expected.

A gradual phase-in of Basel II occurred during our observable period as several banks changed their status from STD to IRB. However, the number of banks that changed their status was small. If we exclude these banks from our sample, our results still hold.

We attempt to provide different robustness tests to confirm our main findings. First, we examine Tier 1 capital as a capital variable, and the findings are displayed in column (9)-(10) in Table 4. The results are similar to those for total regulatory capital in column (3) and (4) of Table 4. In most columns in Table 4, the over-identifying restriction test statistics are sufficiently low to support the conclusion that the moment conditions hold well.

Second, we focus on two sub-samples of EBA and non-EBA banks. The results are reported in column (1)-(4) in Table A2. Montes et al. (2018) focus on an EBA dataset and find that the use of the IRB approach is related to lower equity capital relative to total bank assets. Our evidence suggests that risk-sensitive requirements of the Basel II and III regulations have procyclical effects on bank lending for both EBA and non-EBA banks. However, model (2) in Table A2 shows a negative beta3, indicating that the amount of loans is negatively related to the higher threshold for non-EBA banks. In other word, non-EBA banks are not a focus of the European Banking Authorityâ€™s stress test; therefore, an increase in lending is less likely to cause a capital shortfall.

Third, because half of the sample is composed by Italian and UK banks (140 and 145, respectively), the results may be strongly influenced by these two countries. To test this influence, we removed the UK and Italian banks from our sample and still achieved the consistent findings. The findings are presented in column (5)-(6) in Table A2.

3.3. The effects of the two approaches are different

We compare the estimated capital requirements for IRB and STD banks by using the estimates in Models 3 and 7 of Table 4. First, Table 5 reports the difference evaluated according to the sample means and other percentiles of GDP (x). As indicated in Model 3, the capital requirement $c_t = c_1 - \beta_1 \overline{x}$ of IRB banks is $0.122 - 0.123 \times (-0.003) = 0.1223$ when GDP takes its mean value. This value is higher than the capital requirement c_0 of STD banks by 0.098. In other words, lending by IRB banks is lower than that of STD banks when the macroeconomic condition is normal. More importantly, relative to the lower 5th percentile of $x^{0.05} = -0.063$) and the upper 95th percentile ($x^{0.95} = 0.082$), the capital requirement for IRB banks is calculated as 13% and 11.2%, respectively. The difference in these values is only 1.8%. The variation from the mean is 0.9%.[26] This finding suggests that the causal effect of a business cycle upon the capital requirement for IRB banks is very small.

Second, to test hypothesis 2, we estimate the Wald test statistics for the linear restriction $c_0 = c_1 - \beta_1 \overline{x}$. In other words, the null hypothesis is that the capital requirement for STD banks is equal to that of IRB banks. The test statistics are significant at the 1% level in all models, in almost all percentiles, and in the mean value. The estimated capital requirement of IRB banks is greater than that of STD banks. However, Model 7 shows a negative difference at the 95th percentile, implying that capital requirement of IRB banks is lower than that of

[26]The deviation of the requirement at the 5th percentile is 12.23%-11.2%=1.03%, while that of the 95th percentile is 13-11.2=0.77%. The average of these is 0.9%.

STD banks. This finding indicates that only the highest GDP makes the requirements for IRB banks lower than that of STD banks. In this sense, the risk-sensitive requirement rarely induced too much lending by IRB banks, with high lending only observed at the peak of a business cycle.

Table 5

3.4. Quarterly causality

Macroeconomic conditions are usually sensitive on a quarterly basis. As Table 3 previously indicated, the correlation with the one-year lag of loans is smaller than the correlation of the one-quarter lag. Therefore, the quarterly cyclicality issue should be investigated. Table 6 displays the selected results indicating that IRB banks in the euro area react procyclically to the business cycle. Overall, the previous main findings hold for quarterly data as well.

Table 6

3.5. Changes in requirements before and after the Basel II revision

This section examines whether Basel II/III had positive or negative impacts on the sample banks. As shown in Eq. (13), we use a Basel II/III dummy variable (ψ), which takes a value of one for the post-Basel II period (2008-2014) and zero otherwise.[27] The interaction term between Basel II/III and a change in the requirement ($\psi \Delta c$) is our variable of interest.

[27] The boundary is ambiguous in the euro area because regulators allow two years (2007 and 2008) to apply the Basel II rule. Since there are few banks adopting Basel II fully in 2007, we define the Basel II sub-period as the period starting from 2008.

Table 7 reports our findings. In model 1, we estimate Eq. (13) using all the sample banks, which ignores the fact that some banks use IRB approaches. In other words, we look at the change in lending attitude before and after Basel II without using GDP growth as an explanatory variable. The estimated changes in requirements after Basel II are significantly negative for Model 1. However, in model 2 where we use only STD banks as the sample, the coefficient Δc is not significant. Therefore, Hypothesis 3 is not supported by this estimation result. In other words, STD banks did not change their lending attitude after Basel II was introduced. The results of models 1 and 2 are similar to those of models 3 and 4, where we use risky assets as dependent variables.

