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ORIGINAL RESEARCH

# Bank regulation and systemic risk: cross country evidence

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**Abstract**
Using data for banks from 65 countries for the period 2001–2013, we investigate the impact of bank regulation and supervision on individual banks' systemic risk. Our cross-country empirical findings show that bank activity restriction, initial capital stringency and prompt corrective action are all positively related to systemic risk, measured by *Marginal Expected Shortfall*. We use the staggered timing of the implementation of Basel II regulation across countries as an exogenous event and use latitude for instrumental variable analysis to alleviate the endogeneity concern. Our results also hold for various robustness tests. We further find that the level of equity banks can alleviate such effect, while bank size is likely to enhance the effect, supporting our conjecture that the impact of bank regulation and supervision on systemic risk is through bank's capital shortfall. Our results do not argue against bank regulation, but rather focus on the design and implementation of regulation.

**Keywords** Bank regulation and supervision · Systemic risk · Activity restrictions · Capital shortfall

**JEL Classification** G21 · G28 · G01

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## 1 Introduction

The inappropriate regulations and ineffective monitoring and supervision by official agencies have been regarded as a critical cause of the global financial crisis of 2007–2009 (Goodhart 2008; Schwarcz 2008; Acharya 2009; Laeven and Levine 2009). For example, Acharya (2009) argue that Basel regulations require banks to hold a certain ratio of capital to reduce individual banks' liquidity risk but overlook the correlated risk banks take which can lead to joint failures. Despite the increasing calls for renewed focus on systemic stability and macro-prudential regulation (e.g. Acharya et al. 2012), our understanding of how bank regulation and supervision affect systemic stability tends to be very limited (Arnold et al. 2012; Barth et al. 2013b).

A few studies have examined the impact of bank regulation and/or supervision on systemic stability (e.g., Anginer et al. 2018; Barth et al. 2004; Demirgüç-Kunt and Detragiache 2002, 2011). Based on bank regulation data from the World Bank Survey, Barth et al. (2004) find that banks operating in countries with higher regulatory restriction are more likely to experience a banking crisis. Demirgüç-Kunt and Detragiache (2011), on the other hand, fail to find relationship between the adherence to the Basel core principles and systemic risk measured by a system-wide Z-score. However, there is a lack of evidence on how the current bank regulatory system affects individual banks' exposure to the systemic risk. Our paper thus attempts to fill this gap in the literature.

Bank regulation comprises two main aspects, capital regulation and supervision, and restrictions on non-banking activities. In this paper we argue that both aspects of bank regulation may be positively related to bank's exposure to systemic risk. First, Acharya et al. (2012) and Brownlees and Engle (2017) define a bank's level of systemic risk as its capital shortfall, where a more undercapitalized bank compared to its risk level (but not government required level) contributes more to the whole financial system's (in)stability, conditional on severe distress in the entire system. In an environment of more stringent bank capital regulation and supervision, banks find it harder to raise capital when the entire system is undercapitalized (i.e. economy downturn or financial crisis), and hence are more likely to have capital shortfall. The higher probability of banks' capital shortfall would increase the systemic instability of the country.

Second, the level of regulation stringency can limit the freedom of banks' activities. With stricter regulation, banks will have less opportunity to engage in a wider range of non-traditional bank activities. Based on the portfolio theory, the combined cash flows from non-correlated revenue sources should be more stable than the constituent parts (Baele et al. 2007). In other words, banks who are able to engage in different business lines tend to have more stable revenue flows compared to their peers and are thereby less likely to have capital shortfall when external shock happens. In addition, banks who are allowed to engage in broader activities are more able to raise capital from different sources, which therefore lowers their likelihood of experiencing capital shortfall. Similarly, when banks are only allowed to engage in limited activities, they are more likely to share a similar business structure, and such similarity in banks' business lines could result in lower systemic stability (Allen et al. 2012).

In order to investigate the impact of bank regulation on systemic risk, we use the new database by Barth et al. (2013a) on bank regulation and supervision for more than 180 countries over the period 1999–2011. Following Laeven and Levine (2009) and Li et al. (2019), we consider four aspects of bank regulation, including regulation on bank activities restriction, initial capital stringency, deposit insurer power and prompt corrective action.

Employing the factor analysis, we reduce the four regulation and supervision measures and construct a single measure of bank regulation stringency. We use *Marginal Expected Shortfall* (MES), developed by Acharya et al. (2017), as our main systemic risk measure.

We find that bank activity restriction, initial capital stringency and prompt corrective action are positively related to systemic risk. Such positive association is also found for the total regulation index we developed. This is consistent with our expectation based on the definition of systemic risk adopted in our study, suggesting that banks operating in countries with more stringent regulation and supervision appear to suffer from higher exposure to systemic risk. To alleviate the concern of endogeneity, we first employ the staggered timing of the implementation of Basel II regulation across countries to identify the changes in bank regulation. The results show that the implementation of Basel II increases the bank's systemic risk more than those countries which have not yet implemented the capital regulation, while there is no such a trend before the implementation. We also employ country's latitude as an instrumental variable and conduct two-stage least squares regression analysis for causality referencing, and the same results are observed for the instrumental variable regression analysis. Our findings hold robust after using alternative measure of systemic risk (Brownlees and Engle 2017, SRISK) and variables of a country's institutional quality indexes, as well as employing the weighted-least-square regression analysis to account for the differences in the number of banks across countries.

We then provide further evidence on our conjecture that the impact of bank regulation on systemic risk is through bank's capital shortfall. We would expect this impact to be more intensified if the bank is more likely to experience capital shortfall when in distressed period, and vice versa. Specifically, we posit that the positive impact of bank regulation on systemic risk will be reduced if the bank holds a higher level of capital and if the bank has more diversified revenue flows. We thus introduce two interaction terms of our main regulation measures with bank equity to assets ratio and diversification (measured by non-interest income to total operation income, respectively), and include them in the main regressions. Our results confirm the hypotheses indicated above.

Our findings do not suggest that bank regulation and supervision are detrimental to systemic stability, but instead call for the proper design and implementation of bank regulation. Literature on regulatory forbearance points out that policy makers' control strategy tends to be influenced by strong political forces (e.g., Kane 1980). The global financial crisis has drawn much attention and critiques from the government and public to the banking sector, imposing considerable political forces to the banking regulators and supervisors. As a response, increasing level of bank regulation stringency has been implemented in different countries. However, whether bank regulatory and supervision rules could effectively address the concerns raised by the market and public appears to be unclear due to limited empirical evidence. This paper aims to empirically test the impact of bank regulation on systemic risk based on cross-country evidence and has important policy implications. We contribute to the literature in several ways.

First, the extant literature on bank regulation paid little attention to its impact on systemic risk. Although a few empirical studies have examined this relationship, the measures of systemic risk they used appear to be limited at the country level (Hoque et al. 2015). Our paper contributes to the literature in this regard, examining the impact of bank regulation on individual banks' exposure to the overall systemic risk and providing important evidence. Our findings suggest that the increased similarity in the banking system due to the restrictions on non-banking activities would increase systemic risk. This is consistent with the recent theoretical work on financial stability that highlights the importance of diversity in banking (Wagner 2010, 2011; Allen et al. 2012), showing that some degree of diversification in banks' asset portfolios is socially optimal so that banks do not have to liquidate their identical assets at the same time when financial shocks happen and generate a fire-sale externality that lowers welfare. Our results also highlight the importance of bank regulation in allowing banks more capability to raise capital when the whole system is undercapitalized. This is consistent with the recent changes to Basel III regulation, which promote the build-up of buffers in good times that can be drawn down in periods of stress. Although our paper does not directly test the effect of government capital injection to the financial system during crisis periods, the implication of our results is supportive of government action to reduce the capital shortfall of the banking system. This is also consistent with the empirical evidence provided by Berger et al. (2019) that the U.S. Troubled Assets Relief Program (TARP) significantly reduced banks' contributions to systemic risk.

Second, our paper contributes to the recent emphasis on the determinants of bank systemic risk. Existing literature has found that bank systemic risk is affected by the degree of competition (Anginer et al. 2014a), consolidation (Weiß et al. 2014), the structure of the financial network (Acemoglu et al. 2015), bank diversification (Yang et al. 2020), bank size and their capital level (Laeven et al. 2016). For example, Acemoglu et al. (2015) argue that the structure of the financial network is a determinant of systemic risk, with more diversified patterns of interbank liabilities leading to less fragility when the negative shock is below a critical threshold and vice versa. Laeven et al. (2016) show that systemic risk increases with bank size, but the systemic risk is significantly lower for well-capitalized banks. Although their work does not focus on the effect of regulation or supervision on bank systemic risk, it highlights the importance of appropriately designed regulation. Our paper provides further evidence in support of these arguments, showing that the regulatory and supervisory environment in which banks operate has significant impact on their systemic risk.

The remainder of the paper is structured as follows. Our data, variables and descriptive statistics are presented in Sect. 2. Section 3 discusses the main results of our analyses, and Sect. 4 concludes the paper.

