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Abstract: Whereas the use of macroprudential instruments has been growing since the global financial crisis, there remains a need for verification of their overall and relative effectiveness. Most extant work has focused on the impact of macroprudential policy on house price rises and credit growth. We contend that it is crucial also to address the effectiveness of macroprudential policy and its instruments in reducing the build-up of financial imbalances in the wider economy. We focus on the credit-GDP gap, which besides being recommended to trigger the Basel III countercyclical buffer, is also widely seen as a key indicator of financial imbalances and predictor of financial crises. Accordingly, we assess the effectiveness of macroprudential instruments in reducing the credit-to-GDP gap, determining which instrument(s) would be more effective globally and according to the development of the country's economy.

We use a GMM-difference approach to estimation of determinants of the level of the gap for 43 advanced and emerging market economies using quarterly data over 2000q1-2013q4. GMM-difference with the change in the gap as dependent variable, and two estimates of panel OLS with fixed effects are used as robustness checks. We find a number of tools to be effective including loan-to-value and debt-to-income ratio regulations, notably when the credit gap is positive. In comparison with other extant work, a similar range of tools are effective as for the measures of real credit growth, although the focus of existing policy on bank and household lending, a subset of the total which is captured by the credit-to-GDP gap, raises some potentially important issues.
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Keywords: Macroprudential policy, credit-to-GDP gap, GMM panel estimation.
JEL Classification: E58, G28

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1 Introduction

As the usage of macroprudential policy instruments continues to grow, the effectiveness of these instruments are being analysed. In the last few years since the publication of the first IMF survey in 2010[2] used in Lim et al (2011), there have been numerous empirical studies on the use and effectiveness of macroprudential policy and its instruments. Many of these studies focus on analysing the effect of macroprudential instruments on credit growth and house price rises, and the mitigation of the build-up of imbalances in the housing market. Regarding methodology, most such studies have undertaken GMM panel estimation using macro data for both advanced and emerging market economies (see the survey in Carreras et al (2016)).

The focus on housing and related credit markets is not surprising. Well before the subprime crisis, Borio and Lowe (2002a and b, 2007) suggested that, although it is difficult to predict financial instability before it happens, there are some circumstances where it is appropriate for policymakers to respond to certain imbalances. They noted that, historically, a combination of sustained rapid growth in credit and asset prices can indicate an impending financial crisis, and contended that the gap between the credit-to-GDP ratio and its trend is a key indicator of financial imbalances. Also, while low and stable inflation can promote financial stability, it can increase the likelihood of a surge in credit and asset price growth rather than the demand for goods and services.

More recently, with the introduction of the countercyclical capital buffer in the Basel III Accord framework[3] (BCBS 2010a), policymakers have been focusing on the credit gap more closely. Basel III has placed a prominent role on the credit-to-GDP gap[4] to act as a signalling guide (early warning indicator (EWI)) for policymakers in setting the countercyclical capital buffers. The countercyclical capital buffer aims to ensure that banking sector capital requirements take account of the macro-financial environment in which banks operate. Its primary objective is to use a buffer of capital to achieve the broader macroprudential goal of protecting the banking sector from periods of excess aggregate credit growth that have often been associated with the build-up of system-wide risk.[5] However, the BIS also note that the indicator may give a weaker signal post crisis, when credit gaps often remain high, and hence judgment is needed in reducing buffers more rapidly than the gap would suggest.

In this context, the purpose of this paper is to present empirical analysis on the effectiveness of macroprudential policy and its instruments in affecting the credit-GDP gap, which to our knowledge has not been done before (albeit recommended in recent research by Cerutti et al (2017) of the IMF). We consider this of particular relevance since, as noted, Basel III has given the gap a prominent role as a signal for policymakers in identifying looming build-up of imbalances in the financial market and in setting the countercyclical capital buffers. Although there is a substantial body of work supportive of the relevance of the credit gap, we also note that the gap has been subjected to significant critiques, and we highlight these also in our work.

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[2] See IMF (2010). The survey was sent to 63 countries and the European Central Bank (ECB), including all countries in the G-20 and those subject to mandatory Financial Sector Assessment Programs (FSAPs).

[3] Basel III is a comprehensive set of reform measures, developed by the Basel Committee on Banking Supervision, to strengthen the regulation, supervision and risk management of the banking sector as a result of the 2007-2008 global financial crisis. It made improvements to the Basel II framework (2004). See BIS website, http://www.bis.org/bcbs/basel3.htm?m=3%7C14%7C572.

[4] See BCBS (2010a).

[5] BCBS (2010b).

The article is structured as follows. First, we provide a brief overview of recent empirical research on macroprudential policy tools' effectiveness. Second, we focus on work related to the BIS credit-to-GDP gap and its usefulness or otherwise as an indicator of financial imbalances that may lead on to financial crises[6]. Third, we present an empirical analysis on the effectiveness of macroprudential policy and its instruments in reducing the build-up of imbalances in the credit market as indicated by the credit-to-GDP gap. In this context, we consider, the effectiveness of macroprudential instruments in reducing the level of the credit-to-GDP gap and determine which instrument(s) would be more effective according to the structure of the country's economy.

Dynamic panel regressions are conducted on 43 countries with quarterly data from 2000-2013, using data from the IMF, OECD, and the BIS, with macroprudential tools data from Cerutti et al (2015, 2017). We also undertake robustness checks with alternative econometric approaches .We find a number of tools to be effective (in the sense of showing a significant negative coefficient in a GMM framework that seeks to address issues of endogeneity). These include loan-to-value and debt-to-income ratio regulation, and are effective notably when the credit gap is positive. Emerging market countries in some cases show stronger effects than for the average. Comparison with other extant work suggests a comparable range of tools is effective as for measures of real credit growth, although the focus of policy on bank and household lending raises some potentially important issues, which we note in the conclusion.

2 Recent empirical studies on the effectiveness of macroprudential instruments

Before developing and outlining our empirical analysis on the effectiveness of macroprudential policy in respect of financial imbalances as indicated by the credit-to-GDP ratio, we provide a brief overview of some of the existing empirical research on macroprudential policy and its instruments.

The empirical literature on the effectiveness of macroprudential policy and its instruments is still preliminary and in its developmental stage, as countries formulate and implement their macroprudential policy framework (Galati and Moessner 2014). Also, there are limited data sets that can be used to conduct empirical analysis. Yet, there are several studies that specifically focus on the area of the financial sector where there is the most potential for systemic risk to develop, that is the credit and housing markets and the banking sector.

Lim et al (2011), using the IMF survey (2010) database, suggested that macroprudential instruments have an impact on the procyclicality of credit and leverage. They used a cross-country generalized method of moments (GMM) panel regression for 49 countries over 2002-10 where ten instruments[7] were tested to see their effects on the procyclicality of credit and leverage. They argued that procyclicality in the business cycle is captured by analysing the correlation between growth in credit and leverage with the growth in the GDP. They suggested that this specification has the advantage of showing the effect of the instruments in both the expansionary and recessionary phases of the financial and business cycles. Instrumental variables for the policy instrument and the GMM Arellano-Bond estimator were used to address selection bias and endogeneity. Their findings were that macroprudential policies can affect credit growth and leverage, especially loan-to-value ratios, debt-to-income, reserve requirements, limits on domestic currency loans and dynamic provisioning.

[6] See BCBS (2010a).

[7] These are caps on the LTV, caps on the DTI, caps on foreign currency lending, ceilings on credit or credit growth, reserve requirements, countercyclical/time-varying capital requirements, time-varying/dynamic provisioning, restrictions on profit distribution, limits on net open currency positions (NOP) and limits on maturity mismatch.

Building on the work of Lim et al (2011), Cerutti et al (2017) used the second IMF survey[8] database (2013-2014) which covered 119 countries over the period 2000 – 2013[9], showing the usage of macroprudential instruments and estimating its effect on the credit and housing markets. Again using panel GMM, they found that the macroprudential index (MPI) (summing all the different types of instruments used over the period) was correlated with lower non-financial private sector credit growth, especially in emerging markets. They found a range of policies are effective but especially in the upturn. Regarding country characteristics, they concluded that emerging markets use macroprudential policies more frequently than advanced countries; emerging markets focus on foreign exchange policies, suggesting the dual objective of stabilising the foreign exchange market. Advanced countries use more borrower-based policies, which specifically target consumer spending and the real estate market. Also, there is a weaker effect in more developed and more financially open economies, suggesting some avoidance and/or disintermediation.

Akinci and Olmstead-Rumsey (2015) of the U.S. Federal Reserve System, developed a number of macroprudential indices for 57 advanced and emerging countries covering the period 2001 to 2013 to use in a dynamic GMM panel data model to investigate the effectiveness of macroprudential policy in restraining the growth in credit and asset prices. They focused on domestic banks' housing credit growth and house prices, which are often linked to boom-bust in the financial cycle. Their empirical study concluded that macroprudential policies have been used more actively since the 2007-2008 global financial crisis in both advanced and emerging market economics. They saw that tightening macroprudential actions outweighed the easing actions and these policies targeting credit growth in certain specific sectors such as housing are more effective than policies targeting credit growth on average. Credit growth and house price inflation were lower in these countries where such policies are implemented.

Carreras et al (2016) looked at the transmission of macroprudential policies and its effectiveness in up to 19 OECD countries during the period 2000-2014 using three datasets from the IMF and BIS. They estimated panel error correction models as well as a range of variants for real house price growth and growth in real household sector credit, before testing the additional impact of macroprudential policies. Compared with the existing literature, they suggested that OECD countries allowed a wider and more precise set of control variables, while the error correction approach allows for cointegration which is absent from existing work, while a banking crisis dummy prevents attribution of the crisis effects to policy. All of these might reduce omitted variables bias. They highlighted that some policies are shown to be more effective than others in the 19 OECD countries. These included, in particular, taxes on financial institutions, general capital requirements and strict loan-to-value ratio limits. Limits on foreign currency lending, debt-to-income ratio limits, limits on interbank exposures and concentration limits were also shown to be effective in some estimates.

Crowe et al (2011) and Dell'Ariccia et al (2012) looked at the use of policies that will mitigate general booms and bust cycles in the real estate and credit markets respectively. Firstly, Crowe et al (2011) found that macroprudential measures appear to be the most effective policy to achieve the objective of curbing real estate prices and leverage, because of their ability to attack the problem directly and the

[8] Analysis from the IMF Global Macroprudential Policy Instruments (GMPI) survey (2013-2014). The IMF surveyed the central banks/national authorities of 125 member countries and the Central Bank of West African States (BCEAO) and respondents provided responses to more than 100 detailed questions on about 17 key macroprudential policy tools.

[9] The survey covers 18 different instruments but the focus was on 12 specific instruments.

added benefit of increasing the resilience of the banking system. They found that policies such as LTV limits have a better chance to curb a boom and the narrower the focus of a such a policy, the better the effectiveness and performance of macroprudential policy.

