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Macroprudential policy and the probability of a banking crisis[☆]

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Abstract

The ultimate purpose of macroprudential policy is to avoid financial instability, such as banking crises, which have a long-lasting and devastating effect on the economy. Although a growing number of studies have examined the effects of macroprudential policy on credit growth, few empirical studies have analyzed its effect on the probability of a banking crisis. Does macroprudential policy actually affect the probability of a banking crisis? Do other macroeconomic policies matter for the effectiveness of macroprudential policy? To answer these questions, this paper empirically investigates the effect of macroprudential policy on the probability of a banking crisis and its relationship with other macroeconomic policies. Specifically, using data on 65 countries from 2000 to 2016, we employ a probit model to analyze the effect of changes in the loan-to-value (LTV) ratio on crisis probability. Our results show that macroprudential policy is effective in changing the probability of a banking crisis via a credit channel and that its effectiveness depends on other macroeconomic policies. Changes in the LTV ratio are found to be effective in influencing the probability of a banking crisis in countries that have inflation targeting frameworks, floating exchange rate regimes, and/or no capital controls. Our results underscore the importance of policy coordination among different government bodies to design an appropriate macroprudential policy, especially in the current context of the Covid-19 crisis.
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1. Introduction

Since the global financial crisis in 2008, macroprudential policy has attracted a considerable amount of attention from policymakers as one of the main macroeconomic policy tools for sustainable economic development. In the current context of a widespread Covid-19 crisis across countries, the macroprudential policy is globally attracting more attention again. The ultimate purpose of macroprudential policy is to avoid financial instability, such as banking crises. A growing number of studies have examined the effect of macroprudential policy on credit growth. For example, Cerutti, Claessens, and Laeven (2017) studied the effects of macroprudential policy on the growth in credit and housing prices, while Lombardi and Siklos (2016) constructed an index representing macroprudential policy to analyze its effect on credit growth. Beirne and Friedrich (2017) analyzed the impacts of macroprudential policy on cross-border bank flows. Richter, Schularick, and Shim (2019) investigated the effects of the loan-to-value (LTV) ratio on economic growth, whereas Basto, Gomes, and Lima (2019) explored the effects of the LTV ratio on private lending, and Morgan, Regis, and Salike (2019) explored its effects on residential mortgage loans. Cronin and McQuinn (2016) found that a reduction in the LTV ratio leads to a greater demand for rental accommodation. Zhang and Zoli (2016) also found that the LTV ratio and housing tax curb the growth in housing prices and credit as well as bank leverage.

In the current global turmoil of the economic crisis caused by the coronavirus, macroprudential policy can be one of the most important macroeconomic policy tools to avoid an economic crisis morphing into a financial crisis. During crisis time, there is a common concern that there could be large capital outflows from emerging markets and developing economies, which could lead to liquidity pressures in domestic or foreign currencies in the corporate and banking sectors. This can create maleficent feedback in particular where exchange rate depreciations are large and currency mismatches common. If the Covid-19 crisis is more protracted, the real estate sectors are also likely to be strongly affected, which could in turn potentially lead to amplification from falling asset prices. In this circumstance, deployment of macroprudential policy or capital flow measures (capital control) is now actively discussed among policymakers.

In this paper, we have two policy-oriented research questions. The first policy question is about the relationship between macroprudential policy and the probability of a banking crisis. Does macroprudential policy affect the probability of a banking crisis? To the best of our knowledge, very few studies have analyzed the effects of macroprudential policy on the probability of a banking crisis. Part of the reason is that it is difficult to collect comparable data on macroprudential policy across countries.[1] This is because macroprudential policies include different types of policies and because they differ across countries. Recent analyses show that macroprudential policies have primarily targeted the housing sector, especially in advanced economies (Akinci & Olmstead-Rumsey, 2018).

This paper attempts to overcome this difficulty by using a novel macroprudential dataset recently published by the International Monetary Fund (IMF) (Alam et al., 2019). This database contains levels of LTV ratios across countries, and its coverage is the broadest to date. Specifically, it covers 134 advanced and developing countries from 2000 to 2016. We use this new database to study the effects of macroprudential policy on the probability of a banking crisis.

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[1] Choi, Kodres, and Lu (2018) analyzed the international spillover effects of macroprudential policy on crisis probability. However, their macroprudential variables are dummy variables for tightening, and for this reason, we cannot derive quantitative policy implications similar to what we study in this paper.

We use a probit model to estimate the effects of LTV policy on the probability of a banking crisis, controlling macroeconomic variables. Following the methodology by Nakatani (2018a), who studied the probability of a currency crisis, we also investigate the relationship between macroprudential policy and other types of macroeconomic policies such as monetary policy frameworks, exchange rate regimes, and capital controls. The empirical method of Nakatani (2018a) is also applicable to the banking crisis because it is based on the theoretical model of Nakatani (2016) that predicts the occurrence not only of currency crises but also of banking crises.

The second policy-oriented research question is about the effectiveness of macroprudential policy in relation to other macroeconomic policies, including monetary policy, exchange rate policy, and capital controls. How does macroprudential policy complement or counteract other macroeconomic policies to influence the probability of a banking crisis? For policymakers, this is worth researching because as we elaborated in the second paragraph of this introduction, there is feedback among macroprudential regulations, monetary policy, exchange rate regimes, and capital account restrictions.