Table 7

3.6. Endogeneity issues

Most of the Basel III revisions were agreed upon, at least in outline form, in 2010. However, the implementation schedule was a lengthy process. Some elements were agreed upon in principle but needed to be elaborated over the next few years. Such stepped changes after 2010 may have had a more significant impact on bank lending than the introduction of Basel II. In other words, the choice of the two approaches may be determined simultaneously with the decision of lending in response to such changes. Therefore, in this section, we attempt to address the additional endogeneity issues surrounding the choice of either the IRB or STD approach. The previous approach of using the instrumental variable method overcomes the endogenous characteristics of the dummy d_{it} in the usual sense. To seriously consider the endogeneity issue, we provide the results of another method called the counterfactual method. In this approach, we measure the effect of choosing the IRB approach in a nonparametric manner.

In the counterfactual approach, we evaluate the difference

$$E(l_{it}^0 - l_{it}^1 | d_{it} = 0), \tag{14}$$

where the lending ratio by the IRB bank is denoted by l_{it}^0 and the lending ratio by the counterfactual STD bank is denoted by l_{it}^1. We use the loan ratio to total assets to normalize the loans for each bank.[28] Under the usual assumptions of this method, we estimate the above-defined difference. Note that $d_{it} = 0$ denotes the choice of an IRB approach, as previously defined. To measure this, we match an IRB bank with a STD bank that has the closest propensity score with the IRB bank. The propensity score of becoming an IRB bank is estimated using the previous control and instrument variables. After estimating the propensity score, we use kernel matching in terms of the propensity score. By applying this method, we can estimate the difference in the lending ratio between IRB and STD banks without addressing the correlation between the covariates and error term as long as the covariates can thoroughly explain the likelihood of choosing either of the two approaches.

The average treatment effect on IRB banks of choosing an IRB approach is reported in Table 8. The results of estimating propensity scores are in the lower part of the table. We use the total capital ratio in Model 1 and the tier 1 capital ratio in Model 2 as covariates to estimate the propensity score. We also include the capital shortfall threshold. In both models, the average treatment effects (ATTs) are significantly negative at the 5% level, which implies that choosing IRB results in lower loan ratios in banks.

Table 8

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[28] In the previous parametric approach, we used lending levels because the relationships among variables are structurally defined. In this nonparametric approach, it is better to use the loan ratio as usual in a non-structural estimation.

4. Conclusions

This paper presents an empirical study that reexamines the cyclicality issue of the Basel regulations. We provide evidence that IRB banks procyclically adjust their lending according to GDP; however, the procyclical effect is indeed economically small. Our results reveal that IRB banks mostly face higher capital requirements than the STD banks, although the Basel II/III revision does not have negative impacts on the loans under STD approaches.

Thus, we conclude that the risk-sensitive regulation of Basel II/III had negative impacts on bank lending but that the magnitude of cyclicality due to an increase in requirement is not as large as previously expected. Our analyses suggest that from a lending perspective, regulators can afford to lower the requirement ratio below the current minimum. The trade-off in the high capital requirement is that there will be less bank lending and an ample buffer for times of stress. The policy implication is that regulators should place greater priority on building a buffer in advance of times of stress rather than dampening excess cyclicality. In other words, there is room to make the requirement more sensitive to the cycle, which favours more lending during booms. Additionally, we need to improve the countercyclical buffer regulations in combination with this improvement.

Our results are limited in the sense that our approach focuses on a single factor, namely, the business cycle. Incorporating the financial cycle is left for future work. According to the BCBS (2010) report, buffer capital shows more notable co-movement with the credit/GDP gap ratio than with lending itself. Hence, protecting the banking sector from periods of excess credit growth *relative to the GDP* makes more sense. The buffer itself shrinks, and the remainder is stored in the regulator's buffer, which can be used in the times of stress.

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Appendix 1 Derivation of eq. (7)

The equation can be rearranged as following

$$
\begin{aligned}
&(c_1 - \eta x_t)L_t - K_{t-1} - \lambda\epsilon_{t-1}) > \sigma\epsilon_t \\
&(c_1 - \eta(\kappa x_{t-1} + \gamma\epsilon_t))L_t - K_{t-1} - \lambda\epsilon_{t-1}) > \sigma\epsilon_t \\
&(c_1 - \eta\kappa x_{t-1})L_t - K_{t-1} - \lambda\epsilon_{t-1}) > \eta\gamma\epsilon_t L_t + \sigma\epsilon_t) \\
&\epsilon_t < (c_1 - \eta\kappa x_{t-1})L_t - K_{t-1} - \lambda\epsilon_{t-1})/(\eta\gamma L_t + \sigma) \equiv A_t
\end{aligned}
\tag{15}
$$

Table 1: Frequency distribution of the sample banks

By year			
Year	Number of obs.	Number of IRB banks	Number of STD banks
2005	11	0	11
2006	50	0	50
2007	36	22	14
2008	57	45	12
2009	84	69	15
2010	99	79	20
2011	107	89	18
2012	113	97	16
2013	118	105	13
2014	106	96	10
Total	781	602	179
By country			
Belgium	51	44	7
Germany	74	58	16
Spain	97	47	50
France	91	77	14
United Kingdom	182	145	37
Italy	174	140	34
Luxembourg	9	9	0
The Netherlands	52	39	13
Sweden	51	43	8
Total	781	602	179

(Notes) This table reports frequency distribution of the data sample by year and by country. IRB = Internal–Ratings–Based approach. STD = Standardized approach.