Dell'Ariccia et al (2012) conducted analysis of credit booms and busts with the aim of assessing the effectiveness of macroprudential measures in reducing the risk of a crisis, or at least limiting its consequences. They identified a credit boom episode by analysing the country's private non-financial sector credit-to-GDP ratio. They classified an episode as a boom if either of the following two conditions was satisfied, (i) the deviation from trend is greater than 1.5 times its standard deviation and the annual growth rate of the credit-to-GDP ratio exceeds 10 percent; or (ii) the annual growth rate of the credit-to-GDP ratio exceeds 20 percent. They argued that credit booms are often a result of financial reform and periods of strong economic growth. Booms tend to be more frequent in fixed exchange rate regimes with weak banking supervision. Yet not all booms are bad or end up in a financial crisis and it is difficult to tell a good boom from a bad one that end up in a crisis. They found that macroprudential instruments have proven to be effective in containing booms, and more often in limiting the consequences of busts. Yet, there are some trade-offs which entail costs and distortions in the macroeconomy if these instruments are not carefully designed, coordinated with other policies and with close supervision to ensure the efficacy of the instruments.

Claessens et al (2014) looked at the use of macroprudential policy to reduce banking system vulnerabilities. They assessed the effectiveness of macroprudential policies in 48 countries, including 1650 banks in 23 advanced countries and 1,170 banks in 25 emerging markets and some 18,000 observations. They grouped the macroprudential policies according to whether they are borrower specific (caps on debt-to-income (DTI) and loan-to-value (LTV) ratios), specific to banks' assets or liabilities (limits on credit growth (CG), foreign currency credit growth (FC) and reserve requirements (RR)), and policies that encourage counter-cyclical buffers (counter-cyclical capital (CTC), dynamic provisioning (DP) and profits distribution restrictions (PRD)). There was a final group of miscellaneous policies (which have some overlap with the three groups).

Using panel GMM regressions and relating these policies to changes in individual banks' assets, they found that policies aimed at borrowers are effective in (indirectly) reducing the build-up of banking systems vulnerabilities. Measures aimed at banks' assets and liabilities are very effective, but countercyclical buffers as a group show less promise. The group of miscellaneous policies is also very effective. Also, when distinctions were made between upswings and downswings in the overall credit cycle in the countries, all except for the buffer-based category, directly help reduce asset growth during upswings. And policies aimed at banks' asset and liabilities and miscellaneous measures again are very significant. During a contractionary period, the borrower-based measures help reduce asset growth to a lesser degree. They stop declines in bank asset growth in contractionary periods. Measures aimed at banks' asset and liabilities side and the miscellaneous measures also have positive impact in contractionary periods and measures aimed at building banks' buffers are not productive in downswings.

Kuttner and Shim (2016) looked at a variety non-interest rate policies' effect on house prices and housing credit for 57 economies over 1990-2012. They used panel regressions for growth rates of housing credit and house prices, with controls for lagged growth of the dependent variable, the level of the short rate, the growth in real GNP per capita and the credit/GDP gap, as well as country fixed effects. They found debt-service-to-income limits and increases in housing-related taxes, have significant negative effects on housing credit. Increases in housing-related taxes also moderate house price growth.

There are also country and regional studies which often focus on specific risks or markets segments. Jiménez et al (2012) found that in Spain, countercyclical capital buffers such as dynamic provisioning help

smooth credit supply cycles and in bad times, preserve financial firms' ability to extend credit. They noted that their results are consistent with the suggestion that dynamic provisioning generates countercyclical bank capital buffers, mitigates bank procyclicality in credit supply, and in turn generates net positive real effects at the firm-level. The buffers contract credit availability (volume and cost) in good times, but expand it in bad times. Dynamic provisions are forward-looking provisions and before any credit loss is individually identified on a specific loan, there is a buffer build-up of bank own funds from retained profits in good times that can be used in bad times to cover the realized losses.

Bruno et al (2015) provided a comparative assessment of the effectiveness of macroprudential policies in 12 Asia-Pacific economies, using comprehensive databases of domestic macroprudential policies and capital flow management (CFM) policies. They considered both macroprudential policies that have a domestic credit focus, such as loan to value (LTV) and debt service to income (DTI) caps, as well as CFM policies that address the spill-over of financial conditions through banking sector and bond market capital flows. The data sets include 152 distinct CFM measures on banking and bond inflows and 177 domestic macroprudential measures taken by 12 Asia-Pacific economies for the period 2004-2013. They found that banking sector CFM polices and bond market CFM policies are effective in slowing down banking and bond inflows, respectively. Meanwhile, macroprudential policy is not introduced in a vacuum and it is a complement with other policies such as monetary policy.

Finally, Vandenbussche et al (2012) assessed the relation between macroprudential policies and house price inflation in Central, Eastern, and South-eastern European countries, using panel error correction estimation techniques. Capital ratio requirements and non-standard liquidity measures (marginal reserve ratio on foreign funding or linked to credit growth) reduce house price inflation, according to their results.

3 The BIS Credit-to-GDP gap

Unlike the existing literature summarised above, the focus of our empirical analysis is on the BIS credit-to-GDP gap as a measure of financial imbalances. As an introduction, there follow some stylised facts on the BIS credit-to-GDP gap:

The credit-to-GDP gap (Gap_t) is defined as the difference between the credit-to-GDP ratio (c_t/y_t) and its long-term trend (t_t).[10][11] The gap is calculated as follows.

$$Gap_t = (c_t/y_t) - t_t \qquad (1)$$

The measure of credit is a broad one of credit to the private, non-financial sector in the period, that is, it captures all sources of debt funds for the household and corporate sectors including funds raised abroad. Hence it is a much broader measure of credit than is used in much of the work cited above, including credit to households and companies, from banks, money and bond markets as well as non-bank financial institutions. As such it would be less vulnerable to distortion by disintermediation and innovation that narrower measures such as bank credit (Detken et al 2014). Both variables, GDP and credit are in nominal terms and on a quarterly frequency. The ratio is calculated as follows.

$$\text{Credit-to-GDP ratio}_t = \text{credit}_t / GDP_t * 100\% \qquad (2)$$

[10] BIS (2016), pages 38-39.
[11] BCBS (2010a).

The trend t in the ratio is derived from using the Hodrick-Prescott (HP) filter.[12] The HP filter is a mathematical tool used in macroeconomics to establish the trend of a variable over time. The HP filter is based on assumptions that the credit-to-GDP ratio: (c_t/y_t) can be decomposed into two components: the trend (t_t) and the cycle (c_t), which means $y_t = t_t + c_t$.

By using the Hodrick-Prescott (1997) technique, the BIS note that obtaining the trend involves solving the following optimisation problem:

$$\min_{\{g_t\}_{t=1}^{T}} \Sigma_{t=1}^{T} = \left(\frac{c_t}{y_t} - t_t\right) + \lambda \Sigma_{t=1}^{T} (t_{t+1} - 2t_t + 2t_{t-1})^2 \quad (3)$$

where λ (lambda) is the smoothing parameter. The first term in the loss function penalises the variance of the cyclical component, while the second imposes a penalty on the lack of smoothness in the trend. Hence, the solution to the problem is a trade-off between the smoothness of the trend and how well it fits the original series.

There are three technical features that are important when calculating the BIS credit-to-GDP gap. Firstly, the trend (t_t) is calculated by means of a one-sided (backward-looking) filter. This means, the filter is run recursively for each period over an expanding sample. This is done to capture data constraints in day-to-day policymaking. Secondly, a larger smoothing parameter λ (lambda) of 400,000 is employed. It is assumed that the credit cycles are on average about four times longer than standard business cycles. Thirdly, the BIS credit-to-GDP gap required 10 years of data as the starting point for estimating the trend, which can have a measurement impact on the gap if there is a smaller data time series.

The actual credit-to-GDP ratio is then compared to its long term trend. If the credit-to-GDP ratio is significantly above its trend (that is there is a large positive gap) then this is an indication that credit may have grown to excessive levels relative to GDP, implying financial imbalances. In the Appendix we show charts of the actual gaps in a number of countries that feature in our sample over 2000-16.

4 BIS empirical research on the credit-to-GDP gap

4.1.1 Early warning indicators

It is evident with hindsight that the 2007-2008 financial crisis did not happen overnight, but as a precursor, imbalances built up over a period of time. The same can be said of the many financial and banking crises that have taken place throughout history (see Laeven and Valencia (2012)). Bordo et al (2000) noted the frequency of financial crisis has increased since 1973, the end of the Bretton Woods period (1945 to 1971); Davis (1995, 1999) showed that there were a large number of crises already by the late 1990s, which analysis showed were preceded by prolonged periods of growing vulnerability of the economic and the financial system to an adverse shock.

Early econometric work on banking crisis determinants such as Hardy and Pasarbasioglou (1998) assessed lagged determinants of financial crises for 38 countries 1980-97 using logit estimation; relevant variables included GDP growth; boom-bust cycles of inflation, credit expansion and capital inflows; rising real interest rates and an increasing incremental capital output ratio; declining bank deposits; a sharp fall

[12] See Hodrick and Prescott (1997).

in the real exchange rate, declining imports and an adverse terms-of trade-shock. Davis and Karim (2008) highlighted that the literature was divided between signal extraction methods that generate single (possibly composite) early warning variables and multivariate logit methods. They suggested that logit is the most appropriate approach for a global early warning system (EWS) and signal extraction for a country-specific EWS.

Borio and Lowe (2002a and b), as discussed further below, highlighted some features of banking crises can be used in developing forward-looking early warning indicators (EWIs). Firstly, they noted that banking crises tend to arise primarily from deteriorating economic conditions, particularly declines in asset quality. Secondly, banking crises with significant economic costs in terms of overall output often arise from exposure of several institutions to common risks (factors) such as real estate and equity. Thirdly, vulnerabilities or imbalances tend to build up over time, reflecting the macro-financial linkages[13] between the financial sector and the real economy. Finally, although it is difficult to predict financial instability before it happens, it is possible to detect the build-up of financial imbalances.

However, Davis and Karim (2008) noted that at the time of writing, the practical use of EWSs by policy makers was limited, although given ongoing financial liberalisation they are important for informing policies aimed at preventing crises. They noted as well, that an effective EWS which highlights growing risks of a banking crisis could facilitate policy action that could help head off a potential crisis or limit its effects (costs). Yet, for the EWS to be effective, they suggested that it is essential that the EWS gives advance warning as policy actions take time to be effective. This is a major drawback of many EWS as advance and accurate warning is not always possible and the results of the EWS may not be accurate.

4.1.2 Empirical tests of credit to GDP gaps as early warning indicators

In their initial empirical test of early warning indicators using signal extraction techniques, Borio and Lowe (2002a, b) sought to determine whether the build-up of vulnerabilities can be spotted in time to take preventive action. They argued that large swings in asset prices and credit growth underlie many financial crises. In addition, while low and stable inflation promotes financial stability, it also increases the likelihood that excess demand pressures show up first in credit aggregates and asset prices, rather than in goods and services prices.