Recently, the complementarity between monetary policy and macroprudential policy has been studied frequently (Agur, 2019; Kim, Kim, & Mehrotra, 2019; Kim & Mehrotra, 2018). It is known that macroprudential easing can usefully complement monetary policy by reducing the effects of the adverse shock on output and credit. Macroprudential relaxation can remove regulatory constraints which impede transmission of monetary policy accommodation, and enhance the ability of monetary policy to support economic activity. When the authorities need to tighten monetary policy to limit the inflationary effects of an exchange rate depreciation, macroprudential relaxation can help reduce potential stresses from monetary tightening. However, this relationship between macroprudential policy and macroeconomic policy has not been studied so far in the context of the probability of a banking crisis. In addition, what about the relationship of macroprudential policy with other policies such as capital controls and exchange rate regimes from the viewpoint of crisis probability? There is little research so far that has explored this topic. Thus, we study the roles of macroprudential policy for preventing the banking crisis in relation to the above-mentioned other related macroeconomic policies.

Our main findings are summarized as follows. In a nutshell, a tighter macroprudential policy is found to lower the probability of a banking crisis. Namely, we found that a tightening of the LTV ratio is statistically significantly associated with a lower probability of a banking crisis through a credit channel, as we envisage from the proper objectives of macroprudential policy. We also find that other macroeconomic policies do indeed matter for the effectiveness of macroprudential policy. Specifically, our findings show that changes in the LTV ratio are effective in influencing the probability of a banking crisis in countries that have inflation targeting regimes, floating exchange rate regimes, and/or no capital controls. For policymakers, these are new important empirical findings regarding the probability of a banking crisis that the extant literature has not obtained before.

Our findings contain meaningful and practical policy implications. For example, our findings indicate that countries that have capital controls and/or fixed exchange regimes may not expect the significant impact of macroprudential policies on crisis prevention compared to countries without capital controls and/or with floating exchange rate regimes. The policymakers and regulatory authorities should be cautious about drawing lessons about macroprudential policy from other countries because the effectiveness of macroprudential policy is very different if other countries have different monetary policy frameworks, exchange rate regimes, or capital account restrictions. Therefore, our main message is that policymakers need to take into account other macroeconomic policies when they design macroprudential policy for reducing the likelihood of banking crises.

In other words, the policy coordination among different government agencies could be essential to conducting macroprudential policy effectively.

This paper is structured as follows. In the following section, we review the relevant literature on banking crises and macroprudential policy. Next, we explain our empirical methodology and data to estimate the effects of macroprudential policy on banking crisis probability. Subsequently, we show our baseline estimation results based on the probit model and robustness checks using different binary choice models. Furthermore, we investigate the relationship between other types of macroeconomic policies and macroprudential policy from the banking crisis probability perspective. Other macroeconomic policies studied in this paper include the monetary policy frameworks, exchange rate regimes, and capital controls. Finally, we conclude our analysis with policy implications.

2. Literature review

In this literature review section, we first survey the findings of related empirical papers about banking crises and macroprudential policy. Following this empirical literature, we review papers that analyze theoretical models of macroprudential policies later.

Banking crises have been one of the major causes of economic disruptions and instability. Babecky et al. (2014) found that compared to other types of financial crises, banking crises are the costliest in terms of the overall output loss. Nakatani (2019) estimated that banking crises reduce output by approximately 6–7% on average. Fernandez, Gonzalez, and Suarez (2016) found that banking stability is relevant for economic stability in terms of the volatility of value added in the economy. They also found that banking stability reduces economic volatility more in industries that have greater external financial dependence when they are located in countries with more developed financial and institutional systems. Teimouri and Dutta (2016) analyzed the dynamic adjustment of investment- and bank credit-to-GDP ratios after banking crises, and they found that deleveraging is costly to the economy.

To avoid disruptive banking crises, macroprudential policies have been deployed in many countries. The empirical literature has studied the effectiveness of macroprudential policy on financial markets. Cihak, Demirguc-Kunt, Martinez Peria, and Mohseni-Cheraghlou (2013) documented that crisis countries exhibited lower actual capital ratios, were less strict in the regulatory treatment of bad loans, were less able to demand that banks adjust their equity, provisions or compensation schemes, and had weaker incentives for private agents to monitor banks.

Another area of research has focused on how to predict banking crises. Davis and Karim (2008) constructed an early warning system to predict banking crises. According to their findings, credit and real GDP growth are important for predicting banking crises. Spelta, Pecora, and Rovira Kaltwasser (2019) used an early warning signal of the financial crisis identifying the systemically important banks. Buetel, List, and von Schweinitz (2019) used machine learning to predict banking crises. By contrast, Lee, Posenau, and Stebunovs (2020) built an aggregate vulnerability index to predict banking crises.

Related areas of research have examined the intersections of macroprudential policy and other types of policies such as monetary policy and capital controls. For example, Korinek and Sandri (2016) found that both capital controls and macroprudential policy lead to financial stability by reducing net capital inflows as well as the amount and riskiness of financial liabilities. Bruno, Shim, and Shin (2017) found that macroprudential policy is more effective if it is complemented by monetary policy. Kim and Mehrotra (2018) found similar effects of monetary and macroprudential policies on credit growth, implying a complementary use of the two policies at normal times as

well as a challenge for policymakers during times when buoyant credit growth coincides with low inflation. Thus, in our work, we also analyze the relationship between macroprudential policy and other types of policies, including capital controls, monetary policy, and exchange rate regimes.