Table 2: Summary statistics (yearly, EU 9 countries)

Variables	Obs	Mean	Median	Std. Dev.	Min	Max
GDP	781	-0.003	-0.009	0.048	-0.132	0.119
Regulatory capital	781	22.715	9.394	30.999	0.005	194.009
Tier1 capital	754	18.519	10.795	25.182	0.220	158.155
STD dummy	781	0.229	0	0.421	0.000	1.000
Loan	781	211.791	103.318	261.816	0.027	1661.491
Risky Assets	616	463.433	189.633	635.618	8.054	3507.522
Credit/GDP gap	781	114.164	93.802	39.279	50.418	195.479
Inflation	781	1.936	2.049	1.145	-0.494	4.490
GDP per capita	781	41,960	41,050	9,958	26,511	113,732
Bank size	781	18.973	18.974	1.498	14.231	22.060
Liquidity	781	17.635	15.410	13.338	0.609	94.487
NPL	774	5.486	3.990	5.363	0.050	37.500
Revenue diversification	778	34.449	35.590	22.474	-26.840	101.460
ROA	781	0.216	0.287	0.838	-5.212	3.348

(Notes) This table presents summary statistics of the sample. GDP is HP-filtered GDP. HP-filtered GDP decomposes time–series into GDP growth and cyclical components. The smoothing parameter for HP-filtered GDP is set by 1,600. Regulatory capital is total regulatory capital (Tier 1 + Tier 2). Tier 1 capital is core capital that includes equity capital and reserves. STD dummy equals 1 if a bank adopts Standardized approach and 0 if it adopts Internal-Ratings- Based approach. Loan is total loans. Risky assets is total assets minus government bonds. Credit/GDP gap is calculated as the actual credit/GDP ratio minus its long-term trend. Inflation is measured by the consumer price index that reflects the yearly percentage change in the cost to the average consumer of acquiring a basket of goods and services. GDP per capita is gross domestic product divided by midyear population. Bank size is log of total assets. Liquidity is liquid assets to total assets. NPL is non-performing loans ratio calculated by impaired loans to gross loans. Revenue diversification is the ratio of non-interest incomes to gross revenues. ROA is returns on assets.

Table 3: Time series correlation of GDP and Cross-correlogram of GDP and Loans

Autocorrelation of yearly GDP

Lag	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10
mean	0.082	-0.456	-0.100	-0.106	-0.071	0.074	0.074	0.017	-0.007	-0.007
SD	0.135	0.084	0.166	0.147	0.091	0.078	0.057	0.031	0.016	0.012
Observations	28	28	28	28	28	28	28	28	28	26

Yearly cross-correlogram of GDP and aggregate loan: corr(GDP(t), Loan($t+k$))

Lag (k)	-2	-1	0	1	2
mean	-0.364	0.42	0.525	0.204	-0.056
SD	0.190	0.153	0.187	0.176	0.188
Observations	28	28	28	28	28

Autocorrelation of quarterly GDP

Lag	-1	-2	-3	-4	-5
mean	0.824	0.593	0.355	0.138	-0.046
SD	0.103	0.187	0.216	0.196	0.176
Observations	23	22	22	22	22

Quarterly cross-correlogram of GDP and aggregate loan: corr(GDP(t), Loan($t+k$))

Lag (k)	-2	-1	0	1	2
mean	0.223	0.269	0.356	0.28	0.192
SD	0.323	0.293	0.202	0.244	0.188
Observations	23	23	23	22	22

(Notes) This table presents the autocorrelation of yearly and quarterly GDP and its cross-correlations with aggregate loans.

Table 4: The results of estimating bank lending (GMM, Yearly data)

Model	1	2	3	4	5
Banks	IRB	IRB	IRB & STD	IRB & STD	IRB
Period	2008–2014	2008–2014	2005–2014	2005–2014	2008–2014
Dependent var.	Loans	Loans	Loans	Loans	Risky assets
Capital variable	Regulatory capital	Regulatory capital	Regulatory capital	Regulatory capital	Regulatory capital
Capital requirement for IRB banks					
Constant term c_1	0.121***	0.100***	0.122***	0.133***	0.051***
	(0.000)	(0.003)	(0.000)	(0.001)	(0.001)
Sensitivity of loans	0.105***	0.087***	0.123***	0.106***	0.074***
on GDP β_1	(0.000)	(0.016)	(0.001)	(0.002)	(0.005)
Capital shortfall threshold effects					
β_2	0.003***	0.002***	0.007***	0.011***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
β_3	0.699***	-0.032	0.423***	0.671***	-0.083
	(0.006)	(0.096)	(0.009)	(0.040)	(0.071)
Capital requirement for STD banks					
c_0	n/a	n/a	0.098***	0.104***	n/a
			(0.000)	(0.001)	
Bank specific control variables					
Size_{t-1}	n/a	0.333***	n/a	0.369***	n/a
		(0.053)		(0.014)	
Liquidity_{t-1}	n/a	-0.252***	n/a		n/a
		(0.042)			
NPL_{t-1}	n/a	-0.403***	n/a	-0.632***	n/a
		(0.109)		(0.028)	
Revenue Div_{t-1}	n/a	-0.038*	n/a		n/a
		(0.020)			
ROA_{t-1}	n/a	-1.033***	n/a		n/a
		(0.410)			
Number of obs.	580	580	781	781	421
Number of moments	253	64	136	153	37
Overidentifying test stat.	109.2	56.114	112.9	107.214	43.99
Degree of freedom	108	49	95	87	33
p-value	0.450	0.226	0.102	0.0698	0.0957