Borio and Lowe (2002b) suggested that a small set of variables should be sufficient to capture the build-up of vulnerabilities, because focusing on few variables can improve the reliability of indicators. As a result, they considered three core variables (indicators) that could contain useful information about the development of financial imbalances. The three variables were (1) credit-to-GDP; (2) equity prices (deflated by the price level); and (3) the real effective exchange rate. They suggested that in order to assess the build-up of imbalances or a boom, it is appropriate to employ a measure of the deviation of the variables (level) from its trend.[14]

Therefore the expectation is that if the credit-to-GDP ratio, real equity prices and/or the real effective exchange rate move “sufficiently above” their trend (i.e. exceed some critical threshold), then financial imbalances are emerging, signalling the risk of subsequent financial distress. Tests were also performed on four different combinations of the variables, (1) credit and asset prices; (2) credit and the exchange rate; (3) credit and either asset prices or the exchange rate; and (4) credit and asset prices and the

[13] The term macro-financial linkages often refer to the interaction between the financial sector and the domestic economy (Caprio 2011).

[14] As discussed above, the trend is estimated through a Hodrick-Prescott filter.

exchange rate. They noted that good early warning indicators have two important properties. These properties are, (1) the indicator should predict a high percentage of crises that do occur; and (2) the indicator should have a low false negative, meaning the indicator should not signal a crisis that does not materialise. The credit and exchange rate gaps tended on average to rise one period before and to peak in the crisis year, respectively. But the equity price gap was consistently positive until the crisis year yet peaks well before a crisis. The composite indicators performed well also. Their empirical tests included 40 crises spread over 27 of the 34 countries, with 16 such episodes occurring in industrial countries and 24 in emerging market economies.

Updating the earlier work, Drehmann et al (2011) looked at 36 countries from 1960 onwards using a criterion of the noise to signal ratio. They suggested that across countries and crisis episodes, the credit-to-GDP gap variable exhibits very good signalling properties, as rapid credit growth lifts the gap as early as three or four years prior to the crisis. In addition, the gap typically generates very low "noise," by not producing many false warning signals that crises are imminent. The credit-to-GDP gap, however, is not a reliable coincident indicator of systemic stress in the banking sector, credit spreads may be better.

Subsequently, Drehmann and Juselius (2014) conducted empirical research on 10 indicators[15] for 26 economies, covering quarterly time series starting in 1980, using criteria derived from the receiver operating characteristic (ROC) curve, (the ROC curve is a mapping of the false positive rate (Type II errors) to the true positive rate (the complement of Type I errors). They saw the area under the curve (AUC) as a summary measure. The credit-to-GDP gap performed well over long horizons and the debt service ratio is better in the shorter horizons.[16]

Detken et al (2014) of the ESRB also found favourable results for the indicator properties of the credit-to-GDP gap in the EU-28. They found that in univariate signalling, the gap is the best single leading indicator for systemic banking crises associated with excessive credit growth. Meanwhile, multivariate analysis showed that when the gap is combined with other variables (such as debt service to income, the current account/GDP and real equity price growth) in a multivariate signalling approach, a discrete choice model or a decision tree, the overall signalling performance improves.

5 Critiques of the credit-to-GDP gap

In the light of these positive results, Basel III recommends to use the credit-to-GDP gap as a guide for setting the countercyclical capital buffer (Basel Committee 2010a). Yet, it has faced criticism in context of its role as warning indicator in the countercyclical capital buffer framework and the identification of costly credit boom or banking crisis. Borgy et al (2014), of the Banque de France, for example, mentioned in their study of asset-price booms and banking crises, that existing macroprudential regulations may have given too strong a role to the credit-to-GDP gap ratio, as in their analysis it does not perform

[15] The 10 indicators were, the debt service ratio, credit growth, credit-to-GDP gap, non-core liabilities ratio, property price gap, property price growth, equity price gap, equity price growth, GDP growth and history (the total number of crises in a country between World War II and 2012).

[16] In recent related work, Grintzalis et al (2017) present estimates of finance-adjusted output gaps which incorporate the information on the domestic and global credit cycles for a sample of emerging market economies (EMEs), with a state-space representation of an HP filter augmented with a measure of the credit gap to estimate finance-adjusted output gaps. They measure the domestic and global credit gaps as the deviation of private-sector real credit growth and net capital flows to EMEs from long-term trends, using the asymmetric Band-Pass filter. They find financial cycle information is associated with cyclical movements in output.

particularly well in the identification of costly asset-price booms or systemic banking crises relative to other indicators such as real interest rates and the real stock price.

Barrell et al (2010a) in a logit analysis of precursors to banking crises in OECD countries, found that house prices were key indicators, along with aggregate banking sector leverage and liquidity. Subsequent work found the current account/GDP ratio (Barrell et al 2010b) and a measure of off-balance-sheet activity (Karim et al 2013) to be also relevant. However, in all their estimations they did not find measures related to credit growth to be significant.

Repullo and Saurina (2011) argued that the credit-to-GDP gap ratio could exacerbate the inherent procyclicality of risk-sensitive bank capital regulation. GDP growth is seen as a better indicator for these purposes. In addition, as the credit-to-GDP gap ratio corresponds to the deviation from a filtered trend, its real-time use depends mostly on the reliability of the end-of-sample estimates of credit and GDP. Some authors argue that subsequent revisions of macroeconomic statistics could be as large as the gap itself (Edge and Meisenzahl, 2011), which can raise concerns about the robustness of the credit-to-GDP gap if used as the sole indicator for CCB implementation.

Giese et al (2014) of the Bank of England, in looking that the performance of the credit-to-GDP gap in the UK, saw that it provided timely signals for policy tightening in past episodes of banking system distress. Yet, they were still cautious on performance of the gap in the future and they suggested complementary indicators such as household debt-to-income ratios, leverage ratio, etc. Similarly, Bennani et al (2014) saw that credit-to-GDP gap as well as real credit growth variables perform well in signalling a boom early in the case of France, but other indicators such as measures of property prices, of private sector debt sustainability or of bank balance sheets could also usefully complement the credit-to-GDP gap. As with the case of macroprudential policy, it is not a question of "one size fits all" and no single indicator can be used to identify asset-price booms and banking crises. As Bank of England (2014) suggested, it is therefore important to complement the credit-to-GDP gap measure with other indicators, a point acknowledged in the Basel III Accord guidance and in EU legislation.

Drehmann and Tsatsaronis (2014) from the BIS identified three areas of criticism of the credit-to-GDP gap. These areas are (i) the credit gap is not a good measure for setting the buffer, because it can lead to decisions that conflict with the countercyclical capital buffer objective; (ii) the credit gap is not the best early warning indicator for banking crises, especially in the case of emerging market economies; and (iii) the credit gap has measurement problems.[17] They acknowledged there are relevant measurement issues with the credit-to-GDP gap, particularly the starting point for the calculation and how to deal with structural breaks in the data series. Yet they suggested that the data should be properly adjusted to deal with structural breaks and the gap should be developed using at least ten years of data. Additionally, in their research, they saw that the credit-to-GDP gap performs better in providing policymakers with reliable signals about when to raise the buffer but this does not mean that the credit-to-GDP gap should solely be used, notably during a bust when more rapid release of buffers may be required. Indeed, Detken et al (2014) show that market based indicators (such as overnight swaps or covered bond spreads) are the best indicators to be used to signal that the CCB should be reduced or released.

We now go on to assess the utility of macroprudential tools in reducing the credit to GDP gap and hence resolving financial imbalances.

[17] BIS (2014).

6 Datasets for modelling the impact of macroprudential policy

6.1 Data

Our key data stem on the one hand from the BIS for the credit-to-GDP gap and the other, the IMF GMPI survey data on macroprudential instruments (Cerutti et al 2015, 2017).

In September 2016, the BIS released time-series quarterly data on the credit-to-GDP gap covering 42 countries and one economic region, the Euro area, starting at the earliest in 1961. In May 2017, Colombia was added and is included in our model testing. However, the Euro area is excluded from the panel analysis as many individual countries in the Euro area are already included in the data. The countries in the panel analysis are the following.

Table 1: List of Countries for credit-to-GDP data

Country	ISO Code	Period beginning	IMF category	Income status
Argentina	ARG	2000q1	EME	UMI
Australia	AUS	2000q1	ADV	HI
Austria	AUT	2000q1	ADV	HI
Belgium	BEL	2000q1	ADV	HI
Brazil	BRA	2005q1	EME	UMI
Canada	CAN	2000q1	ADV	HI
Switzerland	CHE	2000q1	ADV	HI
Chile	CHL	2000q1	EME	UMI
China (People's Republic of)	CHN	2000q1	EME	UMI
Colombia	COL	2006Q4	EME	UMI
Czech Republic	CZE	2003q1	ADV	HI
Denmark	DEN	2000q1	ADV	HI
Germany	DEU	2000q1	ADV	HI
Spain	ESP	2000q1	ADV	HI
Finland	FIN	2000q1	ADV	HI
France	FRA	2000q1	ADV	HI
United Kingdom	GBR	2000q1	ADV	HI
Greece	GRC	2000q1	ADV	HI
Hong Kong SAR	HKG	2000q1	ADV	HI
Hungary	HUN	2000q1	EME	HI
Indonesia	IDN	2000q1	EME	LMI
India	IND	2000q1	EME	LMI
Ireland	IRL	2000q1	ADV	HI
Israel	ISR	2001q1	ADV	HI
Italy	ITA	2000q1	ADV	HI
Japan	JPN	2000q1	ADV	HI
Korea	KOR	2000q1	ADV	HI
Luxembourg	LUX	2012q1	ADV	HI
Mexico	MEX	2000q1	EME	UMI
Malaysia	MYS	2000q1	EME	UMI
Netherlands	NLD	2000q1	ADV	HI
Norway	NOR	2000q1	ADV	HI
New Zealand	NZL	2000q1	ADV	HI
Poland	POL	2002q1	EME	HI
Portugal	PRT	2000q1	ADV	HI
Russia	RUS	2005q1	EME	UMI
Saudi Arabia	SAU	2003q1	EME	HI
Singapore	SGP	2000q1	ADV	HI
Sweden	SWE	2000q1	ADV	HI
Thailand	THA	2000q1	EME	UMI
Turkey	TUR	2000q1	EME	UMI
United States	USA	2000q1	ADV	HI
South Africa	ZAF	2000q1	EME	UMI

Source: BIS credit-to-GDP gap statistics. Version: May 23rd 2017. ADV is advanced, EME is emerging market economy, HI is high income, UMI is upper middle income, LMI is lower middle income.