Recently, a growing amount of literature on macroprudential policy is developing theoretical models to study how macroprudential regulations can reduce the probability of a financial crisis. Ma (2020) found that macroprudential policy reduces the probability of crises and smooth consumption at the expense of welfare loss caused by marginally lower economic growth. Flemming, L'Huillier, and Piguillem (2019) found that when the cumulative amount of borrowing is high enough in boom times, it is optimal to use tax debt to make agents internalize the systemic externality of their decisions.

Theoretical models to study the relationship between macroprudential policy and other macroeconomic policies are also becoming more numerous. Agur (2019) showed that leaning against wind-type monetary policy can backfire and lower the financial stability due to multiple equilibria, implying an importance of coordination ability of monetary and prudential authorities. Ghilardi and Peiris (2016) used a DSGE model and found that macroprudential policy can usefully complement monetary policy. Alpanda, Cateau, and Meh (2019) found that LTV regulations are the most effective and least costly policy tool to deal with household imbalances, followed by bank capital regulations and monetary policy, respectively. Mendoza and Rojas (2019) showed that the optimal policy is to tax domestic credit or capital inflows, and therefore capital controls as a separate instrument are not justified. By contrast, Schmitt-Grohé and Uribe (2017) found that the optimal macroprudential capital control policy should be tightened when the debt-to-output ratio becomes high after the fall in the interest rate, i.e. an accommodative monetary policy.

3. Methodology and data

We mainly use a probit model to estimate the probability of a banking crisis. The regression equation to determine the relationship between macroprudential policy and the probability of a banking crisis is defined as follows:

$$Pr(y_{i,t} = 1|x_{i,t}) = \Phi(x'_{i,t}\beta) + \varepsilon_{i,t},$$

where Pr is probability; the subscript i denotes the country, while t denotes the year; y is a dummy variable that takes the value of one if a banking crisis occurs and zero if not; x is the set of independent variables; Φ is the normal cumulative distribution; β is a vector of the maximum likelihood estimate; and ε is an error term. The dates of banking crises are determined by the method developed by Laeven and Valencia (2020). Following the identification method common in the empirical literature, we eliminate all crisis state periods except for the first period (start of the crisis). The macroprudential data are taken from Alam et al. (2019). We use the LTV ratio as our macroprudential policy variable because it is the only macroprudential policy variable that has quantitative information. We use changes in the LTV ratio rather than its level to capture the effects of macroprudential policy because the levels of the LTV ratio might be different across countries, reflecting institutional or financial market development. Theoretically, changes in the LTV ratio affect crisis probability by curbing credit to the economy, especially mortgage lending. Therefore, we multiply changes in the LTV ratio by the credit variable (credit-to-GDP ratio) to capture the precise transmission channel of macroprudential policy. Other explanatory variables are taken from the standard literature (Cerutti et al., 2017; Claessens, Ghosh, & Mihet, 2013). Our control variables include the GDP growth rate, income per capita (GDP per capita), inflation

Table 1
Sample of countries.

Argentina	Denmark	Italy	New Zealand	Slovenia
Australia	Estonia	Japan	Nigeria	South Africa
Austria	Finland	Korea	Norway	Spain
Belgium	France	Kuwait	Peru	Sweden
Brazil	Germany	Latvia	Philippines	Switzerland
Bulgaria	Greece	Lebanon	Poland	Taiwan
Canada	Hong Kong	Lithuania	Portugal	Thailand
Chile	Hungary	Luxembourg	Romania	Turkey
China	Iceland	Malaysia	Russia	Ukraine
Colombia	India	Malta	Saudi Arabia	United Arab Emirates
Croatia	Indonesia	Mexico	Serbia	United Kingdom
Cyprus	Ireland	Mongolia	Singapore	United States
Czech Republic	Israel	Netherlands	Slovak Republic	Uruguay

(consumer price index), current account as a percentage of GDP, and changes in monetary policy (real interest rate).

One issue that might arise when we analyze the banking crisis is a contagion. One could think that we may include a global financial crisis dummy or the VIX index to capture this effect. However, this does not work in our binary choice models because it is well-known that the estimated coefficients will be severely biased when we include time fixed effects (Cruz-Gonzalez, Fernández-Val, & Weidner, 2017). Since any variable that captures contagion in the global financial markets has a time-varying and the same value across countries by nature, we cannot proceed in this direction.

Another possible concern is an omitted variable bias. Although this can occur in any econometric specifications, this bias is generally slight in probit and logit models. For the probit model, Wooldridge (2002) has proved that this bias does not carry over to the effect of the remaining regressors on the outcome. Cramer (2007) confirmed that this also holds for the logit model. Marginal effects do not suffer from the attenuation bias because they are unaffected by omitted covariates. Therefore, in our analyses, it is fair to say that the potential omitted variables do not affect both statistical significance and the size of our estimated regression coefficients.

All data are taken from the IMF's World Economic Outlook database and International Financial Statistics as well as the World Bank's World Development Indicators. The data sample in this study covers the 65 advanced and developing countries from 2000 to 2016 listed in Table 1. The data frequency is annual. The detailed construction and sources of the data are presented in Table 2. The summary statistics for each variable used in this analysis are shown in Table 3.