Table 4: Continued

Model	6	7	8	9	10
Banks	IRB	IRB & STD	IRB & STD	IRB & STD	IRB &STD
Period	2008–2014	2005–2014	2005–2014	2005–2014	2005–2014
Dependent var.	Risky assets	Risky assets	Risky assets	Loans	Risky assets
Capital variable	Regulatory capital	Regulatory capital	Regulatory capital	Tier 1 capital	Tier 1 capital
Capital requirement for IRB banks					
Constant term c_1	0.045***	0.053***	0.051***	0.073***	0.041***
	(0.002)	(0.0001)	(0.000)	(0.000)	(0.000)
Sensitivity of loans	0.075***	0.074***	0.060***	0.139***	0.088***
on GDP β_1	(0.009)	(0.001)	(0.001)	(0.001)	(0.000)
Capital shortfall threshold effects					
β_2	0.001**	0.002***	0.001***	0.005***	0.002***
	(0.000)	(0.0001)	(0.000)	(0.000)	(0.000)
β_3	-0.121	0.637***	0.453***	0.296***	0.041***
	(0.135)	(0.019)	(0.037)	(0.020)	(0.007)
Capital requirement for STD banks					
c_0	n/a	0.052***	0.113***	0.066***	0.032***
		(0.0001)	(0.000)	(0.000)	(0.000)
Bank specific control variables					
Size_{t-1}		n/a		0.019***	
				(0.000)	
Liquidity_{t-1}		n/a		n/a	
NPL_{t-1}	-0.129	n/a	-0.251***	-0.038***	n/a
	(0.123)		(0.020)	(0.007)	
Revenue Div_{t-1}	-0.057	n/a		n/a	n/a
	(0.040)				
ROA_{t-1}	-0.638	n/a	1.894***	n/a	n/a
	(0.531)		(0.124)		
Number of obs.	421	625	625	784	675
Number of moments	37	96	136	171	136
Overidentifying test stat.	38.62	96.884	94.58	111.308	100.2
Degree of freedom	30	81	86	99	90
p-value	0.134	0.110	0.247	0.187	0.217

(Notes) This table reports the results of how sensitively banks alter the amount of loans to the changes in GDP by using nonlinear GMM. The estimated moment condition is

$$E\big(z_{it}((c_1 - \beta_1 x_{t-1} - \beta_2 A_t)L_{it} - K_{i,t-1} - \beta_3 A_t - \sum_{k=4} \beta_k f_{k,i,t-1})\big) = 0, \tag{9}$$

for models 1, 2, 5, and 6. It is

$$E\Big(z_{it}\big((1 - d_{it})\,(c_0 - \beta_1 x_{s,t-1} - \beta_2 A_t)\,L_{it} + d_{it} c_0 L_{it} - K_{i,t-1} - \beta_3 A_{st} - \sum_{k=4} \beta_k f_{k,i,t-1}\big)\Big) = 0. \tag{11}$$

for other models.

For IRB banks, sensitivity of loans to GDP is measured by β_1. Capital shortfall thresholds are measured by β_2, and β_3. The dummy variable d_{it} equals 1 if banks adopt STD approaches and 0 if banks adopt IRB approaches. c_0 represents risk-insensitive capital requirement for STD banks. Dependent variables are either of loans or risky asset. Capital variable is either of regulatory capital or Tier 1 capital. Models (1, 2, 5, 6) use the sample of IRB banks only from 2008 to 2014. Other models use the sample of IRB and STD banks from 2005 to 2014. See Table A1 for variable definition. Standard errors of coefficients are report in parentheses. ***, ** and * denotes significance of 1%, 5% and 10% level, respectively. Sargan's overidentification restriction test statistics are reported.

Table 5: The results of Wald test: Comparison of capital requirements between IRB banks and STD banks

	Mean	Percentiles				
		5%	25%	50%	75%	95%
HP-filtered GDP (x)	-0.003	-0.063	-0.04	-0.009	0.029	0.082
Model 3						
Coefficient difference	0.024	0.032	0.029	0.025	0.020	0.014
Wald test stat. (χ^2)	6121.86	8155.88	7412.78	6338.78	4923.18	2862.75
p-value	0.000	0.000	0.000	0.000	0.000	0.000
Model 7						
Coefficient difference	0.001	0.006	0.004	0.002	-0.001	-0.005
Wald test stat. (χ^2)	72.48	1010.15	567.9	125.02	41.17	920.58
p-value	0.000	0.000	0.000	0.000	0.000	0.000

(Notes) This table reports result of Wald test after GMM estimation in model 3 and 7 of Table 4. The coefficient difference shows the difference in capital requirement $c_1 - \beta_1 x - c_0$. Wald statistics is used to test the linear restriction $c_1 - \beta_1 x - c_0 = 0$.