The IMF dataset on macroprudential instruments cover 119 countries annually over 2000 to 2013. The data are from the IMF's Global Macroprudential Policy Instruments (GMPI) survey. There are 12 survey instruments and 2 additional derived instruments and three summary instruments in the publicly available dataset. The instruments are as follows:

Table 2: Instruments in the IMF Dataset of Macroprudential Tools (2015)

Instrument	Abbreviation	Definition
Survey Instruments		
Loan-to-Value Ratio	LTV	Constrains highly levered mortgage down payments by enforcing or encouraging a limit or by determining regulatory risk weights.
Debt-to-Income Ratio	DTI	Constrains household indebtedness by enforcing or encouraging a limit.
Time-Varying/Dynamic Loan-Loss Provisioning	DP	Requires banks to hold more loan-loss provisions during upturns.
General Countercyclical Capital Buffer/Requirement	CTC	Requires banks to hold more capital during upturns.
Leverage Ratio	LEV	Limits banks from exceeding a fixed minimum leverage ratio.
Capital Surcharges on SIFIs	SIFI	Requires Systemically Important Financial Institutions to hold a higher capital level than other financial institutions.
Limits on Interbank Exposures	INTER	Limits the fraction of liabilities held by the banking sector or by individual banks.
Concentration Limits	CONC	Limits the fraction of assets held by a limited number of borrowers.
Limits on Foreign Currency Loans	FC	Reduces vulnerability to foreign-currency risks.
Reserve Requirement Ratios	RR	Limits credit growth; can also be targeted to limit foreign-currency credit growth.
Limits on Domestic Currency Loans	CG	Limits credit growth directly.
Levy/Tax on Financial Institutions	TAX	Tax on revenues of financial institutions.
Derived and summary Instruments		
Loan-to-Value Ratio Caps	LTV_CAP	Restricts to LTV used as a strictly enforced cap on new loans, as opposed to a supervisory guideline or merely a determinant of risk weights.
FX and/or Countercyclical Reserve Requirements	RR_REV	Restricts to RR which i) imposes a wedge of on foreign currency deposits or ii) is adjusted countercyclically
Total macroprudential instruments	MPI	Sum of MPIF and MPIB
Macroprudential instruments focused on the borrower	MPIF	Sum of LTV_CAP and DTI

Macroprudential instruments focused on the financial institution	MPIB	Sum of other instruments, including RR_REV rather than RR

Source: Cerutti, Claessens and Laeven (2015). Version February 24th, 2015. Notes: each variable is a dummy that takes on two values: 0 for no policy and 1 for policy in effect. The database covers a sample from 2000 to 2013 with annual data.

Reflecting the coverage of the dataset, the period for the analysis is from 2000q1 to 2013q4, with the IMF GMPI survey data being converted from yearly to quarterly data frequency. The measures were coded from the beginning of the year they are actually in place and subsequently all quarters after that starting year until the period they were discontinued. Quarterly data for the measures is the most appropriate approach since we are testing the macroprudential policies' effectiveness against the lowering of the credit-to-GDP gap, which is a quarterly measure, it is appropriate to have a quarterly frequency for the measures.

7 Baseline model for analysing the impact of macroprudential policy

7.1 Model specification

The starting point for the empirical analysis is the work of Cerutti et al (2015, 2017) as noted above, who looked at how the macroprudential index and its various sub-indexes shown in Table 2 relate to the growth in countries' credit and house prices. Also important background is the work of Akinci and Olmstead-Rumsey (2015), who using quarterly data investigated macroprudential policies' effects on total bank credit, housing credit and house prices. We note that both used a GMM specification which they considered most appropriate to deal with potential endogeneity between macroprudential policy and the dependent variable. Lags of the tools should also mitigate potential endogeneity.

The empirical reduced-form regression model used in the analysis is as follows:

$$CGDPGAP_{i,t} = \alpha CGDPGAP_{i,t-1} + + \vartheta MaPP_{i,t-1} + ßBCrisis_{i,t-1} + ÞX_{i,t-1} + \varepsilon_{it} \quad (4)$$

where *i* denotes the countries, t indicates time period. The dependant variable, $CGDPGAP_{i,t}$ denotes the quarterly credit-to-GDP gap. The variable denoted by MaPP is the macroprudential policy index, which captures the macroprudential effect on the credit-to-GDP gap from the beginning of the year they are actually in place and subsequently all quarters after that starting year until the period it is discontinued. We also include a vector of control variables, $X_{c,t}$.

In terms of control variables, the BCrisis variable is a vector capturing the presence of a banking crisis during the period a country experienced a banking crisis as defined by Laeven and Valencia (2013). It is a dummy variable and it is coded in the quarter the crisis starts until the period it was over. Additional control variables, Xc,t, used are as follows, unemployment rate (UNEMPLRATE), real GDP growth rate (REALGDPRATE), inflation rate (INFLATRATE) and the monetary authority bank rate (BANKRATE). The data for these variables are collected from the IMF's International Financial Statistics, the OECD database, the BIS, and International Labour Organisation (ILO). The control variables were tested for significance. In this we follow Cerutti et al (2017) but include unemployment and inflation as additional controls.

Table 3: Control Variables

Variable	Source
Banking crisis dummy (BCRISIS)	Laeven and Valencia (2013)
Central bank rate (BANKRATE)	IMF International Financial Statistics and Bank for International Settlements
Real GDP growth rate (REALGDPRATE)	IMF International Financial Statistics
Unemployment rate (UNEMPLRATE)	IMF International Financial Statistics and International Labour Organisation
Inflation rate (INFLATRATE)	IMF International Financial Statistics

Notes: For some countries, data for certain variables were collected from their central bank and/or national statistical agency. In addition, some data were derived by the authors.

An important issue is how to enter variables into the model. We would prefer to have stationary variables for the regression, in line with the existing literature. A set of results for panel unit root tests is given in Table 4 below, where we see that over 2000q1-2013q4, all the control variables are stationary both according to the Levin-Lin-Chu test (which assumes a common unit root process for all countries) and the Im-Pesaran-Shin test (which allows for individual unit root processes between countries).

The outstanding issue is how to deal with the credit-GDP gap. The logic of a Hodrick Prescott filter is that the difference between the variable and its trend tends to be stationary. This is borne out in practice by the longer runs of data shown in the table, where the full dataset and the data from 1970 and 1980 onwards are stationary. On the other hand the data from 1990 and 2000 onwards fail the stationarity tests, unless the variable is first differenced. We considered that the a priori considerations and the results from the longer term still justified the inclusion of the level of the credit gap as if it were stationary. Accordingly we have it as a level and lagged level in the chosen specification. In Section 9 we show an alternative GMM-difference estimate with the first difference of the gap as a robustness check.

Table 4: Unit Root Tests 2000q1-2013q4

	Levin-Lin-Chu	Im-Pesaran-Shin
BANKRATE	-4.88 (0.00)	-4.1 (0.00)
REALGDPRATE	-4.3 (0.00)	-12.7 (0.00)
UNEMPLRATE	-3.42 (0.00)	-5.04 (0.00)
INFLATRATE	-3.90 (0.00)	-11.88 (0.00)
CGDPGAP	2.3 (0.98)	4.6 (1.0)
CGDPGAP (WITH TREND)	-3.03 (0.00)	2.25 (0.99)
CGDPGAP (NO CONSTANT)	-5.81 (0.00)	n/a
DIFFERENCE OF CGDPGAP	-22.1 (0.00)	-23.7 (0.00)
CGDPGAP FULL SAMPLE FROM 1951 ON	-1.21 (0.11)	-2.81 (0.00)
CGDPGAP SAMPLE FROM 1970Q1	-1.22 (0.11)	-2.74 (0.00)
CGDPGAP SAMPLE FROM 1980Q1	-1.74 (0.04)	-2.39 (0.01)
CGDPGAP SAMPLE FROM 1990Q1	-0.14 (0.44)	-0.12 (0.45)

Note: P-value in parentheses

7.2 Baseline equation (All countries)

We undertook a dynamic panel data regression using the Generalized Method of Moments (GMM) method (Arellano and Bond 1991) in differences using quarterly data from 43 countries (GMM was also

used in Akinci and Olmstead-Rumsey (2015) and Cerutti et al (2017)). The sample begins in 2000q1 and ends in 2013q4. Instruments were second lagged levels of the independent variables and the second lag of the dependent variable. The initial estimates for the baseline model are shown in the following table, together with estimates for the same specification for the periods 2000-2006 and 2007-2013.

Table 5: All countries baseline model 2000q1 to 2013q4 (GMM-difference): Dependent variable Credit-to-GDP gap (CGDPGAP)

Estimation period	Full sample estimate (2000q1-2013q4)	Pre-crisis sample estimate (2000q1-2006q4)	Post-crisis sample estimate (2007q1-2013q4)
CGDPGAP(-1)	0.94***	0.93***	0.90***
	(41.01)	(24.50)	(46.52)
BCRISIS(-1)	-2.20***	-0.85*	-1.06
	(-20.65)	(-1.65)	(-1.49)
UNEMPLRATE(-1)	-1.01***	-0.28***	-1.46***
	(-38.65)	(-4.85)	(-29.26)
INFLATRATE(-1)	-0.19***	-0.18***	-0.48***
	(-9.66)	(-4.35)	(-6.90)
REALGDPRATE(-1)	-0.22***	-0.29***	-1.31***
	(-7.55)	(-5.59)	(-11.96)
BANKRATE(-1)	0.13***	0.14***	0.36**
	(9.54)	(7.39)	(2.58)
Observations	2167	986	1181
Sargan (J-Statistic) (p-value)	0.42	0.46	0.27
Periods included	54	26	28
Cross sections included	43	41	43

Notes: the coefficient values are reported and the t-statistics are reported in parenthesis below each estimated coefficient. Sargan (J-Statistics); p-values were calculated using the command scalar pval=@chisq(J-Statistic, instrument rank - number of regressors in the model. *** significant at 1%, ** 5% and * 10%.

The baseline models were tested for goodness of fit using the Sargan test (J-Statistics). Sargan diagnostics results, test for over-identifying restrictions which is required for consistency. The J-Statistics results indicate that the null hypothesis of over-identifying restrictions are not rejected. The initial estimates for the All countries baseline models are shown in the table 5. Finally, the baseline model coefficients' signs are correct and expected except for the short term policy interest rate (BANKRATE) as a higher cost of credit should reduce credit expansion. One would expect the BANKRATE sign to be negative and inversely related to the CGDPGAP variable. However, the result is consistent with the monetary position of many countries, which lowered their monetary policy rate to almost zero percent in the period 2007 to 2013, thus resulting in a positive relationship with the CGDPGAP variable, although we note that the effect is also significant in the 2000-6 period.

8 Estimated results of the effectiveness of the macroprudential tools

The macroprudential tools were tested one by one using the baseline model, and Table 6 outlines the results for each tool, entered one by one at the first lag. The tools are tested over three periods, 2000q1-2013q4, 2000q1-2006q4 (pre-crisis period) and 2007q1-2013q4 (crisis period). Blanks show estimates that generated a near-singular matrix.