4. Baseline results

In this section, we discuss our baseline estimation results based on the probit model. Column (1) of Table 4 shows the results of the univariate probit model estimating the impact of LTV regulation on the probability of a banking crisis. The results show that the effect of the estimated coefficient of the LTV variable on the probability of a banking crisis is positive and statistically significant at the one percent level (the marginal effects are shown in the brackets in all tables). This means that a higher LTV ratio is associated with a higher banking crisis probability. This is an intuitive result because a higher LTV ratio is deemed to be a loosening of macroprudential policy, which could lead to financial instability. In this paper, this result is a new finding because

Table 2
Data description.

Variable	Definition	Source
Banking crisis	Crisis = 1; no crisis = 0	Laeven and Valencia (2020)
LTV	Yearly average LTV	Alam et al. (2019)
GDP growth	Real GDP growth rate (%)	IMF's World Economic Outlook
Income per capita	GDP per capita, current price in thousand U.S. dollars	IMF's World Economic Outlook
Inflation	Yearly average consumer price inflation rate (%)	IMF's World Economic Outlook
Current account	Current account balance as a percentage of GDP	IMF's World Economic Outlook
Credit	Domestic credit provided by financial sector divided by GDP	World Bank's World Development Indicators
Monetary policy	Real interest rate (%)	World Bank's World Development Indicators
Inflation targeting	Inflation targeting = 1; no inflation targeting = 0	IMF's Annual Report on Exchange Arrangements and Exchange Restrictions
Exchange rate arrangement	Index	Ilzetzki et al. (2019)
Float	Float = 1; Peg = 0	IMF's Annual Report on Exchange Arrangements and Exchange Restrictions
Capital control	Control = 1; no control = 0	IMF's Annual Report on Exchange Arrangements and Exchange Restrictions

Table 3
Summary statistics.

Variable	Mean	Std. dev.	Min	Max
Banking crisis	0.026	0.160	0.000	1.000
LTV	92.479	13.868	35.000	110.000
GDP growth	3.274	3.724	−15.136	25.007
Income per capita	23.450	20.949	0.463	120.857
Inflation	4.012	5.853	−3.749	80.744
Current account	0.683	8.301	−27.386	45.462
Credit	1.087	0.675	0.230	3.475
Monetary policy	5.343	8.375	−26.629	93.915
Inflation targeting	0.494	0.500	0.000	1.000
Exchange rate arrangement	6.676	4.558	1.000	14.000
Float	0.565	0.496	0.000	1.000
Capital control	0.489	0.500	0.000	1.000

few studies have analyzed the effect of macroprudential policy on crisis probability, as discussed in the introduction and literature review.

Next, we show the results of our baseline estimation controlling macroeconomic and monetary policy variables that can affect the probability of a banking crisis. The estimated baseline results are presented in column (2) of Table 4, and the goodness of fit measures for our baseline probit model is shown in Fig. 1. The figure shows that the area under the receiver operating characteristic (ROC) curve is 0.887, indicating that the empirical specification of our baseline probit estimation provides excellent discrimination. Note that this area under the ROC curve (AUROC) is higher than those in the literature (e.g., 0.717 in the logit model by Schularick and Taylor (2012)). Put

Table 4
Baseline results.

Estimation method	(1) Probit	(2) Probit
ΔLTV × Credit	0.0445*** (0.0105) [0.0177]	0.0552*** (0.0203) [0.0040]
GDP growth		−0.1817*** (0.0220) [−0.0133]
Income per capita		−0.0389*** (0.0045) [−0.0029]
Inflation		−0.0928*** (0.0160) [−0.0068]
Current account		−0.0108 (0.0129) [−0.0008]
ΔMonetary policy		−0.0233 (0.0155) [−0.0017]
Sample	All	All
Number of observations	976	661

Note: Standard errors in parentheses. Marginal effects in brackets.
* Significant at the 10% level.
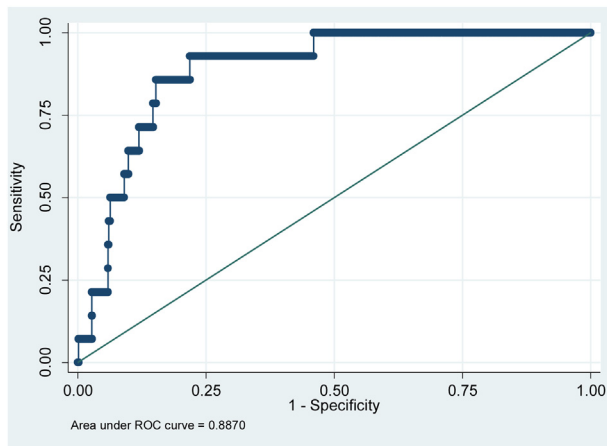** Significant at the 5% level.
*** Significant at the 1% level.

Fig. 1. Area under the ROC curve.

differently, our AUROC in Fig. 1 demonstrates that our probit model is very effective in predicting banking crises.