Table 6: The results of estimating bank lending (GMM, Quarterly data)

Model	1	2	3	4	5	6
Banks	IRB	IRB	IRB	IRB	IRB	IRB
Period	2008–2014	2008–2014	2008–2014	2008–2014	2008–2014	2008–2014
Dependent var.	Loans	Loans	Loans	Loans	Loans	Loans
Capital variable	Regulatory Capital	Regulatory Capital	Tier 1	Tier 1	Core Tier1	Core Tier1
Main Variables						
Capital requirement for IRB banks						
Constant term c_1	0.145***	0.143***	0.122***	0.124***	0.139***	0.141***
	(0.001)	(0.001)	(0.000)	(0.002)	(0.000)	(0.001)
Sensitivity of	0.128***	0.120***	0.113***	0.095***	0.116***	0.057***
GDP β_1	(0.002)	(0.005)	(0.003)	(0.005)	(0.001)	(0.004)
Capital shortfall threshold						
β_2	0.000	0.000**	0.002***	0.002***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
β_3	0.190***	0.096	-0.019	0.029	-0.006	0.057***
	(0.013)	(0.068)	(0.018)	(0.038)	(0.006)	(0.016)
Const	4.683***	5.747***	3.712***	4.216***	3.910***	8.453***
	(0.360)	(0.559)	(0.284)	(0.460)	(0.250)	(0.543)
Bank specific control variables						
Revenue Div_{t-1}	n/a	-0.041***	n/a	-0.020***	n/a	-0.117***
		(0.008)		(0.006)		(0.007)
Number of obs.	451	440	380	369	520	484
Num. of moments	353	353	353	529	353	177
Overident. test	43.89	43.89	32.68	28.57	44.83	44.75
Degree of freedom	40	39	30	29	42	41
p-value	0.310	0.272	0.336	0.488	0.354	0.317

(Notes) This table replicates the same estimation as of Table 4, using quarterly data. The estimated moment condition is

$$E\big(z_{it}((c_1 - \beta_1 x_{t-1} - \beta_2 A_t)L_{it} - K_{i,t-1} - \beta_3 A_t - \sum_{k=4} \beta_k f_{k,i,t-1})\big) = 0, \quad (9)$$

Sensitivity of loans to GDP is measured by β_1. Capital shortfall thresholds are measured by β_2, and β_3. Dependent variable is loans. Capital variables are Regulatory Capital, Tier 1 capital and Core Tier 1. See footnotes of Table 4 and Table A1 for the definition of other variables. Standard errors of coefficients are report in parentheses. *** and ** denotes significance of 1% and 5% level, respectively.

Table 7: The effect of Basel II on bank loans (GMM, yearly data)

Model	1	2	3	4
Countries	EU9	EU9	EU9	EU9
Banks	All	STD	All	STD
Period	2005–2014	2005–2014	2005–2014	2005–2014
Data type	Yearly	Yearly	Yearly	Yearly
Dependent var.	Loans	Loans	Risky assets	Risky assets
Capital variable	Regulatory captial	Regulatory captial	Regulatory captial	Regulatory captial
Main Variables				
c_0	0.066***	0.079***	0.080***	0.080***
	(0.003)	(0.004)	(0.002)	(0.002)
$\psi\Delta c$	-0.005***	-0.000	-0.004**	0.000
	(0.001)	(0.003)	(0.002)	(0.002)
β_3	0.879***	0.879***	0.921***	0.428***
	(0.084)	(0.101)	(0.077)	(0.071)
Bank specific control variables				
Size_{t-1}	-0.017***	-0.012***	-0.011***	-0.011***
	(0.001)	(0.001)	(0.001)	(0.001)
Liquidity_{t-1}	-0.020***	0.058***	-0.085***	0.100***
	(0.006)	(0.012)	(0.015)	(0.021)
NPL_{t-1}	-0.261***	-0.292***	-0.171***	-0.266***
	(0.054)	(0.040)	(0.048)	(0.050)
Revenue Div_{t-1}	-0.008	0.003	0.014*	-0.018
	(0.008)	(0.006)	(0.008)	(0.014)
ROA_{t-1}	0.142	-0.831***	1.382***	-0.616**
	(0.146)	(0.319)	(0.206)	(0.307)
Number of obs.	781	179	625	148
Number of moments	82	82	82	82
Overidentifying test stat.	82.62	40.08	74.35	34.70
degree of freedom	68	35	61	29
p-value	0.109	0.255	0.117	0.215

(Notes) This table reports the results of the impact of Basel II on bank loans between 2004 and 2014 by using panel GMM and yearly data. The sample is extended to include banks in EU 26 countries.

The estimated moment condition is

$$E\Big(z_{it}\big((c_0+\psi\Delta c)L_{it}-K_{i,t-1}-\beta_3 A_{st}-\sum\beta_k f_{k,i,t-1}\big)\Big)=0. \tag{13}$$

A Basel II/III dummy variable ψ equals 1 for after Basel II and 0 otherwise. Δc represents the coefficient for the interaction term between Basel II/III dummy and loan, which takes 0 if Basel II/III dummy takes 0. Dependent variable is loans or risky assets. See Table A1 for the definition of variables. GMM standard deviations of coefficient are report in parentheses. ***, ** and * denotes significance of 1%, 5% and 10% level, respectively.