Table 6: All countries baseline model, macroprudential instruments results: Dependent variable Credit-to-GDP gap (CGDPGAP)

Macroprudential instruments	Full sample estimate (2000q1-2013q4)	Pre-crisis sample estimate (2000q1-2006q4)	Post-crisis sample estimate (2007q1-2013q4)
Loan-to-Value Ratio (LTV (-1))	-2.91*** (-3.80)	1.84 (1.62)	-4.25*** (-3.55)
Debt-to-Income Ratio (DTI(-1))	-9.70*** (-5.65)	-5.39* (-1.90)	-2.30 (-1.00)
Capital Surcharges on SIFIs (SIFI(-1))	------	------	-1.69 (-0.96)
General Countercyclical Capital Buffer/Requirement (CTC(-1))	------	------	5.34 (1.11)
Time-Varying/Dynamic Loan-Loss Provisioning (DP(-1))	-21.14** (-2.16)	36.00** (2.48)	-3.77 (-0.39)
Leverage Ratio (LEV(-1))	-24.93 (-1.23)	------	-9.05*** (-2.63)
Limits on Interbank Exposures (INTER(-1))	-4.47 (-0.91)	26.24** (2.16)	1.67 (0.41)
Concentration Limits (CONC(-1))	-5.59*** (-3.30)	-1.63 (-0.84)	-5.62 (-0.48)
Limits on Domestic Currency Loans (CG(-1))	-30.46 (-1.55)	------	5.44 (0.34)
Levy/Tax on Financial Institutions (TAX(-1))	-3.04 (0.54)	------	5.43*** (2.60)
Reserve Requirement Ratios (RR(-1))	-9.62 (-0.62)	28.06 (1.37)	15.73 (0.99)
Limits on Foreign Currency Loans (FC(-1))	-3.41 (-1.03)	5.88*** (2.88)	9.78*** (3.30)
Loan-to-value ratio caps (LTV_CAP(-1))	-3.27*** (-4.38)	0.09 (0.09)	-4.13** (-2.28)
FX and/or Countercyclical Reserve Requirements (RR_REV(-1))	-8.47 (-0.59)	-18.10*** (-2.65)	23.34 (1.17)
Total macroprudential instruments (MPI (-1))	-1.47*** (-2.75)	1.53*** (2.73)	-0.77* (-1.88)
Macroprudential instruments focused on the borrower (MPIB (-1))	-2.45*** (-2.85)	-1.13 (-1.27)	-1.94** (-1.99)
Macroprudential instruments focused on the financial institution (MPIF (-1))	-1.83*** (-3.64)	4.92*** (4.25)	-0.55 (-1.05)

Note: For MaPP definitions please see Table 2 and for baseline estimates see Table 5. The MaPP instruments coefficient values are reported and the t-statistics are reported in parenthesis below each estimated coefficient. *** significant at 1%, ** significant at 5%, * significant at 10 %. Blanks show estimates that generated a near-singular matrix.

Overall, the results suggest that debt to income limits (DTI), loan-to-value limits (LTV) and LTV used as a strictly enforced cap on new loans (LTV_CAP) were an effective MaPP tool, being significant and negative in the full period. DTI is also significant in the pre-crisis period and LTV and LTV_CAP are significant in the post crisis period. Dynamic provisioning (DP) is significant and negative in the full sample but positive in the earlier period, while concentration limits (CONC) are negative and significant for the full sample only. A number of additional tools were significant and negative in sub periods only, such as the leverage ratio (LEV) in the post crisis period and reserve requirements (RR_REV) in the pre-crisis period. There are also a number of wrong signs such as for limits on interbank deposits (INTER) and on foreign currency loans (FC) in the pre-crisis period and taxes on financial institutions (TAX) and again on FC in the post crisis period.

There is some promise in the other tools like capital surcharges on SIFIs (SIFI) but they have not been used regularly as in the case of LTV and DTI to form a proper conclusion to be drawn on this tool. We note in this context the Bank of England[18] view that the credit-to-GDP gap ratio should be complemented with other early warning indicators such as the debt to Income ratio (i.e. as an indicator as well as being targeted by a tool), the leverage ratio, the loan-to-deposit ratio, spreads on new lending, etc. The summary variables MPI, MPIF and MPIB are significant and negative in the full sample. However, MPIB and MPI are significant but positive in the pre-crisis period, while MPI and MPIB are significant and negative post crisis.

Note that the reserve ratio variables RR and RR_REV are mostly insignificant (except for the pre-crisis period) despite their use as a macroprudential tool, notably in many emerging markets. The difficulty in getting "right signs" for reserve requirements may link to their dual role as an instrument of monetary policy and of macroprudential policy. See for example Izquerido et al. (2013) on related issues in Latin America.

One concern about the tests is that developing countries that have using macroprudential tools longer may have a heavier weight in the coefficient estimates and the effectiveness of the macroprudential tools. This requires further analysis by splitting the countries into groups of developed and developing countries, which we report below. We use leveraged coefficients for emerging markets to see whether their effects differ from the mean, introducing both MaPP(t-1) and MaPP(t-1)*DEME(t-1) where MaPP is the tool and DEME is a dummy for Emerging Market Economies (EMEs), using the IMF category in Table 1. The effects can then be calculated for advanced countries to be MaPP (t-1), whereas for EMEs it is (MaPP(t-1) + (MaPP(t-1)*DEME(t-1))). In each case, for insignificant variables we take the coefficient to be zero. Results are shown in Table 7. Note there is slight difference in results with Table 6 which links to the extra variable and associated instrument.

[18] Bank of England (2014).

Table 7: Macroprudential instruments results with EME dummy using baseline model (All countries): Dependent variable Credit-to-GDP gap (CGDPGAP)

	Full sample estimate (2000q1-2013q4)		Pre-crisis sample estimate (2000q1-2006q4)		Post-crisis sample estimate (2007q1-2013q4)	
Macroprudential instruments	**CGDPGAP (-1)**	**Dummy for EMEs (-1)* CGDPGAP(-1)**	**CGDPGAP (-1)**	**Dummy for EMEs (-1)* CGDPGAP(-1)**	**CGDPGAP (-1)**	**Dummy for EMEs (-1)* CGDPGAP(-1)**
Loan-to-Value Ratio (LTV (-1))	-4.7** (2.5)	3.0 (1.0)	16.5** (2.0)	-19.7** (2.3)	-4.34*** (2.8)	0.81 (0.2)
Debt-to-Income Ratio (DTI(-1))	-8.6** (2.1)	-2.1 (0.4)	-5.1* (1.8)	4.16 (0.9)	-14.0* (1.7)	26.3* (1.9)
Capital Surcharges on SIFIs (SIFI(-1))	-	-	-	-	0.7 (0.5)	-18.9** (2.0)
General Countercyclical Capital Buffer/Requirement (CTC(-1))	-	-	-	-	-	-
Time-Varying/Dynamic Loan-Loss Provisioning (DP(-1))	-	-	-	-	-	-
Leverage Ratio (LEV(-1))	-	-	-	-	2.16 (0.6)	-20.8** (2.4)
Limits on Interbank Exposures (INTER(-1))	-9.9 (1.1)	9.7 (1.0)	-	-	2.03 (0.5)	-4.25 (0.5)
Concentration Limits (CONC(-1))	-14.8*** (4.6)	17.1*** (4.4)	-5.9 (0.5)	5.34 (0.4)	-	-
Limits on Domestic Currency Loans (CG(-1))	-	-	-	-	-	-
Levy/Tax on Financial Institutions (TAX(-1))	-64.7 (0.5)	29.8 (0.3)	-	-	5.04** (2.1)	-9.09 (1.3)
Reserve Requirement Ratios (RR(-1))	-	-	-	-	-	-
Limits on Foreign Currency Loans (FC(-1))	12.6 (1.4)	-16.8 (1.6)	-	-	15.1 (1.1)	-9.34 (0.7)
Loan-to-value ratio caps (LTV_CAP(-1))	-4.59** (2.3)	2.11 (0.8)	19.2*** (3.0)	-23.8*** (3.7)	-4.34** (2.4)	2.7 (0.7)
FX and/or Countercyclical Reserve Requirements	-	-	-	-	-	-

(RR_REV(-1))						
Total macroprudential instruments (MPI (-1))	-1.23 (1.0)	-0.06 (0.03)	1.91 (1.0)	-1.08 (0.5)	0.62 (0.8)	-2.92** (2.4)
Macroprudential instruments focused on the borrower (MPIB (-1))	-3.24* (1.8)	0.49 (0.2)	1.1 (0.7)	-5.43*** (3.1)	-2.59* (1.9)	3.51 (1.5)
Macroprudential instruments focused on the financial institution (MPIF (-1))	-0.53 (0.3)	-2.22 (1.1)	2.43 (0.5)	2.62 (0.5)	0.56 (0.7)	-4.03** (2.6)

Notes: for MaPP instruments definitions please see Table 2 and for baseline estimates see Table 5. The MaPP tools coefficient values are reported and the t-statistics are reported in parenthesis below each estimated coefficient. *** significant at 1%, ** significant at 5%, * significant at 10 % Blanks show estimates that generated a near-singular matrix.

The EME dummy tests the stylised fact that there is much greater experience of macroprudential policy in EMEs, as well as simpler financial structure, and hence different effects could arise from advanced countries. As can be seen in Table 7, there are indeed some significant results for differential effects of macroprudential instruments in EMEs. In the earlier sample (2000-2006), there is an offset for the variable LTV such that the general positive effect on the credit gap becomes zero for EMEs and similarly for LTV_CAP. Hence the result for a positive effect applies to advanced countries only. The MPIB variable is significant and negative for EMEs only in the pre-crisis period, while for DTI there is no significant difference in the negative and significant effect between EMEs and advanced countries . In the later period, there is a strong negative effect from LEV and SIFI which arise for EMEs rather than advanced countries, suggesting a greater effect of the introduction of Basel III in those countries. LTV and LTV_CAP have similar effects for both types of country, while for DTI there is an offset implying a positive effect for EMEs.[19] TAX is shown to have a positive effect for both types of country. Over the full sample however there is only one significant indication of differential results on average, namely for CONC which is positive for advanced countries and zero for EMEs.

Concerning the summary indicators, we have significant effects for MPIB in EMEs pre crisis and for MPI and MPIF for EMEs and MPIB for advanced countries post crisis. The overall sample has MPIB significant for both types of country, in line with the results for LTV, DTI and LTV_CAP.

As a further test, Table 8 reports results where the credit gap is either positive or negative, hence testing whether macroprudential policy could be more effective in boom periods (when the gap is positive). As noted by Lang and Welz (2017), and as shown in the Appendix charts, gaps were often highly negative for prolonged periods in the wake of crises. Of course, countries are also more likely to apply macroprudential policies in boom periods, but the non-zero coefficients in the second column conform that policies have also been applied in times of negative gaps.

[19] The equality of the coefficients (which would imply a zero effect for EMEs) is rejected by a Wald Test at the 10% level.