## 2 Data, variables and descriptive statistics

### 2.1 Data and sample

The dataset used in this study is compiled from several sources. First, we obtain bank level financial information from Datastream. Second, the data of banking regulation and supervision are selected from the Bank Regulation and Supervision Survey database of the World Bank. This database is developed by Barth et al. (2013a) based on four worldwide surveys they completed before.[1] Following Barth et al. (2013b) and Li et al. (2019), we use the Survey I information for the value of the regulatory and supervisor variables for the year 2001, Survey II data for the period 2002–2004, Survey III data for the period 2005–2008 and Survey IV data for the period 2009–2013. Third, in order to measure the systemic risk, we collect the daily stock returns data from Compustat. Fourth, we obtain

[1] Survey I was completed in 1999 and covered 118 countries; Survey II provided information on bank regulatory and supervisory policies in 151 countries for 2002; Survey III captured information on banking policies in 2006 for 142 countries; and Survey IV provided information in 125 countries for 2011 (Barth et al. 2013a).

economic development measures from the World Bank's World Development Indicator (WDI) database.

We then match bank-level information, information about regulation and supervision in different countries and other national data based on data availability. Because of the incomplete overlap among the three datasets, there are a significant number of missing data and the final sample used in our study contains 6305 observations, including banks from 65 countries over the sample period of 2001–2013. It should be noted that the observations in our sample appear to be unbalanced and we attempt to address this concern in the robustness test.

## 2.2 Variables of bank regulation and supervision

We are concerned with four types of regulation and supervision: restriction on bank activities, initial capital stringency, prompt corrective action and deposit insurer power. Variables are defined following the work of Barth et al. (2004) and Barth et al. (2013b).[2] Restriction on bank activities captures the extent to which the regulatory bodies in each county authorise banks to conduct activities in three areas of services (i.e. securities, insurance and real estate). Initial capital stringency measures whether certain funds may be used to initially capitalize a bank and whether they are official. Prompt corrective action is used to measure whether supervisors in a country have the requisite and suitable powers to force automatic enforcement actions based on pre-determined levels of bank solvency deterioration. Deposit insurer power is an index used to measure each country's deposit insurance regime and evolution during the period of 1999–201. The four variables of regulation and supervision are constructed based on certain survey question. Each of them ranges from 0 to 1, with higher value indicating greater restrictions. Detailed information about the construction of each variable can be found in "Appendix 1".

Based on the above four measures of specific types of bank regulation and supervision, we develop a single regulation measure using factor analysis. Specifically, we employ the following equation:

$$Y_{i,s,t} = \beta_i Regulation_{i,s,t} + \varepsilon_{i,t} \tag{1}$$

where $i$, $s$, and $t$ denote for countries, the four regulation variables and years, respectively. $Y_{i,s,t}$ is the value of four regulation measures, *Regulation* is the observation on the common factor, and $\beta$ is the factor loadings. Next, we normalize variable $Y_{i,s,t}$, to have a mean of zero and a variance of one. Following the Eq. (1), we estimate the factors ($Regulation_{ist}$) and their loadings$\beta_i$. The results shows that around 52% of variance for the variable are explained by the common factors. We use the factor with greatest explanatory power as our measure of total regulation, where larger value indicates greater stringency.

## 2.3 Measure of systemic risk

Following Acharya et al. (2017), our study adopts the *Marginal Expected Shortfall* (MES) as the measure for determining the systemic risk exposure of individual banks. The

[2] Detailed information about variable definition, including the specific survey questions used and how the variables are constructed, can be found in "Appendix 1". We only define the variables briefly in this subsection.

systemic expected shortfall of an institution describes the capital shortage a financial institution would experience when there is a systemic event. The capital shortfall depends on the institution's leverage and equity loss conditional on an aggregate market decline. *Marginal Expected Shortfall* (MES) of a financial institution is the expected loss to which an equity investor in a financial institution would be exposed if the systemic declined substantially. Following Acharya et al. (2017), we adopt MES as our systemic risk measure. MES evaluates the average daily return for the market as whole in the tail of its loss distribution:

$$MES_t^i = E\left(R_t^i | R_t^m < C\right) \tag{2}$$

$R_t^i$ is the equity return of financial firm $i$, and $R_t^m$ is the aggregate market index return. A systemic event is defined as a drop of the market index below a threshold, $C$, over a given time horizon. We estimate the MES by following Acharya et al. (2017) at a standard risk level of 5%, using daily data for equity return from Datastream. For better interpretation of our results, we take the negative value of MES to ensure that our measures are increasing in systemic risk.

### 2.4 Other control variables

We control for a set of bank-specific and country-specific variables in the regression analysis, including bank size, profitability, market-to-book value, loan loss provision, GDP growth, inflation and economic freedom, which have been used in some previous studies of bank regulation and risk (Barth et al. 2004; Delis et al. 2011; Anginer et al. 2014a). For example, Anginer et al. (2014a) find that larger banks pose greater systemic risk, while banks with higher market-to-book value tend to have lower systemic risk exposure. Nijskens and Wagner (2011) find that banks with higher ROA tend to use CDS to protect against defaults on their portfolios, and this helps to decrease individual risk, while increasing the joint risks.

Bank size is measured by the natural logarithm of individual bank's total assets. We use return on average assets (ROAA) to capture the profitability of banks, and market-to-book value (MTBV) to control for bank growth opportunities. Loan loss provisioning is an accounting indicator that directly influences the volatility and cyclicality of bank earnings, as well as information properties of banks' financial reports with respect to reflecting loan portfolios' risk attributes (Bushman and Williams 2012).

With regard to the country-level factors, GDP growth is the annual growth rate of GDP, and inflation is defined as the percentage change of GDP deflator. Following Li et al. (2019), we derive the variable of Economic Freedom from the Heritage Foundation. It is the mean value of an index of economic freedom in terms of trade freedom, business freedom, investment freedom, and property rights for the period 2001–2013. The Economic Freedom measures the extent to which individuals and firms can enjoy freedom from their governments in conducting their business. All variable definitions can be found in "Appendix 2".

**Table 1** Summary statistics for the regulation variables

| Country | N | Activity restriction | Initial capital stringency | Prompt corrective action | Deposit insurer power | Regulation total |
|---|---|---|---|---|---|---|
| Argentina | 71 | 0.418 | 0.531 | 0.511 | 0.707 | 0.564 |
| Australia | 127 | 0.445 | 0.780 | 0.880 | 0.139 | 0.633 |
| Austria | 108 | 0.468 | 0.441 | 0.674 | 0.0540 | 0.446 |
| Bahrain | 75 | 0.613 | 0.489 | 0.849 | 0.0889 | 0.600 |
| Bangladesh | 115 | 0.470 | 0.333 | 0.964 | 0.464 | 0.619 |
| Belgium | 20 | 0.394 | 0.583 | 0.825 | 0.300 | 0.571 |
| Botswana | 15 | 0.438 | 0.333 | 0.800 | 0 | 0.427 |
| Brazil | 124 | 0.573 | 0.543 | 0.867 | 0 | 0.580 |
| Bulgaria | 13 | 0.466 | 0.333 | 0.554 | 0.231 | 0.417 |
| Canada | 129 | 0.532 | 0.793 | 0.407 | 0.616 | 0.642 |
| Chile | 81 | 0.610 | 0.309 | 0.747 | 0.208 | 0.538 |
| China | 13 | 0.692 | 0.0256 | 0.808 | 0 | 0.456 |
| Colombia | 53 | 0.568 | 0.509 | 0.594 | 0.160 | 0.516 |
| Croatia | 44 | 0.607 | 0 | 0.598 | 0.333 | 0.422 |
| Cyprus | 25 | 0.532 | 0.333 | 0.920 | 0 | 0.514 |
| Czech | 11 | 0.409 | 0.485 | 0.530 | 0.561 | 0.514 |
| Denmark | 231 | 0.341 | 0.766 | 0.561 | 0.181 | 0.481 |
| Ecuador | 16 | 0.500 | 0.667 | 0.600 | 0.167 | 0.536 |
| Egypt | 99 | 0.383 | 0.316 | 0.899 | 0.167 | 0.472 |
| Finland | 28 | 0.536 | 0.869 | 0.286 | 0.0536 | 0.479 |
| France | 361 | 0.386 | 0.695 | 0.554 | 0.391 | 0.533 |
| Germany | 248 | 0.150 | 0.536 | 0.502 | 0.490 | 0.378 |
| Greece | 58 | 0.444 | 0.833 | 0.604 | 0.0144 | 0.523 |
| Hong Kong SAR | 70 | 0.584 | 0.505 | 0.821 | 0.124 | 0.590 |
| Hungary | 17 | 0.548 | 0.431 | 0.941 | 0.176 | 0.605 |
| Iceland | 14 | 0.554 | 0.190 | 0.381 | 0.119 | 0.326 |
| India | 380 | 0.434 | 0.344 | 0.781 | 0.0158 | 0.426 |
| Indonesia | 150 | 0.714 | 0.333 | 0.988 | 0.341 | 0.713 |
| Ireland | 13 | 0.462 | 0.333 | 0.769 | 0.167 | 0.471 |
| Israel | 91 | 0.420 | 0.667 | 0.799 | 0.0440 | 0.534 |
| Italy | 301 | 0.509 | 0.762 | 0.328 | 0.203 | 0.486 |
| Japan | 875 | 0.484 | 0.623 | 0.939 | 0.0838 | 0.609 |
| Jordan | 106 | 0.352 | 0.333 | 0.628 | 0 | 0.327 |
| Kazakhstan | 8 | 0 | 0 | 0.800 | 0 | 0.113 |
| Kenya | 33 | 0.625 | 0.859 | 0.885 | 0.621 | 0.872 |
| Kuwait | 166 | 0.667 | 0.333 | 0.509 | 0 | 0.438 |
| Lebanon | 33 | 0.616 | 0.333 | 0.770 | 0.212 | 0.558 |
| Lithuania | 13 | 0.688 | 0.667 | 0.723 | 0.590 | 0.778 |
| Luxembourg | 23 | 0.283 | 0.667 | 0.804 | 0.0362 | 0.467 |
| Malaysia | 139 | 0.249 | 0.667 | 0.622 | 0.157 | 0.420 |
| Malta | 20 | 0.406 | 0.833 | 0.900 | 0.0833 | 0.624 |
| Mexico | 74 | 0.429 | 0.802 | 0.786 | 0.273 | 0.635 |
| Morocco | 68 | 0.413 | 0.647 | 0.831 | 0.0662 | 0.541 |