Table 8: Treatment effects of adopting IRB approach on bank lending

Outcome vars: Loan ratio					
Model	Number of obs	ATT	Standard error	t-stat	p-value
1	450	-0.067	0.029	-2.310	0.021
2	515	-0.066	0.028	-2.320	0.021

Propensity score estimation

Dependent variable: 1 if IRB bank and 0 if STD bank

variables	coefficient	Std. error	z statistics	p-value
GDP growth	2.729	2.110	1.290	0.196
Capital shortfall threshold (A_t)	0.068	0.036	1.890	0.058
Capital ratio	-0.044	0.042	-1.040	0.299
Size	0.000	0.000	2.040	0.041
Liquidity ratio	-0.004	0.008	-0.500	0.614
NPL ratio	-1.088	2.471	-0.440	0.660
Revenue diversification	-0.329	0.141	-2.340	0.019
ROA	0.075	0.103	0.730	0.467
Credit to GDP GAP	-0.005	0.004	-1.280	0.199
Inflation	-0.061	0.083	-0.730	0.463
GDP per capita	0.000	0.000	2.860	0.004
Country NPL ratio	0.174	0.033	5.220	0.000
Country capital asset ratio	0.052	0.138	0.380	0.706
Country liquid asset ratio	0.155	0.072	2.160	0.031
Constant	-2.257	1.528	-1.480	0.140
Number of obs =	450			
Log likelihood ratio	90.87			
p-value	0			
Pseudo R^2	0.211			

(Notes) This table reports the results of estimating average treatment effect on the treated (ATT). Treatment group is IRB banks and control group is STD banks. The sample period is from 2007 to 2014. The propensity score is estimated by probit regression where the dependent variable takes 1 for IRB bank and 0 for STD bank. Kernel matching is used to estimate ATT. Outcome variable is loan ratio. In model 1, capital ratio is total capital ratio and it is tier 1 capital ratio in model 2. Bank-specific variables are capital shortfall threshold (A_t), bank size, liquidity, NPL, Revenue diversification and ROA. Country variables are Credit/GDP gap, inflation, GDP per capita, NPL ratio, capital asset ratio, and liquid asset ratio. All covariates are lagged one year. ***, ** and * denotes significance of 1%, 5% and 10% level, respectively.

Appendix

Table A1: variable definition

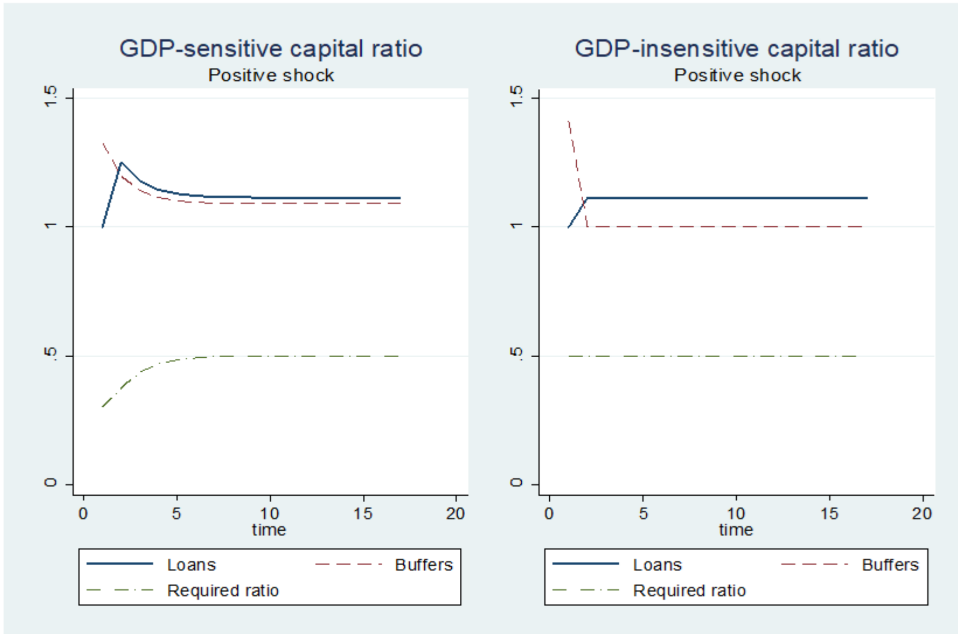
Variable	Definition	Source
GDP	GDP growth was downloaded from World Bank. GDP variable is estimated to get HP-filtered GDP. HP-filtered GDP decomposes time–series into GDP growth and cyclical components. The smoothing parameter for HP-filtered GDP is set by 1,600.	World Bank and author's calculation
Regulatory capital	Regulatory capital is total regulatory capital (Tier 1 + Tier 2).	Bankscope
Tier1 capital	Tier1 capital is Tier 1 regulatory capital.	Bankscope
STD dummy	STD dummy equals 1 if banks adopt Standardized approaches and 0 if banks adopt Internal Rating Based approaches.	Author's collection
Loan	Loan is total loans to total assets.	Bankscope
Risky Assets	Risky assets is total assets minus government bonds	Bankscope and author's calculation
Credit to GDP GAP	Credit to GDP gap is calculated as the actual credit/GDP ratio minus its long-term trend.	World Bank
Inflation	Inflation is measured by the consumer price index that reflects the yearly percentage change in the cost to the average consumer of acquiring a basket of goods and services	World Bank
GDP per capita	GDP per capital is gross domestic	World Bank
Bank size	Log of total assets	Bankscope and author's calculation
Liquidity	Liquidity is liquid assets to total assets.	Bankscope
NPL	NPL is non-performing loans calculated by impaired loans to gross loans.	Bankscope
Revenue diversification	Revenue diversification is non-interest incomes to gross revenues.	Bankscope
ROA	ROA is return on assets	Bankscope