Table 8: Macroprudential instruments results for positive and negative credit-to-GDP gaps (CGDPGAP) using baseline model (2000q1-2013q4, All countries)

Macroprudential instruments	Dependent variable: Positive Credit-to-GDP gap (CGDPgap)	Dependent variable: Negative Credit-to-GDP gap (CGDPgap)
Loan-to-Value Ratio (LTV (-1))	-	3.23*** (28.6)
Debt-to-Income Ratio (DTI(-1))	-8.75*** (12.3)	-0.28 (0.3)
Capital Surcharges on SIFIs (SIFI(-1))	-1.82 (0.7)	1.83 (1.5)
General Countercyclical Capital Buffer/Requirement (CTC(-1))	1.89 (0.5)	-
Time-Varying/Dynamic Loan-Loss Provisioning (DP(-1))	-	3.86 (1.5)
Leverage Ratio (LEV(-1))	-	2.04 (0.5)
Limits on Interbank Exposures (INTER(-1))	-28.7*** (20.0)	-0.06 (0.1)
Concentration Limits (CONC(-1))	-9.84*** (4.3)	-
Limits on Domestic Currency Loans (CG(-1))	1.19 (1.2)	-
Levy/Tax on Financial Institutions (TAX(-1))	-10.46*** (5.7)	2.13* (1.7)
Reserve Requirement Ratios (RR(-1))	-2.68 (1.6)	-
Limits on Foreign Currency Loans (FC(-1))	2.55*** (5.6)	5.29** (2.3)
Loan-to-value ratio caps (LTV_CAP(-1))	-	2.97 (24.5)
FX and/or Countercyclical Reserve Requirements (RR_REV(-1))	-2.34 (1.4)	-
Total macroprudential instruments (MPI (-1))	-	1.09*** (15.5)
Macroprudential instruments focused on the borrower (MPIB (-1))	-4.75*** (14.7)	1.4*** (7.8)
Macroprudential instruments focused on the financial institution (MPIF (-1))	-1.18*** (4.6)	1.35*** (3.3)

Notes: for MaPP instruments definitions please see Table 2, for specification see Table 5. The MaPP tools coefficient values are reported and the t-statistics are reported in parenthesis below each estimated coefficient. *** significant at 1%, ** significant at 5%, * significant at 10 %. Blanks show estimates that generated a near-singular matrix.

In general, the results confirm that policy is more effective in reducing gaps during periods of positive gaps. DTI, INTER, CONC and TAX are highly significant for positive gaps and not for the negative gaps, this also carries over to the summary variables MPIB and MPIF. For LTV. TAX and LTV_CAP there are positive

effects when gaps are negative. FC is positive for the both positive and negative gaps. MPI, MPIB and MPIF are all positive for the negative gaps. Overall, these results are consistent with the conclusion of Cerutti et al (2017) noted above, that policies are effective but especially in the upturn.

We summarise the work here and compare results for our work with other work using the same IMF dataset of macroprudential instruments and time period in Table 9 below.

Table 9: Summary table of results for sign and significance of macroprudential instruments in equations for credit-to-GDP gap

Table	Table 6			Table 7 (implicit coefficients)						Table 8		Memo items:	
Sample date	00-13	00-06	07-13	00-13		00-06		07-13		00-13	00-13	00-13	00-13
Country coverage	All	All	All	Advanced	EME	Advanced	EME	Advanced	EME	All: positive gap	All: negative gap	Carreras et al (2016)	Cerutti et al (2017)
LTV	-***		-***	-**	-**	+**		-***	-***		+***		
DTI	-***	-*		-**	-**	-*	-*	-*	+*	-***		+*	-**
SIFI									-**				
CTC													
DP	-***	+**											-***
LEV			-***						-**				
INTER		+**								-***		-***	-**
CONC	-***			-***						-***			-*
CG													
TAX			+***					+**	+**	-***	+*	-***	
RR													
FC		+***	+***							+***	+**		-*
LTV_ CAP	-***		-**	-**	-**	+***	-***	-**	-**				-*
RR_REV		-***											-*
MPI	-***	+***	-*						-**		+***	-**	-***
MPIB	-***		-**	-*	-*		-***	-*	-*	-***	+***		-**
MPIF	-***	+***							-**	-***	+***	-***	-***

Notes: for MaPP instruments definitions please see Table 2 and for specifications see Table 5. For Table 7, the effects are calculated as advanced country: as for MaPP (-1), for EME (MaPP(-1) + (MaPP(-1)*DEME(-1))) where DEME is the Dummy for Emerging Market Economies. Signs of significant variables are shown where *** significant at 1%, ** significant at 5% * significant at 10%. Dependent variable for Carreras et al (2016) is log of real household credit growth; dependent for Cerutti et al (2017) is non-financial private sector credit growth. Blanks show estimates that generated a near-singular matrix or an insignificant coefficient.

It is noteworthy that the tools that we find most consistently effective in reducing the credit-to-GDP gap are the housing market focused tools, the loan-to-value ratio and the debt-to-income ratio. There is also a significant result for dynamic provisioning and concentration in the full sample, and for leverage post crisis.

It is also of interest to compare our results with those of two other extensive studies using the same dataset of macroprudential tools estimated over the same time period, namely Carreras et al (2016) and Cerutti et al (2017). As noted above, the Carreras et al paper used as a target variable the growth rate of real household credit, while the Cerutti et al work focused on the growth of total credit to the non-financial private sector, although they noted that effects were greater for household credit. The former paper was for advanced countries only, the latter for a much wider range of both advanced and emerging/developing countries. They both featured a banking crisis dummy to avoid crediting the crisis effect to the tools. It can be seen that the results for these papers were similar to ours regarding the effectiveness of macroprudential instruments, with both highlighting interbank limits and LTV or LTV_CAP; the Carreras et al paper also found effectiveness for taxes on financial institutions, while the Cerutti et al paper also found effectiveness for DTI, foreign currency lending limits and dynamic provisioning in limiting credit growth.

Two differences between the dependent variable for our study and these studies are that we include (following the BIS) total non-financial credit in the dependent variable deflated by GDP and assessed relative to trend credit/GDP. The tools that most influence the credit gap (LTV and DTI) may influence non-financial private sector credit growth largely via their influence on household sector credit (except to the extent entrepreneurs raise funds for their companies by borrowing on their home equity).

9 Robustness checks

We ran three robustness checks on the above estimates. First we reran the basic GMM equations with the difference of the credit gap as a dependent and lagged dependent variable. This accordingly takes the view that stationarity over the data period is required, in the light of the tests in Table 4 showing that the variable is not stationary over the period 2000-13. Second, in line with Akinci and Olmstead-Rumsey (2015) and Kuttner and Shim (2016), we estimated the specification by Panel OLS with fixed effects as an alternative to GMM. One estimate used cross section fixed effects only, the other also added time series fixed effects. The results of estimation are shown in Table 10. For the GMM with difference of the gap, the growth rate of GDP is not significant so is omitted. Other variables are as in the earlier levels based estimation, including the positive sign for the interest rate variable. Sargan's J is again satisfactory. The two panel OLS estimates used all the variables from Table 5, as the growth rate of GDP is also significant, and again had a positive and significant interest rate effect.

Table 10: All countries variant models 2000q1 to 2013q4

	GMM with difference of CGDPGAP	Panel OLS with cross-section fixed effects	Panel OLS with cross-section and time series fixed effects
Dependent	DCGDGAP	CGDPGAP	CGDPGAP
CONSTANT		2.512 (10.4)	2.18 (8.4)
CGDPGAP(-1)		0.981 (190.6)	0.983 (184.7)
DCGDPGAP(-1)	0.103 (18.5)		
BCRISIS(-1)	-5.99 (6.5)	-0.777 (4.4)	-0.763 (3.6)
UNEMPLRATE(-1)	-0.962 (20.9)	-0.28 (10.3)	-0.237 (8.3)
INFLATRATE(-1)	-0.15 (9.1)	-0.0877 (5.0)	-0.0954 (5.4)
REALGDPRATE(-1)		-0.0803 (4.3)	-0.0589 (2.5)
BANKRATE(-1)	0.0457 (2.9)	0.0542 (3.3)	0.0484 (2.7)
Observations	2124	2210	2210
Sargan (J-Statistic) (p-value)	0.43	n/a	n/a
Periods included	53	55	55
Cross sections included	43	43	43

Notes: the coefficient values are reported and the t-statistics are reported in parenthesis below each estimated coefficient. Sargan (J-Statistics); p-values were calculated using the command scalar pval=@chisq(J-Statistic, instrument rank - number of regressors in the model. *** significant at 1%, ** 5% and * 10%.

Table 11 shows the results for the different macroprudential tools using these estimates. It can be seen that in each case the outcome for LTV and DTI is quite consistently favourable, and accordingly the summary variable MPIB is also significant. In the GMM specification with the difference of the gap as dependent variable, LTV_CAP, DTI, the tools for interbank exposure limits (INTER) and FX and/or Countercyclical Reserve Requirements (RR_REV) are significant and negative although LTV per se is not significant and FC has the wrong sign and is significant. Accordingly, the summary variable MPIB is also significant. As regards the fixed effects specifications there is consistent significance for LTV, DTI and MPIB with the correct sign, while DP, LEV and MPIF have the wrong (positive) sign. We may conclude that the main results for the macroprudential tools are robust to these alternative specifications.

Table 11: MaPP tools results for variant equations (All countries, 2000q1-2013q4)

Macroprudential instruments	GMM with difference of CGDPgap	Panel OLS with cross-section fixed effects	Panel OLS with cross-section and time series fixed effects
Loan-to-Value Ratio (LTV (-1))	-2.17 (0.8)	-0.468** (2.3)	-0.431** (2.0)
Debt-to-Income Ratio (DTI(-1))	-3.48* (1.7)	-0.5* (1.9)	-0.495* (1.8)
Capital Surcharges on SIFIs (SIFI(-1))	-	0.074 (1.1)	0.33 (0.6)
General Countercyclical Capital Buffer/Requirement (CTC(-1))	-	-1.09 (0.8)	-0.858 (0.6)
Time-Varying/Dynamic Loan-Loss Provisioning (DP(-1))	-5.08 (0.2)	1.07* (1.9)	1.02* (1.8)
Leverage Ratio (LEV(-1))	2.86 (0.2)	0.855* (1.9)	1.06** (2.3)
Limits on Interbank Exposures (INTER(-1))	-9.63*** (3.2)	0.223 (0.7)	0.354 (1.1)
Concentration Limits (CONC(-1))	1.22 (0.8)	0.465 (1.2)	0.196 (0.5)
Limits on Domestic Currency Loans (CG(-1))	-	0.832 (1.0)	0.871 (1.1)
Levy/Tax on Financial Institutions (TAX(-1))	-2.64 (0.4)	0.25 (0.9)	0.471 (1.6)
Reserve Requirement Ratios (RR(-1))	-12.6 (1.2)	0.917 (1.3)	0.897 (1.3)
Limits on Foreign Currency Loans (FC(-1))	1.91*** (5.9)	-0.165 (0.5)	-0.048 (0.2)
LTV_CAP(-1)	-5.49** (2.7)	-0.349 (1.4)	-0.273 (1.1)
RR_REV(-1)	-20.8** (2.2)	0.917 (1.3)	0.897 (1.3)
MPI(-1)	-0.92 (1.6)	0.023 (0.3)	0.07 (0.9)
MPIB(-1)	-2.87*** (3.2)	-0.28* (1.9)	-0.259* (1.7)
MPIF(-1)	-0.91 (1.3)	0.167* (1.7)	0.248** (2.3)

Notes: for MaPP instruments definitions please see Table 2, for specification see Table 10. The MaPP instruments coefficient values are reported and the t-statistics are reported in parenthesis below each estimated coefficient. *** significant at 1%, ** significant at 5%, * significant at 10 %. Blanks show estimates that generated a near-singular matrix.