We interpret our baseline results as follows. The estimated coefficient on the LTV regressor is similar to the previous result in column (1) of the univariate case. Specifically, the sign and

statistical significance of the coefficient on the LTV variable in column (2) are the same as those in column (1), while its size is slightly larger. Our positive estimated coefficient on the LTV variable once again shows that a tightening of the LTV ratio is associated with a lower probability of a banking crisis through the credit channel. This main result is consistent with theory, and this is the first study to estimate this effect on banking crisis probability.

For information purposes, the results of the control variables are summarized below. First, the coefficient on real GDP growth is negative and statistically significant at the one percent level. This means that higher economic growth is associated with a lower probability of a banking crisis. This is also consistent with economic theory because if the economy grows faster, borrowers can make higher earnings, and hence, it is easy for them to repay debt. In this situation, it is less likely that commercial banks will face defaults by borrowers, and therefore, higher economic growth will lead to a lower probability of a banking crisis.

Second, the coefficient on GDP per capita is negative and statistically significant at the one percent level. This variable is assumed to capture the degree of economic development. Thus, our results indicate that if the economy approaches a higher per capita GDP, it is less likely to face a banking crisis.

The third control variable in column (2) is inflation. The estimated coefficient on inflation is statistically significant at the one percent level and negative. This is also consistent with economic theory because we expect existing borrowers to profit from an increase in inflation, as their relative nominal debt burdens decline.

Moreover, although it is not statistically significant, the sign of our estimated coefficient on current account is consistent with the prediction of economic theory. A positive current account balance means that savings by domestic residents are higher than their borrowings from abroad. If the economy has enough savings, domestic borrowers will be less likely to default. The negative coefficient on the current account-to-GDP ratio in column (2) confirms this prediction but without statistical significance.

Finally, our empirical results show that the monetary policy variable is not statistically significant but has the expected sign. The negative coefficient on the monetary policy variable indicates that monetary tightening is associated with a lower probability of a banking crisis. This result makes sense, as a loose monetary policy can lead to a credit bubble, which often results in banking crises.

5. Robustness checks

As the next step, in robustness checks, we conduct analyses of our baseline results using alternative binary choice models. We use logit and tobit models for this purpose, and the results are presented in columns (3) and (4) of Table 5, respectively.

In sum, we find that the sign of each variable in the logit and tobit models is the same as that in the baseline probit model. The LTV variable is now statistically significant at the five percent level, showing that a loosening of the LTV ratio is associated with a higher probability of banking crises. We also find that the estimated coefficients on the LTV variables are larger in the logit and tobit models than in the baseline probit model, while their marginal effects, shown in brackets, are smaller than the those of the baseline results. The statistical significances of the other independent variables in Table 5 are the same as those of the baseline results in Table 4. Thus, it is fair for us to conclude that our baseline results are robust to different binary choice models.

Table 5
Robustness checks.

Estimation method	(3) Logit	(4) Tobit
ΔLTV × Credit	0.1110**	0.1393**
	(0.0442)	(0.0620)
	[0.0000]	[0.0000]
GDP growth	−0.3302***	−0.4520***
	(0.0467)	(0.1265)
	[−0.0001]	[−0.0000]
Income per capita	−0.00852***	−0.0000***
	(0.0128)	(0.0000)
	[−0.0000]	[−0.0000]
Inflation	−0.2258***	−0.2356***
	(0.0430)	(0.0753)
	[−0.0000]	[−0.0000]
Current account	−0.0125	−0.0264
	(0.0268)	(0.0329)
	[−0.0000]	[−0.0000]
ΔMonetary policy	−0.0498	−0.0603
	(0.0327)	(0.0415)
	[−0.0000]	[−0.0000]
Sample	All	All
Number of observations	661	661

Note: Standard errors in parentheses. Marginal effects in brackets.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

For the remainder of the analyses, we continue to use the probit model for two reasons. First, we are interested in analyzing the probability of a banking crisis, and to that end, the use of a probit model is the most straightforward method. Second, according to our results, the AUROC is found to be higher for the probit model (0.887) than for the logit model (0.878).

6. Monetary policy framework

Next, we control and investigate the relationship between the monetary policy framework and macroprudential policy in Table 6. Since in some countries the central bank or monetary authority conducts both macroprudential policy and monetary policy together, it is necessary to include both policy variables in the estimation, which we already did in our baseline estimation, to avoid omitted variable bias. However, including the monetary policy variable as a control variable may not be enough to address all the effects from the monetary policy framework, as some countries are strongly committed to achieving price stability in the form of inflation targeting, which cannot be captured by the interest rate variable itself.

In column (5) of Table 6, we included a dummy variable for inflation targeting countries, based on the classifications by the IMF's Annual Report on Exchange Arrangements and Exchange Restrictions. Our results in column (5) show results that are quite similar to the baseline results presented in column (2) of Table 4. Specifically, the estimated coefficients have exactly the same statistical significance and are not particularly different in terms of their sizes, including the coefficient on the LTV variable, in which we are interested. Thus, the estimated effect of LTV

Table 6
Relationship with the monetary policy framework.