Table A2: Robustness tests

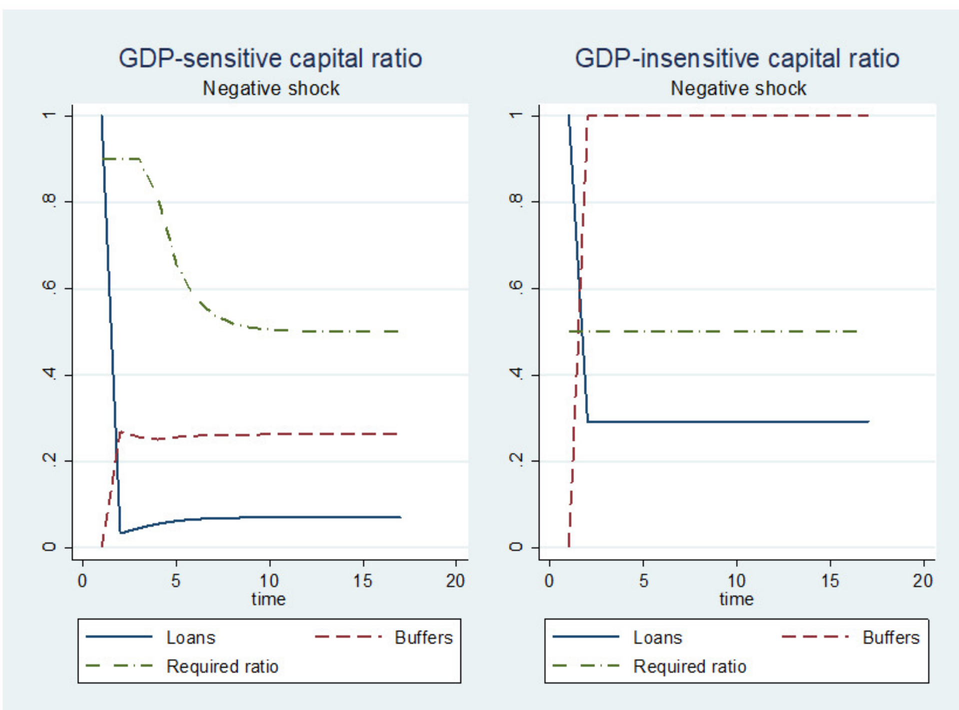
	EBA banks		non-EBA banks		Removing the UK and Italy	
Model	1	2	3	4	5	6
Banks	IRB	IRB & STD	IRB	IRB & STD	IRB	IRB & STD
Period	2008–2014	2005–2014	2008–2014	2005–2014	2008–2014	2005–2014
Data type	Yearly	Yearly	Yearly	Yearly	Yearly	Yearly
Dependent var.	Loans	Loans	Loans	Loans	Loans	Loans
Capital var	Regulatory capital	Regulatory capital	Regulatory capital	Regulatory capital	Regulatory capital	Regulatoy capital
Main Variables						
β_0	0.118***	0.137***	0.091***	0.105***	0.105***	0.107***
	(0.003)	(0.000)	(0.015)	(0.000)	(0.000)	(0.000)
β_1	0.136***	0.135***	0.000	0.105***	0.150***	0.165***
	(0.007)	(0.001)	(0.015)	(0.001)	(0.002)	(0.001)
β_2	0.001*	0.004***	0.004***	0.005***	0.001***	0.001***
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
β_3	-0.009	-0.033	-0.112	-0.082***	0.859***	0.954***
	(0.081)	(0.016)	(0.129)	(0.000)	(0.038)	(0.018)
ψ	n/a	0.111***	n/a	0.079***	n/a	0.097***
		(0.000)		(0.000)		(0.000)
Bank specific control variables						
Size_{t-1}	0.468***	0.34***	0.182***	0.142***		
	(0.034)	(0.01)	(0.025)	(0.005)		
Liquidity_{t-1}	-0.256***		-0.187***			
	(0.017)		(0.028)			
NPL_{t-1}	-0.233***	-0.476***	-0.236***	-0.488***		
	(0.052)	(0.014)	(0.079)	(0.005)		
Revenue Div_{t-1}	-0.087***		-0.022*			
	(0.009)		(0.011)			
ROA_{t-1}	-0.452		1.031***			
	(0.286)		(0.306)			
Number of obs.	307	399	273	382	310	425
Number of moments	64	153	64	153	253	136
Overidentifying test stat.	38.749	57.736	38.386	63.406	61.507	74.280
degree of freedom	35	55	36	63	61	72
p-value	0.304	0.375	0.362	0.462	0.458	0.404

(Notes) This table reports robustness checks by using Tier 1 capital to instead of regulatory capital and analysis for EBA banks and non-EBA banks. Dependent variables are loans. Capital variables are Regulatory capital. Regulatory capital is total regulatory capital (Tier 1 + Tier 2). Bank specific variables are size, liquidity, NPL, Revenue Div and ROA and all bank specific variables are lagged one year. Size is log of total assets. Liquidity is liquid assets to total assets. NPL is non-performing loans calculated by impaired loans to gross loans. Revenue Div is non-interest income to gross revenues. ROA is returns on assets. GMM standard deviations of coefficient are report in parentheses. ***, ** and * denotes significance of 1%, 5% and 10% level, respectively.