10 Conclusions

Although the literature and research are still developing, a number of countries' regulators have been given the legislative authority to formally develop a macroprudential policy framework and there is a rapid growth in the usage of macroprudential instruments in many countries. Research has shown macroprudential policy and its tools are effective in reducing the build-up of imbalances in the financial system and we make an additional contribution to this literature, focusing on a variable that to our knowledge has not yet been assessed as a target (as opposed to a trigger) for macroprudential policy, the credit-GDP gap. Its importance is underlined not only by favourable research on its predictive power for banking crises, but also given its role as a trigger for implementation of the Basel III countercyclical buffer.

The results suggest that the impact of macroprudential policy on the credit gap is most apparent for housing market related tools such as LTV and DTI, which is comparable with other empirical analysis using the same dataset of tools for growth of credit to the non-financial sector (Cerutti et al 2017) globally, and for a narrower measure, namely household credit growth (Carreras et al 2016) in advanced countries. In this context, it is important to mention that the nature of macroprudential policy to date is that it commonly affects mainly the banks and the household sector. Similarly, the recently-introduced counter cyclical buffer applies to banks, although there may be situations where the factors driving growth in the gap, which is recommended to prompt rises in the CCB, might not be bank credit or household sector related (e.g. non-bank financial institutions credit or bond issue). This shows the need for careful analysis of causes of a rising gap and the ratio should be complemented with other early warning indicators (Bank of England (2014), Drehmann and Tsatsaronis (2014)).

Clearly, a wide measure of credit deflated by GDP and its trend such as in the "gaps" is in principle less likely to be less impacted by typical macroprudential policies, since corporate sector credit is usually not impacted by LTV or DTI measures, for example, while even the CCB does not affect credit by non-bank financial institutions or market credit (unless assets are held on or off banks' balance sheets). Also, the application of macroprudential policy may be complicated by the presence of multiple regulators in advanced countries. (On the other hand it may also be less subject to disintermediation as an indicator.) These points may apply less to emerging market economies whose domestic financial system is typically bank based, and regulatory structures simpler, but their capital flows require alternative macroprudential measures (such as reserve requirements) and our current work does not suggest a strong impact of these policies on the credit gap per se.

An important issue for both types of economy is whether lending from non-bank financial institutions or non-household lending such as commercial property lending is affected by macroprudential measures, which will not be the case for those policies bearing solely on the housing market. For example, commercial property lending has historically been central to most banking crises (Davis 1995, 1999), and although the subprime crisis originated in US residential lending, failed banks in countries such as the UK were also severely impacted by losses in commercial property. Another point is that financial instability may often be based on over lending in specific regions rather than the country as a whole.

These considerations suggest that there should be further assessment of macroprudential policies' potential influence on non-bank financial institutions lending, money and bond markets, the commercial property sector, capital inflows, and regionally. It could also be considered whether household sector credit growth is more risky for the wider economy than corporate lending, as the current configuration of macroprudential policy often seems to imply.

Finally, as regards further research, this could utilise the graduated macroprudential database of Cerutti et al (2016) as well as that of Kuttner and Shim (2016), and it could use the GMM system specification of Arellano and Bover (1995) and Blundell and Bond (1998). Separate regressions for advanced and EME countries and further robustness checks could also be undertaken. Further work with bank level data could be envisaged. In addition, following the above discussion, consideration should be given to the generation of specific "gaps" to sub-sectors, regions or markets and their relationship to banking crises (for an example of the US see Bassett et al 2015).

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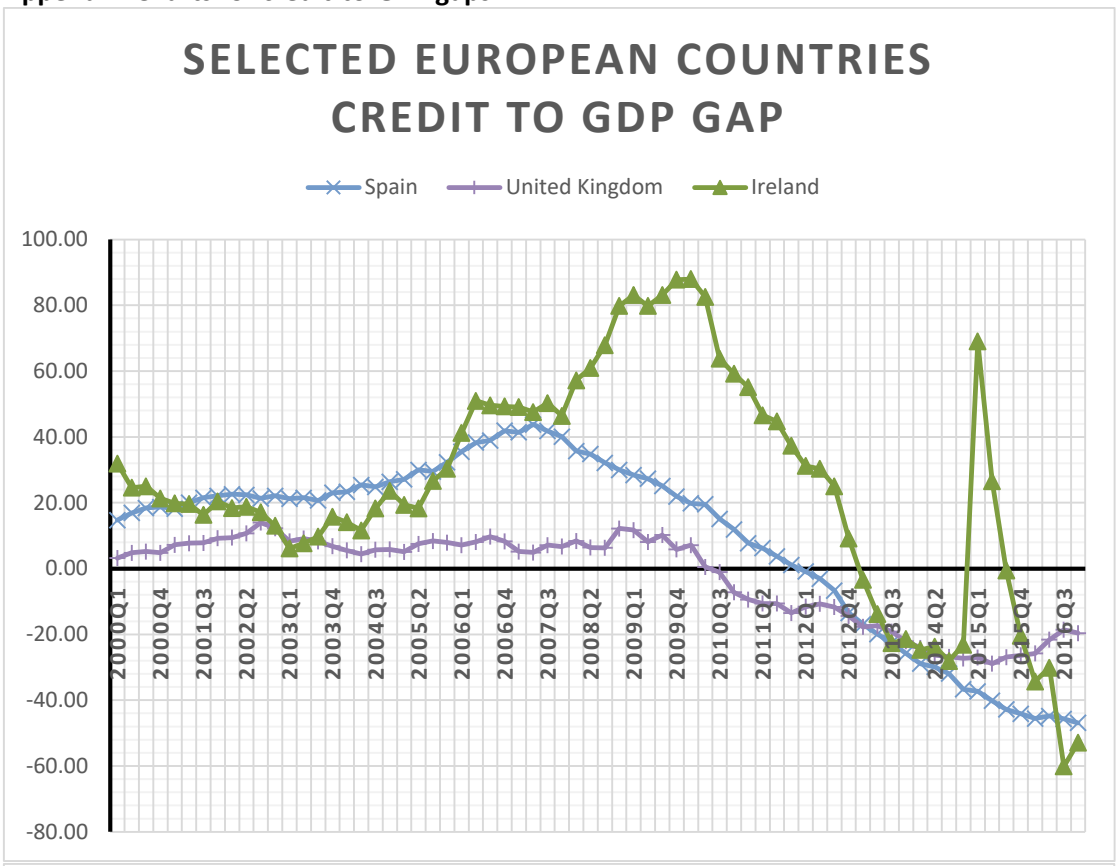
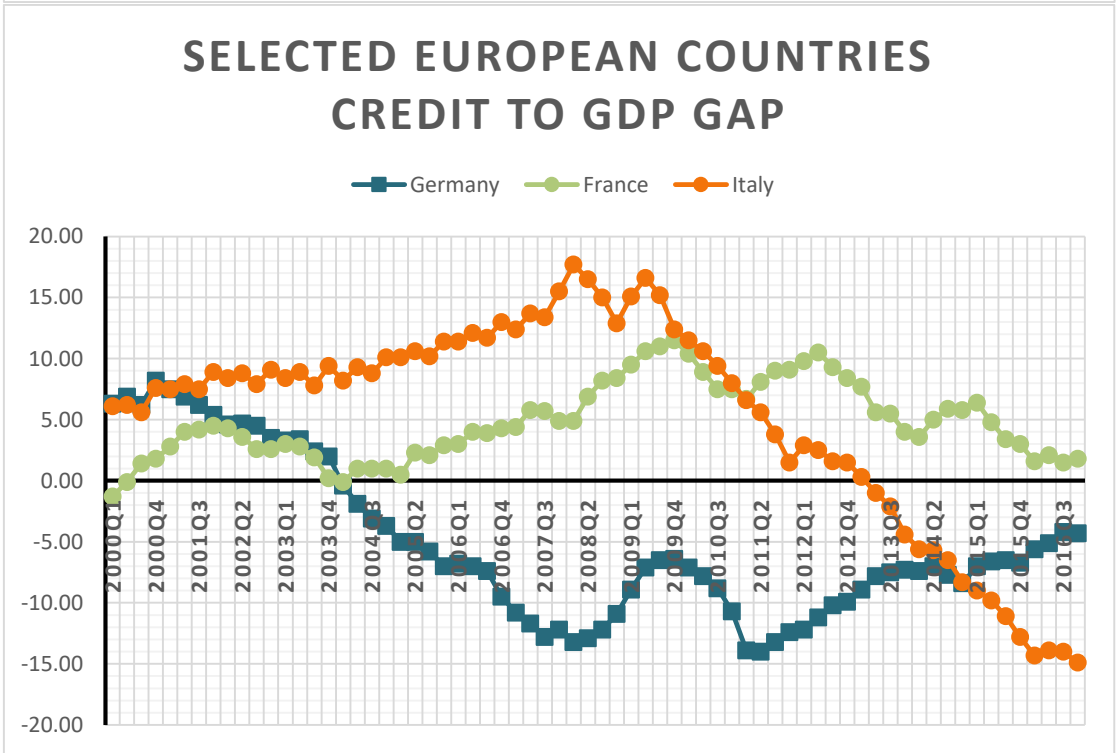
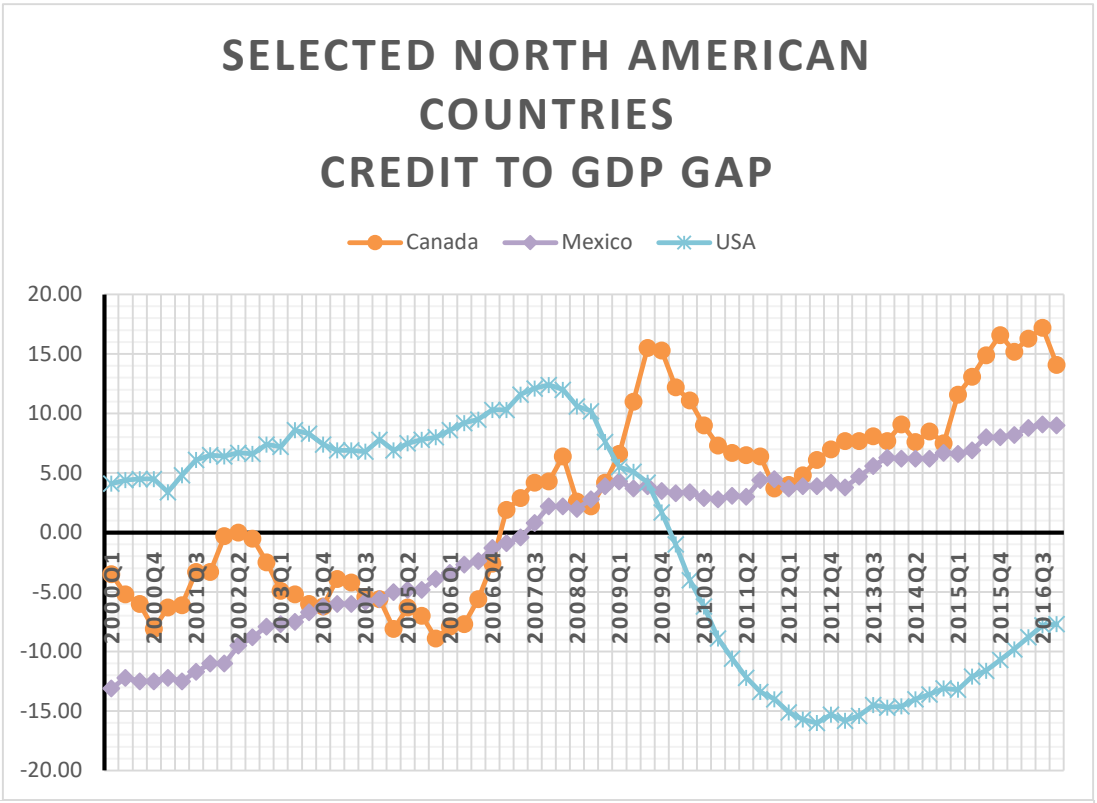
Appendix: Charts for credit-to-GDP gaps