Estimation method	(5) Probit	(6) Probit	(7) Probit
ΔLTV × Credit	0.0590***	0.0442***	0.0428
	(0.0204)	(0.0212)	(0.0733)
	[0.0035]	[0.0008]	[0.0038]
GDP growth	−0.1613***	−0.2024***	−0.1550***
	(0.0225)	(0.0401)	(0.0258)
	[−0.0096]	[−0.0036]	[−0.0136]
Income per capita	−0.0269***	−0.0203***	−0.0046***
	(0.0046)	(0.0063)	(0.0068)
	[−0.0016]	[−0.0004]	[−0.0040]
Inflation	−0.0687***	−0.3060***	−0.0621***
	(0.0154)	(0.0563)	(0.0157)
	[−0.0041]	[−0.0055]	[−0.0055]
Current account	−0.0181	−0.0949***	−0.0043
	(0.0120)	(0.0360)	(0.0141)
	[−0.0011]	[−0.0017]	[−0.0004]
ΔMonetary policy	−0.0199	0.0022	−0.0196
	(0.0148)	(0.0444)	(0.0163)
	[−0.0012]	[0.0000]	[−0.0017]
Inflation targeting	−0.9950***		
	(0.1865)		
	[−0.0594]		
Sample	All	Inflation targeting	No inflation targeting
Number of observations	661	341	320

Note: Standard errors in parentheses. Marginal effects in brackets.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

policy on banking crisis probability does not change from the baseline results when we control inflation targeting framework with a dummy variable. We also find that the coefficient on the dummy variable for inflation targeting countries has a negative sign and is statistically significant at the one percent level, implying that inflation targeting countries tend to experience a lower probability of banking crises.

In columns (6) and (7), we compare the results by splitting the sample countries into inflation targeting countries and noninflation targeting countries. We found two interesting results. First, we found that the monetary policy framework does indeed matter for the effectiveness of macroprudential policy. The columns show that the effect of macroprudential policy on the probability of banking crises is effective only in inflation targeting countries. This is one of the most interesting and important new findings of this paper. A possible interpretation of this result is as follows. Price bubbles, including housing price bubbles, tend to be relatively well controlled by the monetary policy in inflation targeting countries. In such a situation, macroprudential policy can become more effective in attaining banking stability by affecting credit volume. Second, the current account variable is statistically significant only for inflation targeting countries. This may be because in countries without inflation targeting regimes, external shocks can be adjusted by price fluctuations (presumably via adjustment in the exchange rate).

Table 7
Relationship with exchange rate regimes.

Estimation method	(8) Probit	(9) Probit	(10) Probit	(11) Probit
ΔLTV $\times$ Credit	0.0571***	0.0626***	0.0737	0.0473***
	(0.0205)	(0.0203)	(0.1411)	(0.0215)
	[0.0021]	[0.0032]	[0.0080]	[0.0027]
GDP growth	−0.1226***	−0.1293***	−0.1487***	−0.1884***
	(0.0247)	(0.0236)	(0.0364)	(0.0289)
	[−0.0046]	[−0.0066]	[−0.0162]	[−0.0109]
Income per capita	−0.0196***	−0.0280***	−0.0430***	−0.0381***
	(0.0048)	(0.0046)	(0.0071)	(0.0058)
	[−0.0007]	[−0.0014]	[−0.0047]	[−0.0022]
Inflation	−0.0063	−0.0277	−0.0476	−0.1179***
	(0.0146)	(0.0169)	(0.0297)	(0.0222)
	[−0.0002]	[−0.0014]	[−0.0052]	[−0.0068]
Current account	−0.0094	−0.0071	0.0108	−0.0456**
	(0.0124)	(0.0117)	(0.0152)	(0.0228)
	[−0.0004]	[−0.0004]	[0.0012]	[−0.0026]
ΔMonetary policy	−0.0129	−0.0142	−0.0160	−0.0238
	(0.0165)	(0.0155)	(0.0210)	(0.0225)
	[−0.0005]	[−0.0007]	[−0.0017]	[−0.0014]
Exchange rate arrangement	−0.1616***			
	(0.0218)			
	[−0.0061]			
Float		−1.2085***		
		(0.1875)		
		[−0.0614]		
Sample	All	All	Peg	Float
Number of observations	661	661	188	473

Note: Standard errors in parentheses. Marginal effects in brackets.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

7. Exchange rate regimes

Furthermore, we study the effects of macroprudential policy on banking crisis probability in relation to exchange rate regimes. In doing so, we take three approaches. In the first approach, we use an index that captures the flexibility of exchange rate regimes. In the second approach, we use a dummy variable for floating exchange rate regimes. In the third approach, we split our sample countries into groups of different exchange rate regimes when we implement regressions.

Our results on the effects of exchange rate regimes are shown in columns (8)–(11) of Table 7. In this table, column (8) is the regression results based on the inclusion of the variable indicating exchange rate flexibility constructed by Ilzetzki, Reinhart, and Rogoff (2019). Column (9) shows the estimation results including the dummy variable for floating exchange rate regimes. We follow the method by Nakatani (2017b, 2018a) to construct this variable. Finally, in Table 7, the probit estimation results for the countries with pegged exchange rate regimes are presented in column (10), while those for floating exchange rate regimes are presented in column (11).

The estimated coefficient on the variable representing exchange rate arrangement is negative and statistically significant at the one percent level in column (8). Recalling that a higher value of

this variable means a more flexible exchange rate regime, our results indicate that countries with more flexible exchange rate regimes tend to experience a lower probability of banking crises. This might be a reflection of the role of the exchange rate as a shock absorber. For example, in the face of any financial or real shock, the exchange rate can adjust to absorb shocks to achieve stability in the market if the currency is floating (Nakatani, 2018b). The estimated coefficient on the LTV variable in column (8) is very similar to the baseline result in column (2) of Table 4, showing the robustness of our empirical results for the effectiveness of macroprudential policy.