**Table 1** (continued)

| Country | N | Activity restriction | Initial capital stringency | Prompt corrective action | Deposit insurer power | Regulation total |
|---|---|---|---|---|---|---|
| Niger | 6 | 0.542 | 0.389 | 0.611 | 0 | 0.430 |
| Nigeria | 20 | 0.625 | 0.333 | 0.800 | 0.333 | 0.604 |
| Norway | 201 | 0.428 | 0.333 | 0.477 | 0.558 | 0.457 |
| Oman | 23 | 0.435 | 0.667 | 0.696 | 0.0580 | 0.509 |
| Pakistan | 173 | 0.413 | 0.541 | 0.910 | 0 | 0.518 |
| Panama | 2 | 0.563 | 0.333 | 1 | 0 | 0.556 |
| Peru | 68 | 0.479 | 0.711 | 0.708 | 0.206 | 0.587 |
| Poland | 159 | 0.307 | 0.667 | 0.642 | 0 | 0.414 |
| Portugal | 47 | 0.431 | 0.695 | 0.706 | 0.0426 | 0.516 |
| Qatar | 34 | 0.463 | 0.333 | 0.765 | 0 | 0.427 |
| Russian | 8 | 0.656 | 0.667 | 0.550 | 0.167 | 0.594 |
| Singapore | 38 | 0.257 | 0.675 | 0.654 | 0.0746 | 0.416 |
| Slovakia | 33 | 0.419 | 0.798 | 1 | 0.232 | 0.692 |
| South Africa | 23 | 0.688 | 0.667 | 0.400 | 0 | 0.515 |
| Spain | 94 | 0.328 | 0.397 | 0.555 | 0.291 | 0.386 |
| Sri Lanka | 109 | 0.636 | 0.538 | 0.583 | 0 | 0.513 |
| Sweden | 41 | 0.329 | 0.561 | 0.167 | 0.0610 | 0.245 |
| Switzerland | 235 | 0.609 | 0.694 | 0.792 | 0.294 | 0.695 |
| Thailand | 163 | 0.248 | 0.444 | 0.803 | 0.0542 | 0.386 |
| Tunisia | 56 | 0.375 | 0 | 0.600 | 0 | 0.225 |
| Venezuela | 109 | 0.398 | 0.502 | 0.811 | 0.0734 | 0.483 |
| Zimbabwe | 4 | 0.625 | 0.667 | 0.800 | 0.167 | 0.665 |
| Total | 6305 | 0.450 | 0.554 | 0.708 | 0.183 | 0.518 |

This table includes the countries that are included in our study. Column N represents the number of observations from this country in the sample period 2001–2013. The remainder of the table reports the mean figures (in percentage form) of the regulation variables over the sample period for each country. A detailed description of the definitions of the variables is included in "Appendix 1"

## 2.5 Descriptive statistics

Table 1 summarises the mean value for the regulation variables in each country during the sample period 2001–2013.[3] We observe a wide variation in the four specific regulation measures and also the total regulation index. *Activity Restriction* varies from the lowest value of zero in Kazakhstan and of 0.15 in Germany to a high value of 0.692 in China and of 0.714 in Indonesia, indicating that Indonesia and China forbid banks from engaging in most non-bank activities, while banks in Germany and Kazakhstan have relatively more freedom to extend their operations into securities, insurance or real estate markets. Finland has the highest *Initial*

[3] We exclude banks in the US and UK from our main analysis because the large number of banks in the two countries would have overrepresented the sample if they were included (about one third observation of the whole sample). However, we re-estimate the baseline regression by including US and UK banks and the results are reported in "Appendix 2". Our baseline results still hold.

*Capital Stringency*, with a value of 0.869, while the mean value of *Initial Capital Stringency* in Kazakhstan, Tunisia and Croatia are equal to zero, representing that banks in these three countries can include assets other than cash or government securities and borrowed funds as regulatory capital. With respect to *Prompt Corrective Action*, Panama and Slovakia have the highest mean value of 1, while Sweden has the lowest value of 0.167. *Deposit Insurer Power* varies from the lowest value of zero in fifteen countries, mainly developing countries such as Brazil, China, Jordan, Pakistan, and South Africa and etc., to the highest value of 0.707 in Argentina. Among the sample countries, Kenya has the highest *Total Regulation Index* value (0.872), while Kazakhstan has the lowest (0.113).

Table 2 provides the descriptive statistic and correlation analysis for the variables of systemic risk, regulation, bank-specific and country-specific factors for the entire sample. In panel A, we report the summary statistics for all the variables we used in our baseline analysis. We observe a wide variation in the systemic risk measure for the sample banks over the period of 2001 to 2013, with a mean value 0.992 and standard deviation 1.140.

The mean value of the *Activity Restriction* variable is 0.45, showing that the average level of restriction on bank activities is medium. Banks on average have a value of 0.554 for *Initial Capital Stringency*, suggesting that more than half of the banks in the sample can include funds other than cash, government securities and borrowed funds as regulatory capital. The *Prompt Corrective Action* variable shows a mean value of 0.708, indicating that on average the supervision power is high in the sample banks. However, the power of deposit insurer in most countries appears to be limited as the average value of *Deposit Insurer Power* is only 0.183.

In terms of control variables, the average of *Market-to-book-value* (MTBV) is 1.398, ranging from 25th percentile of 0.760 to 75th percentile of 1.750. We use the natural logarithm of total assets to measure the size of the banks. On average, the logarithm value of total assets is 9.322, with a standard deviation of 2.389. We observe a large variation in the *LLP* variable, with an average value of 0.233% and standard deviation of 2.973. The value at 25th percentile is 0.0488% while it reaches to 0.271% at 75th percentile. *GDP growth* and *Inflation* reports the mean value as 2.970 and 4.263 respectively. The *Economic Freedom Index* presents significant variation from 59.20 (25th percentile) to 70.90 (75th percentile), with 65.35 on average.

In panel B, we report the Pearson correlations for the variables used in this paper. We find that regulation stringency tends to be positively related to systemic risk. Furthermore, we observe that countries with greater regulation and supervision stringency tend to have lower GDP growth, higher inflation but more economic freedom, and banks operating in these countries tend to be larger but have lower market-to-book value. We will explore the relation more rigorously in later multivariate analysis.

## 3 Empirical results

### 3.1 Baseline results

We start with five baseline models using OLS to examine the association between bank regulation and systemic risk. More specifically, we estimate the following equation:

$$MES_{ijt} = \alpha + \beta \times regulations_{jt} + \Omega \times bank\ and\ country\ controls_{ijt} + \gamma_i + \lambda_t + \varepsilon_{ijt} \quad (3)$$

The dependent variable is the systemic risk measured by *MES* of bank $i$ in country $j$ in year $t$. The main independent variable is the regulation variables, namely *Activity Restriction, Initial Capital Stringency, Prompt Corrective Action, Deposit Insurer Power* and the

**Table 2** Descriptive statistics and correlation analyses

| Variable | N | Mean | Standard deviation | 25th | Medium | 75th |
|---|---|---|---|---|---|---|
| *Panel A: summary statistics* | | | | | | |
| MES | 6305 | 0.992 | 1.140 | 0.0959 | 0.751 | 1.640 |
| Activity restriction | 6305 | 0.450 | 0.222 | 0.313 | 0.438 | 0.563 |
| Initial capital stringency | 6305 | 0.554 | 0.241 | 0.333 | 0.667 | 0.667 |
| Prompt corrective action | 6305 | 0.708 | 0.263 | 0.500 | 0.800 | 1 |
| Deposit insurer power | 6305 | 0.183 | 0.244 | 0 | 0 | 0.333 |
| Regulation total | 6305 | 0.518 | 0.178 | 0.395 | 0.526 | 0.673 |
| MTBV | 6305 | 1.398 | 0.980 | 0.760 | 1.160 | 1.750 |
| LgTA | 6305 | 9.322 | 2.389 | 7.632 | 9.153 | 10.96 |
| LLP | 6305 | 0.233 | 2.973 | 0.0488 | 0.140 | 0.271 |
| ROAA | 6305 | 1.005 | 4.516 | 0.320 | 0.830 | 1.600 |
| GDP growth | 6305 | 2.970 | 3.702 | 1.136 | 2.587 | 5.278 |
| Inflation | 6305 | 4.263 | 6.348 | 0.795 | 2.555 | 6.387 |
| Economic freedom | 6305 | 65.35 | 8.882 | 59.20 | 64.90 | 70.90 |

| | Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Panel B: correlation matrix* | | | | | | | | | | | | | | |
| (1) | MES | 1 | | | | | | | | | | | | |
| (2) | Activity restriction | 0 | 1 | | | | | | | | | | | |
| (3) | Initial capital stringency | 0.027** | 0.01 | 1 | | | | | | | | | | |
| (4) | Prompt corrective action | 0.139*** | 0.189*** | 0.034*** | 1 | | | | | | | | | |
| (5) | Deposit insuer power | −0.072*** | −0.047*** | 0.077*** | −0.162*** | 1 | | | | | | | | |
| (6) | Regulation total | 0.056*** | 0.683*** | 0.474*** | 0.576*** | 0.278*** | 1 | | | | | | | |
| (7) | MTBV | 0.094*** | −0.042*** | −0.061*** | −0.058*** | 0.014 | −0.076*** | 1 | | | | | | |