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10.00
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0.00
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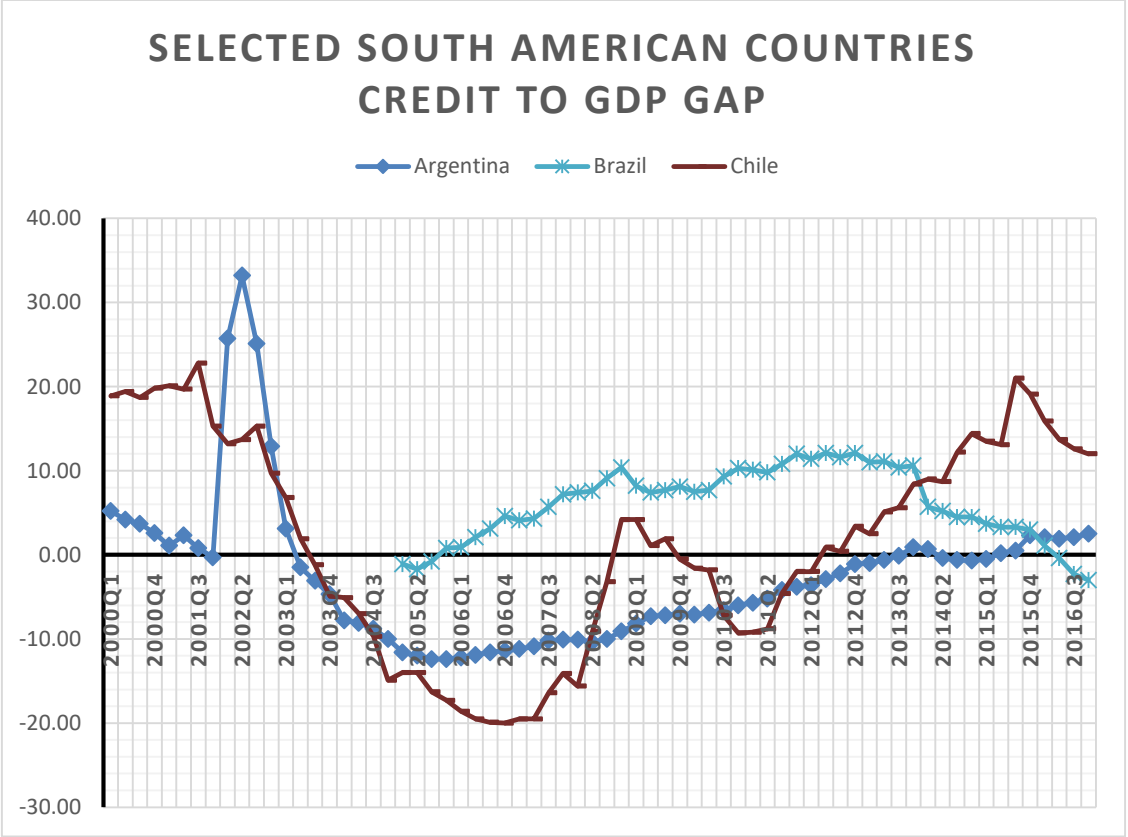
2016Q3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CREDIT TO GDP GAP
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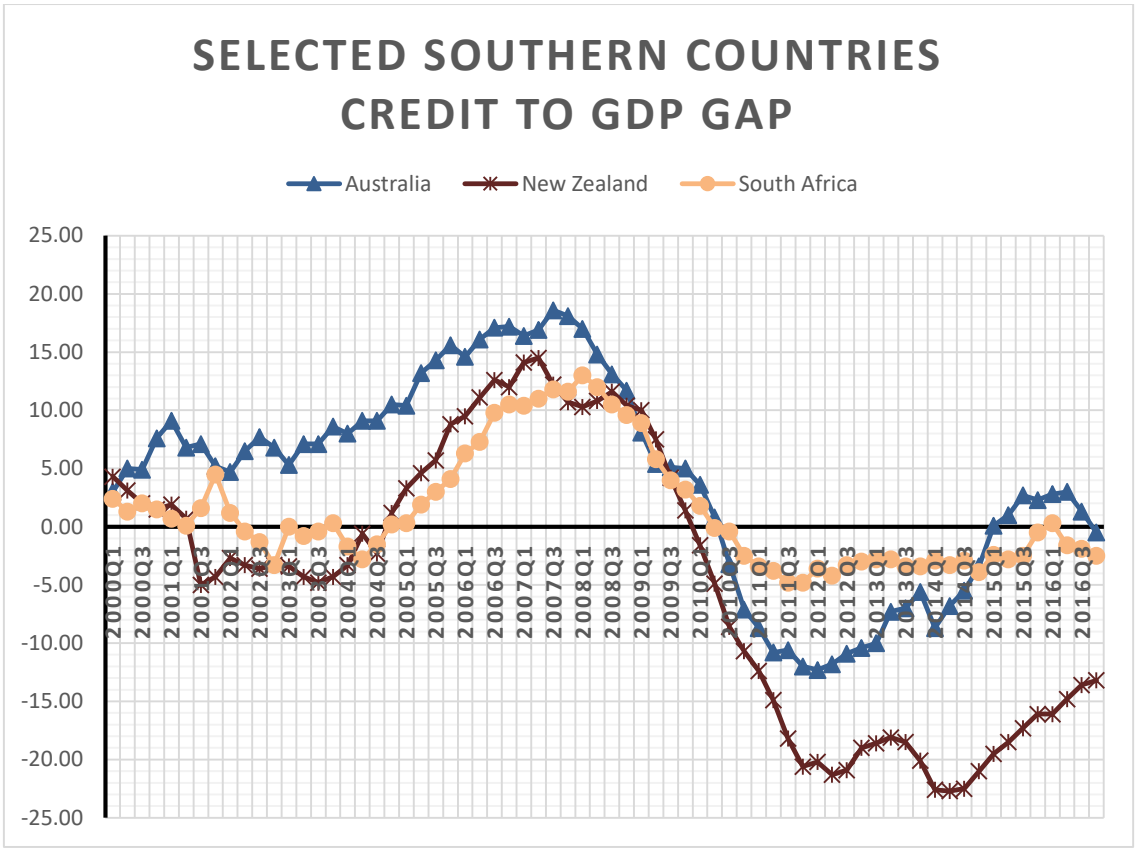
2015Q4
2016Q3


SELECTED SOUTHERN COUNTRIES
CREDIT TO GDP GAP
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New Zealand
South Africa
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15.00
10.00
5.00
0.00
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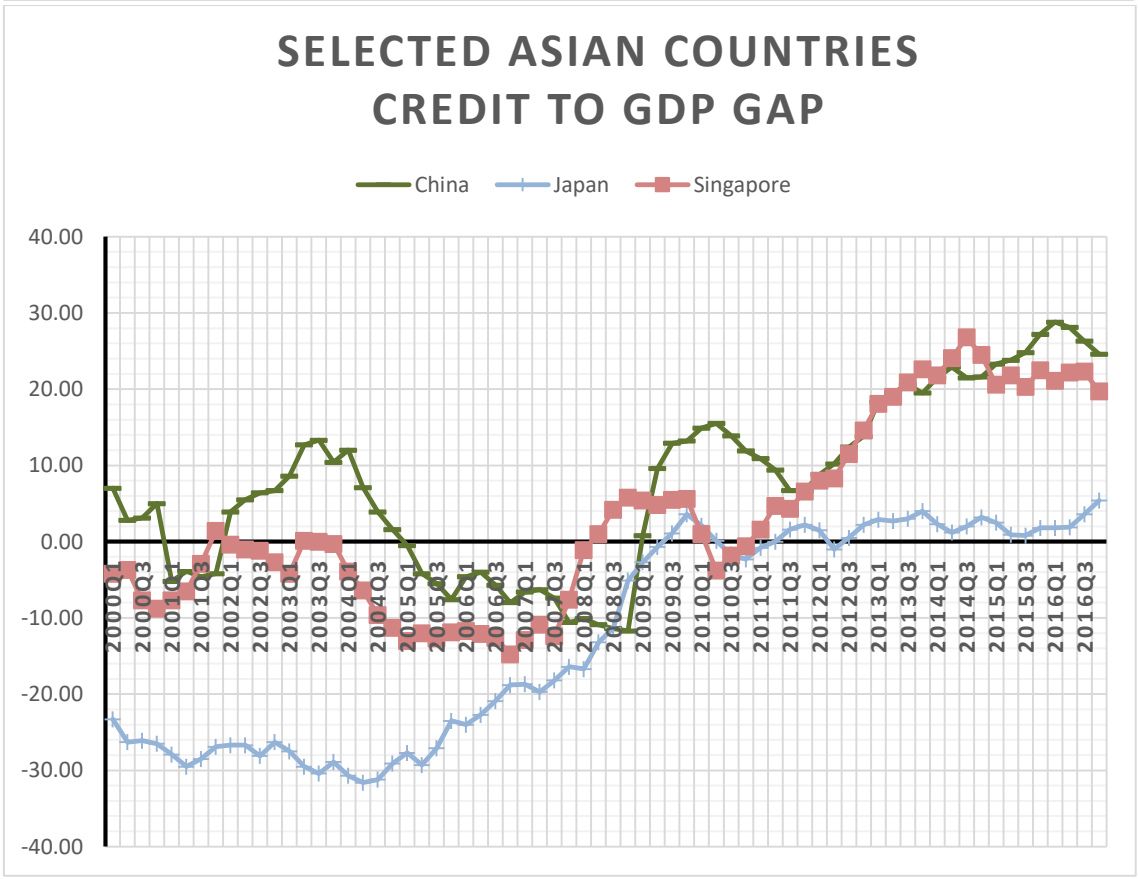
2016Q1
2016Q3


SELECTED ASIAN COUNTRIES
CREDIT TO GDP GAP
China
Japan
Singapore
40.00
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
2000Q1
2000Q3
2001Q1
2001Q3
2002Q1
2002Q3
2003Q1
2003Q3
2004Q1
2004Q3
2005Q1
2005Q3
2006Q1
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2013Q3
2014Q1
2014Q3
2015Q1
2015Q3
2016Q1
2016Q3