Supporting this finding, column (9) shows that the estimated coefficient on the dummy variable for floating exchange rate regimes is also negative and statistically significant at the one percent level. This outcome once again shows that countries with more flexible exchange rate regimes experience lower crisis probabilities. The coefficient on the LTV variable in column (9) of Table 7 is also highly statistically significant, and its magnitude and sign are almost the same as the results presented thus far, indicating the robustness of our main finding that a tighter macroprudential policy is effective in lowering the probability of a banking crisis.

The abovementioned findings in columns (8) and (9) are supported by the estimation results based on subsamples (pegged/floating regimes) presented in columns (10) and (11) of the same table. Column (10) shows that the LTV ratio is no longer statistically significant for countries with pegged exchange rate regimes, while column (11) shows that it is positive and statistically significant at the one percent level. These results confirm our finding that macroprudential policy is effective only for countries with more flexible exchange rate regimes. This finding is consistent with the results by Kim et al. (2019) who found that the negative effects of macroprudential policy shock on credit and GDP are more significant in countries with flexible exchange rate regimes. It is also consistent with the latest empirical results by Poghosyan (2020) who found that the effects of lending restriction measures on house prices and credit are stronger in EU countries outside of the euro area, although he only studied European countries. We will discuss further policy implications in the conclusion section.

8. Capital controls

Finally, we empirically delve into the relationship between the effectiveness of macroprudential policy and capital controls. Our analyses of the relationship between macroprudential policy and capital controls are shown in columns (12)–(14) of Table 8. Column (12) presents the results including a dummy variable for capital controls. We use the definition of capital controls by Glick, Guo, and Hutchison (2006) and Nakatani (2017b) to construct capital control dummies. Column (13) shows the regression results for countries with capital controls, while column (14) shows the regression results for countries without capital controls.

Column (12) shows that the capital control dummy is highly statistically significant and has a negative sign, implying a lower banking crisis probability for countries with capital controls. The estimated coefficient on the LTV variable in this column is positive and statistically significant at the ten percent level with its size smaller than the baseline. As elaborated in the next paragraph, the results presented in columns (13) and (14) explain this outcome well.

We make a very interesting comparison between countries with and without capital controls, presented in columns (13) and (14), respectively. The estimated coefficient on the LTV variable is positive for both groups, but it is statistically significant only for countries without capital controls. That is, there is a stark contrast in the effectiveness of macroprudential policy between countries with and without capital controls. Namely, macroprudential policy is effective in changing the probability of a banking crisis in countries without capital controls, while it is not so in countries

Table 8
Relationship with capital controls.

Estimation method	(12) Probit	(13) Probit	(14) Probit
ΔLTV × Credit	0.0039*	0.0268	0.0718***
	(0.0213)	(0.0365)	(0.0228)
	[0.0024]	[0.0027]	[0.0040]
GDP growth	−0.1591***	−0.1974***	−0.1655***
	(0.0240)	(0.0268)	(0.0432)
	[−0.0099]	[−0.0198]	[−0.0093]
Income per capita	−0.0340***	−0.0266***	−0.0487***
	(0.0043)	(0.0060)	(0.0074)
	[−0.0021]	[−0.0027]	[−0.0027]
Inflation	−0.0496***	−0.0997***	−0.0908**
	(0.0172)	(0.0179)	(0.0394)
	[−0.0031]	[−0.0100]	[−0.0051]
Current account	−0.0221	0.0032	−0.0197
	(0.0142)	(0.0172)	(0.0241)
	[−0.0014]	[0.0003]	[−0.0011]
ΔMonetary policy	−0.0168	−0.0581**	0.0053
	(0.0162)	(0.0236)	(0.0237)
	[−0.0010]	[−0.0058]	[0.0003]
Capital control	−0.8997***		
	(0.1846)		
	[−0.0559]		
Sample	All	Capital control	No capital control
Number of observations	656	334	322

Note: Standard errors in parentheses. Marginal effects in brackets.
* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

with capital controls. This finding that macroprudential policy is effective only for countries without capital controls has never been obtained in the extant empirical literature, although this confirms the prediction of the theoretical model by Mendoza and Rojas (2019) who showed that the optimal policy is not to impose capital controls separately from taxing domestic credit. Our finding has very important implications for policymakers, as we discuss further in the next section.

9. Conclusion and policy implications

We analyzed the effects of macroprudential policy on the probability of a banking crisis using an annual country panel dataset composed of 65 countries from 2000 to 2016. Among policymakers, there has been vigorous debate on this topic, particularly since the recent global financial crisis as well as the ongoing Covid-19 crisis. Although the major purpose of macroprudential policy is to avoid financial instability, such as banking crises, few studies have analyzed its effect on the probability of banking crises. This paper filled this gap by utilizing a new macroprudential dataset that contains LTV ratios that are comparable across countries and that has the broadest coverage to date. Our main research questions are "Does macroprudential policy affect the probability of a banking crisis?" and "Do other macroeconomic policies matter for the effectiveness of macroprudential policy?"