**Table 2** (continued)

| | Variables | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) | (12) | (13) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (8) | lgTA | 0.167*** | 0.058*** | −0.062*** | 0.025** | 0.085*** | 0.052*** | 0.090*** | 1 | | | | | |
| (9) | LLP | −0.024* | −0.004 | −0.016 | 0.001 | −0.020* | −0.016 | −0.012 | 0.025** | 1 | | | | |
| (10) | ROA | −0.073*** | −0.028** | −0.012 | −0.016 | 0.013 | −0.026** | 0.019 | −0.016 | −0.303*** | 1 | | | |
| (11) | GDP Growth | −0.048*** | −0.075*** | −0.216*** | 0.070*** | −0.068*** | −0.125*** | 0.149*** | 0.125*** | −0.01 | 0.109*** | 1 | | |
| (12) | Inflation | −0.116*** | 0.018 | −0.252*** | −0.036*** | −0.02 | −0.121*** | 0.093*** | 0.116*** | 0.009 | 0.119*** | 0.216*** | 1 | |
| (13) | Economic Freedom | 0.029** | 0.033*** | 0.248*** | −0.038*** | 0.081*** | 0.135*** | −0.006 | −0.155*** | −0.006 | −0.068*** | −0.269*** | −0.468*** | 1 |

This table provides the summary statistics for the variables of the regulation, bank-specific and country-specific variables used in baseline analysis over the sample period of 2001–2013. The sample consists of 6305 banks across 65 countries. The variables are defined as outlined in "Appendix 1". N denotes the number of observations

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

**Table 3** Baseline results

| | (1) Activity restriction | (2) Initial capital stringency | (3) Prompt corrective action | (4) Deposit insurer power | (5) Regulation total |
|---|---|---|---|---|---|
| Regulation | 0.204** | 0.361*** | 0.200*** | −0.093 | 0.419*** |
| | (0.091) | (0.081) | (0.077) | (0.062) | (0.105) |
| MTBV | 0.072*** | 0.073*** | 0.076*** | 0.071*** | 0.076*** |
| | (0.024) | (0.024) | (0.024) | (0.024) | (0.024) |
| lgTA | −0.110** | −0.113** | −0.108** | −0.128*** | −0.090** |
| | (0.045) | (0.044) | (0.044) | (0.044) | (0.044) |
| LLP | −0.010* | −0.010* | −0.010* | −0.010* | −0.010* |
| | (0.005) | (0.005) | (0.005) | (0.005) | (0.005) |
| ROAA | −0.002 | −0.002 | −0.003 | −0.003 | −0.002 |
| | (0.005) | (0.005) | (0.005) | (0.005) | (0.005) |
| GDP growth | 0.006* | 0.004 | 0.006* | 0.005 | 0.006* |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |
| Inflation | −0.001 | −0.001 | −0.001 | −0.002 | −0.000 |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |
| Economic freedom | 0.006 | 0.004 | 0.005 | 0.004 | 0.006 |
| | (0.005) | (0.005) | (0.005) | (0.005) | (0.005) |
| _cons | 1.335** | 1.323** | 1.292** | 1.629*** | 1.051* |
| | (0.598) | (0.590) | (0.595) | (0.589) | (0.595) |
| Bank-fixed effect | Yes | Yes | Yes | Yes | Yes |
| Time-fixed effect | Yes | Yes | Yes | Yes | Yes |
| N | 6305 | 6305 | 6305 | 6305 | 6305 |
| Adj. R-sq | 0.267 | 0.270 | 0.268 | 0.267 | 0.269 |

This table reports the panel regression results of the estimation of different regulations and systemic risk from 65 countries for the period from 2001 to 2013. The dependent variable is the systemic risk measure by MES. Control variables include *MTBV*, *lgTA*, *LLP*, *ROAA*, *GDP Growth*, *Inflation and Economic Freedom*. Detailed definitions of the variables can be found in "Appendix 1". Bank fixed effect and year fixed effects are both included. The standard errors for the regressions are estimated as heteroskedasticity-robust standard errors clustered for banks and are presented in brackets *, **, and *** represent statistical significance at the 10%, 5%, and 1% significance level, respectively

*Total Regulation Index*, respectively. Control variables include bank-level and country-level variables since these factors could potentially affect systemic risk. $\gamma_i$ is bank fixed effects to control time invariant bank heterogeneity and $\lambda_t$ is calendar year fixed effects. The standard errors for the regressions are estimated as heteroscedasticity-robust standard errors clustered for banks and presented in brackets. Table 3 reports the results.

We find a positive relationship between the majority of regulation stringency variables (*Activity Restriction*, *Initial Capital Stringency*, *Prompt Corrective Action* and *Regulation Total*) and systemic risk. In column (1), we observe a positive relation between *Activity Restriction* and *MES*, suggesting that banks in countries with tough activity restriction are exposed to higher systemic risk. Traditional portfolio theory predicts that the combined cash flows from non-correlated revenue sources should be more stable than the constituent parts (Baele et al. 2007). Activity restrictions may result in herding behavior and greater correlated risk taking (Anginer et al. 2014a), as the structure of bank portfolios will become more similar and risks are highly correlated among those banks. Wagner (2010) argues that diversification in banks' activities can reduce systemic risk and increase welfare, while similarity cannot. Less restriction on bank activities allows banks to engage in a broad range of activities, which has the potential to decrease conglomerate risk (Kwan and Laderman 1999). Our results provide evidence to support the above arguments. This is also consistent with findings of previous empirical work. Based a country-level database to analyse the influence of bank activity restrictions on the likelihood of a banking crisis, Barth et al. (2004) find that greater regulatory restrictions on bank activities are associated with an increase in the likelihood of suffering a major crisis. Beck et al. (2006) show that imposing fewer restrictions on bank activities can reduce banking system fragility.

Similarly, we find a significantly positive association between *Initial Capital Stringency* and systemic risk in column (2). Capital requirement has been one of the most important bank regulatory instruments under the work of the Basel Committee of Banking Supervision. Capital, as a buffer for losses in bad times and also an incentive adjustor, is likely to reduce the principal-agent problem between shareholders and debt-holders and prevent excessive risk taking (Chortareas et al. 2012; Ellis et al. 2014; Pasiouras et al. 2006). In this sense, better capitalized banks seem to contribute less to systemic risk (Laeven et al. 2016).

However, if systemic risk is defined as capital shortfall of individual bank when the whole financial system is under distress, greater capital stringency may lead to increased systemic risk as it can create challenges for banks, especially in the crisis time. When the system is undercapitalized, it will no longer supply credit for the routine business. Banks under greater capital stringency will find more difficult to raise capital, and hence will be more likely to experience capital shortfall and exposure to greater systemic instability. Moreover, stringent regulation design in banking can cause the boundary problem (Goodhart 2008). If regulations are asymmetric between the banking industry and other financial sectors, such as the insurance sector, banks will be tempted to engage in regulatory arbitrage which could conceivably lead to an increase in overall systemic risk (Allen and Gale 2007). Therefore, it is not surprising that a positive association between *Initial Capital Stringency* and systemic risk is found in this study, suggesting that banks under greater initial capital stringency tend to have higher systemic risk.

Our results in Column (3) show that the enhanced *Prompt Corrective Power* can also contribute negatively to the financial stability of the market in the sample countries. There are strong theoretical explanations arguing for greater official supervision power. Banks are difficult to monitor, especially for the debtholders who are not in a position to monitor managers because they are small and uninformed (Dewatripont and Tirole 1993; Santos 2001). From this perspective, a strong official supervision can monitor and discipline banks, prevent managers from excessive risk-taking behaviour, and thus reduce market failure (Beck et al. 2006).

However, such an argument is based on the assumption that the supervisory agencies are acting according to public interest. Under the private interest or regulatory capture view (Barth et al. 2004; Agoraki et al. 2011), governments and supervisors may act in the interest of a few specific groups, e.g. powerful banks, rather than the society. If this held true then a stronger supervisory power might actually have uncertain and even adverse implications for bank's lending behaviour (Beck et al. 2006; Agoraki et al. 2011). In the study by Barth et al. (2004), no significant association is found between official supervisory power and the likelihood of suffering a crisis. Greater government intervention may also undermine the self-regulation faction in the banking system and increase moral hazard due to a decline in market discipline (Gropp and Vesala 2004;

Hryckiewicz 2014). Hryckiewicz (2014) investigates the impact of policy injections into banks in 23 countries during the 2007–2009 financial crisis, and finds that government interventions are strongly correlated with subsequent risk increase in the bank sector. He argues that the increased role of the government in the banking sector might encourage politicians to act in self-interests. Our results provide evidence to support the view of private interest, showing higher prompt corrective power leads to increased systemic risk.