Figure 1 : impulse response to a negative shock
A:Positive shock

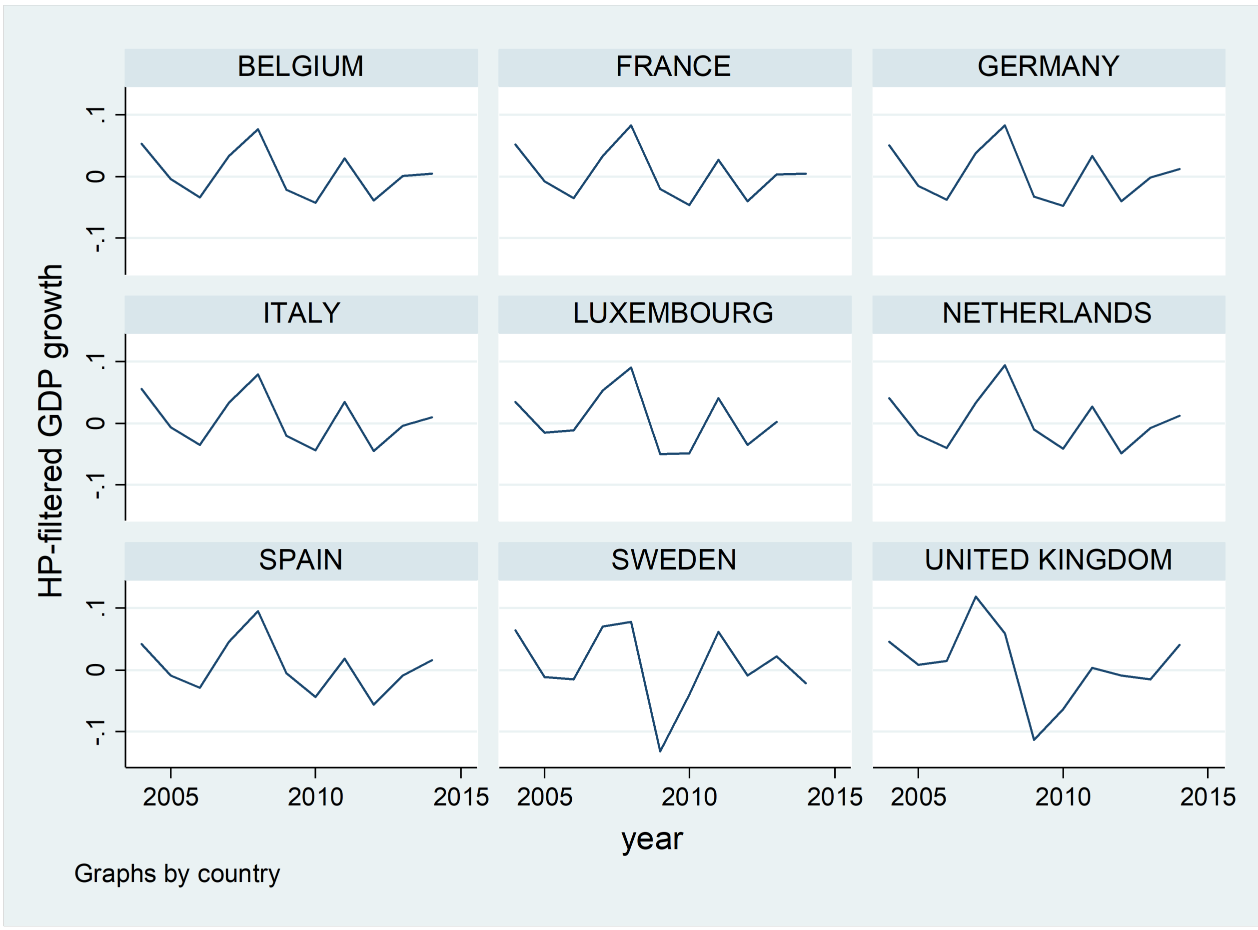


B:Negative shock



(Notes) Figure 1 shows the results of model calibration. The first graph shows the impulse of positive shock in GDP under GDP-sensitive capital requirement on loans, capital buffers and required ratio. The second graph shows the same impulse under GDP-insensitive capital requirement. The third graph shows the impulse of negative shock in GDP under GDP-sensitive capital requirement on loans, capital buffers and required ratio. The forth graph shows the same impulse under GDP-insensitive capital requirement.

Figure 2: Yearly HP-filtered GDP growth



(Note) Figure 2 depicts the yearly HP-filtered GDP for 9 European countries during the period 2005-2014. The smoothing parameter for HP-filtered GDP is set by 1,600.