We showed four main findings that provide meaningful policy implications for central bankers and financial regulatory authorities. First, macroprudential policy is found to be effective in avoiding banking crises by curbing credit growth. In other words, we found that a tightening of the LTV ratio is statistically significantly associated with a lower probability of banking crises, and vice versa, through a credit channel. This finding is consistent with the objectives of macroprudential policy, as it aims to attenuate credit booms and to avoid the instability of banking systems. Second, we found that the monetary policy framework matters for the effectiveness of macroprudential policy. Specifically, our results indicate that macroprudential policy is effective only in inflation targeting countries. Our interpretation is that price bubbles, including housing price bubbles, tend to be relatively well controlled by monetary policy in inflation targeting countries. In such a situation, macroprudential policy can become more effective in attaining banking stability by affecting credit volume. Third, exchange rate regimes also matter for the effectiveness of macroprudential policy. More specifically, macroprudential policy is more effective in countries with more flexible exchange rate regimes. This might reflect the fact that the floating exchange rate regimes are more vulnerable to shocks that trigger financial crises, as found by Nakatani (2018a), and there is more room for macroprudential policy to deal with these shocks (e.g. risk premium shock). Fourth, macroprudential policy is effective in avoiding banking crises in countries without capital controls but not in countries with capital controls. This is in line with the theoretical model by Mendoza and Rojas (2019). All four of these findings are new and very important for policymakers, including monetary and financial regulatory authorities.

What are the policy implications that can be drawn from this research? Our analyses indicate that the effectiveness of macroprudential policy depends on other macroeconomic policies. We found that macroprudential policy is more effective in countries with an inflation targeting framework or floating exchange rate regimes or in countries without capital controls. Thus, policymakers need to consider the combination of multiple different macroeconomic policies when formulating macroprudential policies. This implies that conversation and communication between different authorities are crucial for designing macroprudential policy. This is because financial regulatory authorities (or central banks) are usually in charge of macroprudential policy, while the monetary policy framework is the responsibility of monetary authorities, exchange rate policies can be covered by the ministry of finance, and capital controls are managed by the ministry of economy, for example. In such a situation, policy dialogues should be carried out across different government bodies for policy coordination to achieve financial stability. They need to discuss what the primary objective of macroprudential policy is and how other types of macroeconomic policies can interact with it.

This message is particularly important in the context of the ongoing policymakers' efforts to combat the Covid-19 crisis for good and clear public policy communication. To agree on policies in the thick of the crisis, the government can set up a task force of senior officials gathered in a crisis management committee, which includes all governmental agencies in charge of managing the financial crisis (i.e., the monetary authority, ministry of finance, supervisory agencies, ministry of economy, etc.). They should have primary responsibility for agreeing the coordinated policy lines and communication strategy. Although it is out of scope for this paper, fiscal policy can also play a role in supporting firms, banks and households in providing liquidity through various packages and reducing the likelihood of their defaults in the short term. A combination of macroprudential policy with fiscal policy would carry more responsibility especially if the interest rate is close to zero and there is limited scope for the use of monetary policy (Gustafsson, Stockhammar, & Österholm, 2016).

One of the main policy messages of our analysis is that policymakers and financial regulatory authorities should be very cautious about learning lessons from other countries' experiences. This is because the effectiveness of macroprudential policy differs significantly across countries that have different monetary policy frameworks, exchange rate policies, and capital flow measures. In particular, our findings indicate that the LTV policy is not effective in changing the probability of a banking crisis in countries that have capital controls, pegged exchange rate regimes, and/or no inflation targeting framework. In these countries, policymakers need to find other types of macroprudential or macroeconomic policies that can effectively prevent a banking crisis.

Our empirical results also contain practically meaningful implications for policymaking in the area of the housing sector. For example, the relationship between capital controls and macroprudential policy could be very important, especially in real estate sectors, where foreign investors can play a major role in creating housing booms, which in turn can lead to a banking crisis. In recent years, some countries that have experienced housing booms due to foreign buyers have introduced a ban on the purchase of residential property by foreign residents. In this case, such countries used capital controls as a policy tool to stabilize their housing markets. The results of our research indicate that for countries without capital controls, a certain macroprudential policy such as LTV regulations may be effective in attaining banking stability by containing credit growth.

Based on the new findings in this article, let us conclude our paper by proposing a future research topic. Although a growing number of papers are now studying the interactions of macroprudential policy with monetary policy and capital controls, the theoretical literature analyzing the direct link between macroprudential policy and exchange rate policy is scant (Lubis, Alexiou, & Nellis, 2019). Future research should further investigate the complementary relationship between macroprudential policy and exchange rate policy. For example, exchange rate flexibility can influence the economic bubble through domestic asset and import price inflation as well as balance sheets of firms, households, and commercial banks. Recently, Nakatani (2017a) proved that an optimal monetary policy response to prevent currency crises depends on structural vulnerability characterized by the relative size of foreign currency denominated debt and exports because depreciation of exchange rates could either boost or hinder economic growth. In this sense, the optimal exchange rate policy may differ across economies depending on their economic structure, and complementary roles of macroprudential policy could also differ. The types of macroprudential policy (e.g. borrower-based; capital-based; liquidity-based) could also matter in this regard. The proposed potential future research question is "what is the mechanism by which macroprudential policy interacts with exchange rate flexibility?" To the best of our knowledge, there is no theoretical model that has been used to investigate this topic to date.

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