Last, the coefficient for the *Total Regulation Index* shown in column (5) is significantly positive, consistent with the aforementioned results. All these results suggest that banks under strict regulation and supervision tend to have higher systemic risk. One potential reason is that under more stringent regulation and supervision, banks will have more difficulty in raising capital and be more likely to experience capital shortfall.

The only regulation variable for which no significant relationship exists is *Deposit Insurer Power*. Following the establishment of the first national insurance system in the U.S. in 1934, explicit deposit insurance schemes to prevent widespread bank runs have been adopted in different countries since the 1980s (Demirgüç-Kunt and Detragiache 2002; Barth et al. 2004). However, it has been widely recognised that deposit insurance can aggravate the moral hazard problem in the banking sector by encouraging excessive risk-taking behaviour (Barth et al. 2004; Bisias et al. 2012; Anginer et al. 2014b). Depositors can monitor bank risk-taking behaviour by charging higher interest rates, but they may have less incentive to monitor banks if deposits are insured, and the lack of market discipline is likely to result in excessive risk taking culminating in banking crises (Anginer et al. 2014b). The higher the individual risk, the greater the capital shortfall when banks are in distress, and consequently the more they contribute to systemic instability.

More empirical evidence tends to support this argument (e.g., Barth et al. 2004; Demirgüç-Kunt and Detragiache 2002). For example, Barth et al. (2004) find a positive association between the generosity of the deposit insurance scheme and the possibility of suffering a major banking crisis, and such a relationship is economically large. More recently, Anginer et al. (2014b) find that deposit insurance increases systemic fragility in the years leading to 2007–2009 financial crisis, but lower bank systemic risk in countries with deposit insurance coverage during crisis. Their findings suggest that the ''moral hazard effect'' of deposit insurance dominates in good times, while the ''stabilization effect'' of deposit insurance dominates in turbulent times. The cancelling effects of deposit insurance power in the sample countries may explain why there is no significant relationship found in our study.

In terms of control variables, the signs and significance levels of these variables are in line with our expectations. For bank specific characteristics, the coefficient on bank size (measured as logarithm of total assets) appears to be negatively and statistically significant in all regressions, indicating that larger banks are less likely to be exposed to higher systemic risk. While the *MTBV* is positively relative to the systemic risk, which suggests that higher market valued banks are exposing to higher systemic risk. Besides, we find a weak evidence (statistically significant at 10% level across all models) showing that the LLP is negatively related to systemic risk, which suggests that banks with lower level of loan loss provision tend to be exposed to higher systemic risk.

**Table 4** Endogeneity test: Basel II implementation and systemic risk

| Dependent variable | (1) MES | (2) MES |
|---|---|---|
| Basel II Dummy | 0.175** | |
| | (0.085) | |
| Basel II t − 4 | | − 0.275 |
| | | (0.213) |
| Basel II t − 3 | | − 0.063 |
| | | (0.177) |
| Basel II t − 2 | | − 0.074 |
| | | (0.127) |
| Basel II t − 1 | | − 0.084 |
| | | (0.090) |
| Basel II t + 1 | | 0.281*** |
| | | (0.094) |
| Basel II t + 2 | | 0.269** |
| | | (0.131) |
| Basel II t + 3 | | 0.478*** |
| | | (0.170) |
| Basel II t + 4 | | 0.484** |
| | | (0.215) |
| Basel II t + 5 | | 0.781*** |
| | | (0.265) |
| Basel II t + 6 | | 0.999*** |
| | | (0.314) |
| _cons | 1.204* | 1.061 |
| | (0.715) | (0.787) |
| Control variables | Yes | Yes |
| Bank fixed effect | Yes | Yes |
| Year fixed effect | Yes | Yes |
| N | 4880 | 4880 |
| Adj. R-sq | 0.285 | 0.287 |

This table reports the panel regression results of the estimation of different regulations and systemic risk from 65 countries for the period from 2001 to 2013. The dependent variable is the systemic risk measure by MES. Column (1) reports the results of estimation Basel II implementation and systemic risk. Basel II Dummy which equals to one for the time after the country adopted Basel II and 0 otherwise. Column (2) reports the dynamic change of systemic risk prior/after the Basel II implementation. *Basel* $\mathrm{II}_{it}$ is set to one for years prior/after Basel II implementation and zero otherwise. Control variables include MTBV, lgTA, LLP, ROAA, GDP Growth Inflation and Economic Freedom. Detailed definitions of the variables can be found in "Appendix 1". Bank fixed effect and year fixed effects are both included. The standard errors for the regressions are estimated as heteroskedasticity-robust standard errors clustered for banks and are presented in brackets *, **, and *** represent statistical significance at the 10%, 5%, and 1% significance level, respectively

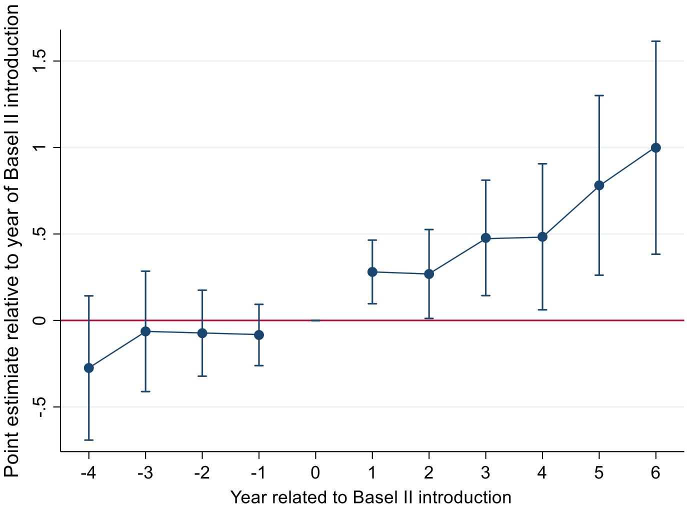


**Fig. 1** Basel II implementation and systemic risk: dynamic results. This figure presents the dynamic impact of Basel II implementation on systemic risk. The impact of Basel II on systemic risk is shown by the connected dots; the vertical bars correspond to 95% confidence intervals with bank-level clustered standard error. All estimates are relative to the year before Basel II implementation. Specifically, we report estimated coefficients from the following specification: $Y_{it} = \alpha + \beta_{-4}\textit{Basel}\ \mathrm{II}_{it-4} + \beta_{-3}\mathrm{Basel\ II}_{it-3} + \beta_{-2}\mathrm{Basel\ II}_{it-2} + \beta_{-1}\mathrm{Basel\ II}_{it-1} + \beta_1\mathrm{Basel\ II}_{it+1} + \cdots + \beta_6\mathrm{Basel\ II}_{it+6} + \Omega \times \textit{bank and country controls}_{ijt} + \gamma_i + \lambda_t + \varepsilon_{ijt}$. Where the $\textit{Basel}\mathrm{II}_{it}$ equals to one in the years after the country in which bank is located implement the Basel II in year $t$ and zero otherwise.$\textit{Basel}\,\mathrm{II}_{it-4}$ is set to one for years up to and including 4 years prior to Basel II implementation and zero otherwise, $\textit{Basel}\,\mathrm{II}_{it+6}$ set to one for years up to and including 6 years after Basel II implementation. The omitted variable in this regression is the year of Basel II implementation ($t=0$). $\gamma_i$and $\lambda_t$ are bank and year fixed effects, respectively

## 3.2 Endogeneity tests

The results from our baseline regression analysis have documented a positive relationship between regulation stringency and systemic risk. However, there might be concerns about endogeneity, such as reverse causality. For example, if policymakers or government observed that banks in their countries are exposing to a higher systemic risk, they would probably enforce more restrict regulatory and supervisory policies in the banking sector. In this section, we conduct analyses to address the potential endogeneity between bank regulation and systemic risk.

### 3.2.1 Basel II implementation and systemic risk

First, we employ the staggered timing of the implementation of Basel II regulation across countries. Basel II was designed to improve the way that regulatory capital requirements could reflect underlying risks and address the financial innovation accrued in previous years.[4] Following the release of Basel II in June 2004, different countries adopted this new framework at a staggered process. In our sample, Australia was the first country implementing Basel II in 2005, followed by Japan, Brazil and other countries which implemented it in 2007. This allows us to use countries that had not adopted it at a point of time to control for potentially confounding effects. We estimate the difference in systemic risk exposure of banks in a country before and after the Basel II implementation to such differences for banks in countries where Basel II has not been implemented during same time period. If strict regulation and supervision increases the individual banks' exposure to systemic risk, we would expect an increase in systemic risk after the implementation of Basel II. We manually collect the time of individual countries implementing Basel II, and then introduce a dummy variable of Basel II, which equals to one for the time after the country adopted Basel II and 0 otherwise. The baseline regression was re-run by replacing the variable of $Regulations_{i,t}$ with Basel II Dummy. The result is reported in column (1) of Table 4.

As expected, the coefficient of Basel II Dummy is positive and significant at 95% confidence level, showing that the adoption of Basel II is related to higher MES, which means the implementation of Basel II tends to increase systemic risk in a country.

Although the staggered adoption of Basel II represents an exogenous shock to bank regulation, country-level factors that manifest differently across countries could affect the timing of Basel II adoption in different countries. To ensure there is no trend before the event, we further examine the dynamic of the relation between Basel II implementation and bank systemic risk exposure by including a series of dummy variables in Eq. (3) to trace out the year-by-year effects of Basel II implementation on systemic risk. Specifically, we conduct analysis for the following Eq. (4):

$$\begin{aligned} Y_{it} = \alpha + \beta_{-4} \mathit{Basel}\ \mathrm{II}_{it-4} + \beta_{-3}\mathrm{Basel\ II}_{it-3} + \beta_{-2}\mathrm{Basel\ II}_{it-2} + \beta_{-1}\mathrm{Basel\ II}_{it-1} \\ + \beta_{1}\mathrm{Basel\ II}_{it+1} + \cdots + \beta_{6}\mathrm{Basel\ II}_{it+6} + \Omega \times \mathit{bank\ and\ country\ controls}_{ijt} + \gamma_i + \lambda_t + \varepsilon_{ijt} \end{aligned} \tag{4}$$

where the the dynamic change of systemic equals to one in the years before (after) the country in which bank is located implement the Basel II in year $t$ and zero otherwise. *Basel* II $_{it-4}$ is set to one for years up to and including 4 years prior to Basel II implementation and zero otherwise; *Basel* II $_{it+6}$ set to one for years up to and including 6 years after Basel II implementation. The omitted variable in this regression is the year of Basel II introduction (t = 0). Therefore, we can estimate the dynamic effect of Basel II implementation on systemic risk relative to the year of implementation. If there is an increasing systemic risk simultaneously happened with the implementation of Basel II, we should observe a trend before and after the implementation of Basel II. Otherwise, the result derived from column (1) should not result from reverse causality.

Figure 1 plots the coefficients estimate of Basel II implementation and their associated 95% confidence intervals as shown by the vertical bars of Eq. (4).[5] Overall, we find that the coefficients on Basel II are insignificant for years before implementation except years up to

[4] Basel II comprises three pillars: a) Minimum Capital Requirements, which seeks to develop and expand the standardised rules on the calculation of total minimum capital requirements for credit, market and operational risk; b) supervisory review process, which is intended to encourage banks to develop and use better risk management techniques in monitoring and managing their risks; c.) Market Discipline, which aims to promote effective use of disclosure as a lever to strengthen market discipline and encourage sound banking practices (Committee on Banking Supervision 2004).

[5] Regression results for model (4) are reported in column (2) of Table 4.

**Table 5** Endogenous test: instrumental variables analysis

| | (1) Activity restriction | (2) Initial capital stringency | (3) Prompt corrective action | (4) Deposit insurer power | (5) Regulation total |
|---|---|---|---|---|---|
| *Panel A: first stage* | | | | | |
| Latitude | 0.496*** | −0.641*** | −0.336*** | −1.195*** | −0.387*** |
| | (0.111) | (0.248) | (0.108) | (0.087) | (0.077) |
| Control variables | Yes | Yes | Yes | Yes | Yes |
| First stage F-test (*p* value) | 0.000*** | 0.000*** | 0.000*** | 0.000*** | 0.000*** |
| *Panel B: second stage* | | | | | |
| Regulation | 0.412* | 1.354* | 1.061* | 1.793* | 0.536* |
| | (0.224) | (0.735) | (0.576) | (0.973) | (0.291) |
| MTBV | 0.072*** | 0.072*** | 0.086*** | 0.078*** | 0.075*** |
| | (0.024) | (0.024) | (0.026) | (0.025) | (0.024) |
| lgTA | −0.125*** | −0.122*** | −0.123*** | −0.129*** | −0.125*** |
| | (0.044) | (0.043) | (0.043) | (0.045) | (0.044) |
| LLP | −0.009* | −0.010* | −0.009* | −0.011* | −0.009* |
| | (0.006) | (0.005) | (0.006) | (0.006) | (0.006) |
| ROAA | −0.002 | −0.002 | −0.002 | −0.004 | −0.002 |
| | (0.005) | (0.005) | (0.005) | (0.005) | (0.005) |
| GDP Growth | 0.007* | 0.005 | 0.009** | 0.002 | 0.006* |
| | (0.004) | (0.004) | (0.004) | (0.004) | (0.003) |
| Inflation | −0.001 | 0.004 | 0.003 | −0.002 | 0.000 |
| | (0.003) | (0.004) | (0.004) | (0.003) | (0.003) |
| Economic freedom | 0.005 | 0.009* | 0.003 | 0.007 | 0.005 |
| | (0.005) | (0.005) | (0.006) | (0.005) | (0.005) |
| _cons | 1.432*** | 0.611 | 0.934** | 1.322*** | 1.322*** |
| | (0.538) | (0.506) | (0.471) | (0.512) | (0.512) |
| Bank-fixed effect | Yes | Yes | Yes | Yes | Yes |

**Table 5** (continued)

| | (1)<br>Activity restriction | (2)<br>Initial capital stringency | (3)<br>Prompt corrective action | (4)<br>Deposit insurer power | (5)<br>Regulation total |
|---|---|---|---|---|---|
| Time-fixed effect | Yes | Yes | Yes | Yes | Yes |
| N | 6305 | 6305 | 6305 | 6305 | 6305 |
| Adj. R-sq | 0.266 | 0.266 | 0.266 | 0.266 | 0.266 |

This table reports the two-stage least squares regression results of the estimation of different regulations and systemic risk from 65 countries for the period from 2001 to 2013. The dependent variable is the systemic risk measure by MES. Instrumental variables for bank regulations is latitude. We report both the first and second stage results. In the first stage regression, we regress bank regulation measures on the latitude of the country. In the second stage, we use the predicted value of bank regulation measures from the first stage as the independent variable. Panel A reports the corresponding first-stage regression results with endogenous variable bank regulation as dependent variable. Panel B reports the second-stage regression results from the 2SKS analysis. The independent variable is the systemic risk measured by MES. Bank-fixed effect and time-fixed effects are included. The standard errors for the regressions are estimated as heteroskedasticity-robust standard errors clustered for banks and are presented in brackets *, **, and *** represent statistical significance at the 10%, 5%, and 1% significance level, respectively and 4 years prior to implementation. We can confirm that there is no trend of systemic risk change prior to Basel II implementation. On the other side, we observe that the coefficients become significantly positive since the first and following years after Basel II implemented. Compared to that for first year after the implementation, the coefficients for the second year of implementation and afterwards almost double, indicating that implementation of Basel II has a positive impact on banks' systemic risk.

### 3.2.2 Instrumental variable analysis

Next, we use the Instrumental Variable approach to address the potential issue. Following previous studies of theoretical and empirical work in the law, institution, and finance literature (e.g., Acemoglu et al. 2001; Beck et al. 2003), the latitude of the country is selected as our exogenous variable.

The endowment theory suggests that the initial endowment and geographical environment shape the construction of institution and policies, which can be used to explain the cross-country variations in financial intermediary and financial institution development (La Porta et al. 1999; Acemoglu et al. 2001; Beck et al. 2003). Therefore, the location tends to affect the bank regulation and supervision framework in different countries, but it is less likely to affect directly banks' systemic risk. Therefore, we use Latitude, which is the absolute value of the latitude of the country and normalized to take value between 0 and 1, as instrumental variable for causal inference.[6] We employ a two-stage least squares (2SLS) model to conduct the instrumental variable analysis, and the results are reported in Table 5.

In panel A, we present the first stage results of the two-stage least squares regressions. We find that the instrumental variable, Latitude, is significantly and negatively related to regulation variables (except for *Activity Restrictions*), suggesting that the historical endowments can affect the regulation and supervision framework in different countries. Previous studies suggest that countries located in high latitude area are richer and less interventionist, therefore the regulation and supervision in banking of these countries tend to be less restrict (La Porta et al. 1999). The results of F-test also suggest that the instrumental variables are valid in our first stage estimation.

In panel B, we report the second stage results by using the predicted value of regulation variables from the first-step regressions. We find that the coefficient of all our regulation variables are all positively and significantly related to systemic risk. Overall, our main empirical findings are robust to the instrumental variable regression analyses.

## 3.3 Robustness test

In this section, we conduct a series of additional regression analyses to verify the robustness of our main results. As mentioned in Sect. 2.1, the countries included in our sample are based on data availability. As a result, there might be concerns with our baseline results because of the existence of unbalanced observations cross countries. Therefore, we firstly run the analysis for Eq. (3) by employing the weighted-least-square regression to address the issue of unbalanced panel data. We take the inverse of the number of the observations for a country as the weight for each bank in the country so that each country receives the

[6] Similar approach has been used in previous studies for estimating impact of bank regulation and supervision (e.g., Barth et al., 2009, 2013b; Beck et al., 2006; Houston et al., 2011).

**Table 6** Robustness test: WLS regression

| | (1)<br>Activity restriction | (2)<br>Initial capital stringency | (3)<br>Prompt corrective action | (4)<br>Depositor | (5)<br>Regulation total |
|---|---|---|---|---|---|
| Regulation | 0.410*** | 0.551*** | 0.433*** | −0.084 | 0.766*** |
| | (0.111) | (0.100) | (0.096) | (0.080) | (0.129) |
| MTBV | 0.042 | 0.047 | 0.050 | 0.044 | 0.049 |
| | (0.033) | (0.033) | (0.033) | (0.033) | (0.033) |
| lgTA | −0.154** | −0.149** | −0.133** | −0.188*** | −0.103* |
| | (0.060) | (0.058) | (0.060) | (0.059) | (0.060) |
| LLP | −0.010 | −0.011* | −0.010 | −0.011 | −0.010 |
| | (0.007) | (0.007) | (0.007) | (0.007) | (0.007) |
| ROAA | 0.003 | 0.003 | 0.002 | 0.003 | 0.002 |
| | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) |
| GDP growth | 0.003 | 0.000 | 0.004 | 0.001 | 0.004 |
| | (0.004) | (0.004) | (0.004) | (0.004) | (0.004) |
| Inflation | −0.004 | −0.003 | −0.003 | −0.005 | −0.002 |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |
| Economic freedom | 0.006 | 0.008 | 0.005 | 0.004 | 0.008 |
| | (0.007) | (0.006) | (0.006) | (0.006) | (0.006) |
| _cons | 1.875** | 1.586** | 1.559** | 2.405*** | 1.144 |
| | (0.749) | (0.714) | (0.732) | (0.726) | (0.741) |
| Bank-fixed effect | Yes | Yes | Yes | Yes | Yes |
| Time-fixed effect | Yes | Yes | Yes | Yes | Yes |
| N | 6305 | 6305 | 6305 | 6305 | 6305 |
| Adj. R-sq | 0.352 | 0.355 | 0.353 | 0.349 | 0.356 |

This table reports the WLS regression results of the estimation of different regulations and systemic risk from 65 countries for the period from 2001 to 2013. The weight is the inverse of the number of observations for a country. The dependent variable is the systemic risk measure by MES. Control variables include *MTBV*, *lgTA*, *LLP*, *ROAA, GDP Growth Inflation and Economic Freedom*. Detailed definitions of the variables can be found in "Appendix 1". Bank fixed effect and year fixed effects are both included. The standard errors for the regressions are estimated as heteroskedasticity-robust standard errors clustered for banks and are presented in brackets *, **, and *** represent statistical significance at the 10%, 5%, and 1% significance level, respectively

equal weight in the estimation. The results are reported in Table 6. Consistent with our main regression results presented in Sect. 3.1, the relationship between the majority of regulation variables and systemic risk are positive and significant, showing that our main findings are robust and are less likely to be biased due to unbalanced observation cross countries.

Second, regressions are run to test the relationship between systemic risk and the five variables of bank regulation and supervision based on two subsamples. For the first subsample, we exclude countries with less than 10 observations in each year, and the results are shown in the left side of Table 6. The total observations of Japan account for around 13.88% of the full sample and the predominance of the banks in Japan may bias our results. So we run the regressions after dropping banks in Japan from our sample. Results of regression analyses with the subsample of excluding Japan are presented in the right side

**Table 7** Robustness test: subsamples

| | Without countries less than 10 observations per year | | | | | Without Japan | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Activity restriction | Initial capital stringency | Prompt corrective action | Deposit insurer power | Regulation total | Activity restriction | Initial capital stringency | Prompt corrective action | Deposit insurer power | Regulation total |
| Regulation | 0.288** | 0.652*** | 0.328*** | −0.074 | 0.706*** | 0.249*** | 0.317*** | 0.241*** | −0.088 | 0.445*** |
| | (0.114) | (0.112) | (0.095) | (0.071) | (0.134) | (0.090) | (0.083) | (0.079) | (0.061) | (0.105) |
| MTBV | 0.047 | 0.052* | 0.058* | 0.047 | 0.057* | 0.092*** | 0.092*** | 0.096*** | 0.090*** | 0.096*** |
| | (0.029) | (0.029) | (0.030) | (0.029) | (0.029) | (0.026) | (0.026) | (0.026) | (0.026) | (0.026) |
| lgTA | −0.188*** | −0.195*** | −0.168*** | −0.215*** | −0.140** | −0.066 | −0.084* | −0.067 | −0.092** | −0.050 |
| | (0.064) | (0.061) | (0.065) | (0.063) | (0.063) | (0.046) | (0.046) | (0.046) | (0.046) | (0.046) |
| LLP | −0.009 | −0.010 | −0.009 | −0.009 | −0.009 | −0.009* | −0.009* | −0.009 | −0.009 | −0.009 |
| | (0.007) | (0.007) | (0.007) | (0.007) | (0.007) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) |
| ROAA | −0.005 | −0.005 | −0.006 | −0.006 | −0.006 | −0.006 | −0.006 | −0.006 | −0.007 | −0.006 |
| | (0.006) | (0.007) | (0.006) | (0.007) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) |
| GDP growth | 0.010 | 0.007 | 0.013* | 0.009 | 0.013 | 0.008** | 0.006* | 0.008** | 0.007** | 0.008** |
| | (0.008) | (0.008) | (0.008) | (0.008) | (0.008) | (0.004) | (0.003) | (0.004) | (0.004) | (0.004) |
| Inflation | −0.004 | −0.005 | −0.003 | −0.005 | −0.003 | 0.001 | 0.001 | 0.001 | 0.000 | 0.002 |
| | (0.004) | (0.004) | (0.004) | (0.004) | (0.004) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |
| Economic freedom | 0.025*** | 0.023*** | 0.022** | 0.022** | 0.026*** | 0.006 | 0.003 | 0.005 | 0.004 | 0.006 |
| | (0.009) | (0.009) | (0.009) | (0.009) | (0.009) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) |
| _cons | 0.906 | 0.826 | 0.744 | 1.396* | 0.211 | 0.892 | 1.111* | 0.811 | 1.289** | 0.624 |
| | (0.768) | (0.734) | (0.751) | (0.750) | (0.750) | (0.648) | (0.634) | (0.649) | (0.637) | (0.646) |
| Time fixed effect | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Bank fixed effect | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| N | 4391 | 4391 | 4391 | 4391 | 4391 | 5430 | 5430 | 5430 | 5430 | 5430 |
| Adj. R-sq | 0.278 | 0.285 | 0.279 | 0.276 | 0.283 | 0.234 | 0.235 | 0.234 | 0.232 | 0.236 |

This table presents the results of regression analyses of the relationship between systemic risk and regulations by using the subsample: (a) without countries less than 10 observations in each year; (b) the subsample excluded observations of Japan since it counts around 13.88% of the full sample. Detailed definitions of the variables can be found in "Appendix 1". Bank fixed effect and year fixed effects are both included. The standard errors for the regressions are estimated as heteroskedasticity-robust standard errors clustered for banks and are presented in brackets. *, **, and *** represent statistical significance at the 10%, 5%, and 1% significance level, respectively

**Table 8** Robustness test: alternative measure of country-level governance

| | (1) Activity restriction | (2) Initial capital stringency | (3) Prompt corrective action | (4) Deposit insurer power | (5) Regulation total | (6) Activity restriction | (7) Initial capital stringency | (8) Prompt corrective action | (9) Deposit insurer power | (10) Regulation total |
|---|---|---|---|---|---|---|---|---|---|---|
| Regulation | 0.193** | 0.377*** | 0.189** | −0.092 | 0.410*** | 0.267*** | 0.352*** | 0.195** | −0.095 | 0.454*** |
| | (0.090) | (0.080) | (0.077) | (0.062) | (0.105) | (0.091) | (0.079) | (0.076) | (0.062) | (0.104) |
| MTBV | 0.071*** | 0.072*** | 0.075*** | 0.070*** | 0.075*** | 0.063*** | 0.065*** | 0.067*** | 0.063*** | 0.068*** |
| | (0.024) | (0.024) | (0.024) | (0.024) | (0.024) | (0.024) | (0.024) | (0.024) | (0.024) | (0.024) |
| lgTA | −0.113*** | −0.111*** | −0.111*** | −0.129*** | −0.094** | −0.083* | −0.091** | −0.088** | −0.106** | −0.066 |
| | (0.042) | (0.042) | (0.042) | (0.042) | (0.042) | (0.043) | (0.043) | (0.042) | (0.042) | (0.043) |
| LLP | −0.010* | −0.010* | −0.010* | −0.010* | −0.010* | −0.009* | −0.010* | −0.009 | −0.010* | −0.009* |
| | (0.005) | (0.005) | (0.006) | (0.006) | (0.005) | (0.006) | (0.006) | (0.006) | (0.006) | (0.006) |
| ROAA | −0.003 | −0.003 | −0.003 | −0.003 | −0.003 | −0.004 | −0.003 | −0.004 | −0.004 | −0.003 |
| | (0.005) | (0.005) | (0.005) | (0.005) | (0.005) | (0.005) | (0.005) | (0.005) | (0.005) | (0.005) |
| GDP growth | 0.005 | 0.003 | 0.005 | 0.004 | 0.005 | 0.004 | 0.003 | 0.004 | 0.003 | 0.004 |
| | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |
| Inflation | −0.001 | −0.000 | −0.001 | −0.001 | −0.000 | 0.000 | 0.001 | 0.001 | −0.000 | 0.001 |
| | (0.003) | (0.002) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) | (0.003) |
| Control of corruption | 0.248** | 0.286*** | 0.234** | 0.250** | 0.249** | | | | | |
| | (0.104) | (0.105) | (0.105) | (0.105) | (0.104) | | | | | |
| Overall governance index | | | | | | 0.826*** | 0.747*** | 0.756*** | 0.761*** | 0.805*** |
| | | | | | | (0.158) | (0.153) | (0.156) | (0.154) | (0.156) |
| _cons | 1.538*** | 1.348*** | 1.435*** | 1.719*** | 1.261*** | 0.891** | 0.903** | 0.898** | 1.203*** | 0.651 |
| | (0.389) | (0.382) | (0.393) | (0.385) | (0.390) | (0.407) | (0.400) | (0.407) | (0.399) | (0.408) |
| Time fixed effect | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Bank fixed effect | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

Table 8 (continued)

| | (1) Activity restriction | (2) Initial capital stringency | (3) Prompt corrective action | (4) Deposit insurer power | (5) Regulation total | (6) Activity restriction | (7) Initial capital stringency | (8) Prompt corrective action | (9) Deposit insurer power | (10) Regulation total |
|---|---|---|---|---|---|---|---|---|---|---|
| N | 6305 | 6305 | 6305 | 6305 | 6305 | 6305 | 6305 | 6305 | 6305 | 6305 |
| Adj. R-sq | 0.268 | 0.271 | 0.268 | 0.268 | 0.270 | 0.273 | 0.275 | 0.273 | 0.272 | 0.275 |

This table reports the results of regression analyses of the relationship between systemic risk and regulations by using alternative country-level governance variables. In column (1)–(5), we use the control of corruption as the governance index. In column (6)–(10), we use the overall governance index of six country-level governance indicators, including voice and accountability, political stability, governance effectiveness, regulatory quality, rule of law and control of corruption. Detailed definitions of the variables can be found in "Appendix 1". Bank fixed effect and year fixed effects are both included. The standard errors for the regressions are estimated as heteroskedasticity-robust standard errors clustered for banks and are presented in brackets. *, **, and *** represent statistical significance at the 10%, 5%, and 1% significance level, respectively of Table 7. All regressions include year and bank fixed effects. Our main findings still hold for both subsamples.

Third, previous studies suggest that a nation's level of corruption can affect banks' lending behaviour (Barth et al. 2009; Houston et al. 2011). Therefore, we add two additional variables of country-level institutional quality as an explanatory variable to check the robustness of our results. Considering the high correlation between economic freedom index and the governance indicator (Delis et al. 2011), we remove the economic freedom from the models when running the regression analyses with institutional quality indices.

The first variable of institutional quality we use is the Control of Corruption, which measures the extent to which public power is exercised for private gains. Higher value of this measure indicates a better control of corruption. We also include an overall governance index that measures the overall political and institutional quality of a country. The overall governance index captures six dimensions of a nation's governance, including Governance effectiveness, Political stability, Regulatory Quality, Rule of law, Voice and accountability, as well as Control of corruption. Higher value of this index indicates a better institutional environment in a country. The data are derived from the World Bank World Governance Indicator database. The results are reported in Table 8.

We observe a positive and significant relationship between the governance index and systemic risk. A business environment with better control of corruption and governance, as well as more economic freedom, would allow banks to interact with the real economies in a more transparent and organized manner, which in turn increases the interconnectedness of the whole banking system. This increased interconnectedness improves the financial market development, but at the same time increases the potential systemic risk when financial markets collapse (Allen et al. 2012; Acemoglu et al. 2015). Overall, our main findings remain unchanged, showing that regulation variables are significantly and positively related to systemic risk.

Last, we employ an alternative measure of systemic risk, namely SRISK, to assess the relationship between bank regulation and systemic risk. Brownlees and Engle (2017) introduce SRISK to measure an individual financial institution's contribution to the systemic risk, which has been widely used by subsequent studies (e.g., Iqbal and Vähämaa 2019; Jouida 2019). SRISK is concerned with the capital shortfall of a firm conditional on a severe market decline, and is a function of its size, leverage and risk. Specifically, SRISK measures how much capital the financial institution would need in a crisis time to maintain a given capital-to-assets ratio. The measure can readily be computed using balance sheet information and an appropriate Long Run Marginal Expected Shortfall (*LRMES*) estimator. Following previous studies such as Brownlees and Engle (2017) and Berger et al. (2019), we measure SRISK based on the following equation:

$$\begin{aligned} SRISK_{i,t} &= E_{t-1}(Capital\ Shortfall_i | Crisis) \\ &= E_{t-1}\left(k\left(Debt_i + Equity_i\right) - Equity_i | Crisis\right) \\ &= kDebt_{i,t-1} - (1-k)\left(1 - LRMES_{i,t}\right)Equity_{i,t} \end{aligned} \tag{5}$$

where $k$ is the capital requirement, and we set $k$=8% in this research. $LRMES_{i,t}$ is the long-run marginal expected shortfall at time $t$ for bank $i$, defined as the decline in equity values conditional on a financial crisis. Higher value of SRISK indicates greater contribution of systemic risk.

**Table 9** Alternative measure of systemic risk: SRISK

| | (1) Activity restriction | (2) Initial capital stringency | (3) Prompt corrective action | (4) Deposit insurer power | (5) Regulation total |
|---|---|---|---|---|---|
| Regulation | 0.581*** | 0.279*** | 0.212* | −0.239* | 0.561*** |
| | (0.205) | (0.098) | (0.114) | (0.130) | (0.196) |
| MTBV | −0.044 | −0.047 | −0.045 | −0.051 | −0.040 |
| | (0.040) | (0.041) | (0.041) | (0.042) | (0.040) |
| lgTA | −0.152 | −0.213 | −0.193 | −0.222 | −0.159 |
| | (0.149) | (0.150) | (0.154) | (0.151) | (0.154) |
| LLP | −0.037 | −0.036 | −0.035 | −0.036 | −0.036 |
| | (0.028) | (0.028) | (0.028) | (0.028) | (0.029) |
| ROAA | −0.025*** | −0.025*** | −0.025*** | −0.025*** | −0.025*** |
| | (0.009) | (0.009) | (0.009) | (0.009) | (0.009) |
| GDP growth | −0.007 | −0.010* | −0.008 | −0.009 | −0.008 |
| | (0.005) | (0.006) | (0.005) | (0.006) | (0.005) |
| Inflation | 0.012* | 0.011* | 0.012* | 0.011 | 0.013* |
| | (0.007) | (0.007) | (0.007) | (0.007) | (0.007) |
| Economic freedom | −0.026*** | −0.033*** | −0.032*** | −0.033*** | −0.029*** |
| | (0.010) | (0.010) | (0.010) | (0.010) | (0.010) |
| _cons | 2.600 | 3.618* | 3.388* | 3.903** | 2.788 |
| | (1.847) | (1.887) | (1.949) | (1.913) | (1.940) |
| Bank-fixed effect | Yes | Yes | Yes | Yes | Yes |
| Time-fixed effect | Yes | Yes | Yes | Yes | Yes |
| N | 5510 | 5510 | 5510 | 5510 | 5510 |
| Adj. R-sq | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |

This table reports the panel regression results of the estimation of different regulations and systemic risk measured by SRISK from 65 countries for the period from 2001 to 2013. The dependent variable is the systemic risk measure by MES. Control variables include *MTBV*, *lgTA*, *LLP*, *ROAA*, *GDP Growth Inflation and Economic Freedom*. Detailed definitions of the variables can be found in "Appendix 1". Bank fixed effect and year fixed effects are both included. The standard errors for the regressions are estimated as heteroskedasticity-robust standard errors clustered for banks and are presented in brackets *, **, and *** represent statistical significance at the 10%, 5%, and 1% significance level, respectively

**Table 10** Heterogeneity effects

| | (1) Activity restriction | (2) Initial capital stringency | (3) Prompt corrective action | (4) Deposit insurer power | (5) Regulation total |
|---|---|---|---|---|---|
| *Panel A* | | | | | |
| Regulation | 0.292*** | 0.564*** | 0.424*** | −0.045 | 0.705*** |
| | (0.110) | (0.119) | (0.110) | (0.087) | (0.133) |
| Regulation × equity/assets | −0.008 | −0.018** | −0.019*** | −0.004 | −0.024*** |
| | (0.007) | (0.008) | (0.007) | (0.006) | (0.007) |
| Equity/assets | 0.005 | 0.010* | 0.014** | 0.001 | 0.013*** |
| | (0.005) | (0.006) | (0.006) | (0.004) | (0.005) |
| _cons | 1.226* | 1.129* | 1.102* | 1.594** | 0.850 |
| | (0.671) | (0.660) | (0.661) | (0.657) | (0.668) |
| Other control variables | Yes | Yes | Yes | Yes | Yes |
| Time fixed effect | Yes | Yes | Yes | Yes | Yes |
| Bank fixed effect | Yes | Yes | Yes | Yes | Yes |
| N | 6305 | 6305 | 6305 | 6305 | 6305 |
| Adj. R-sq | 0.268 | 0.271 | 0.270 | 0.267 | 0.271 |
| *Panel B* | | | | | |
| Regulation | 0.206** | 0.356*** | 0.273*** | −0.108* | 0.529*** |
| | (0.100) | (0.108) | (0.079) | (0.064) | (0.123) |
| Regulation * diversification | −0.014 | 0.017 | −0.180*** | 0.045 | −0.273* |
| | (0.107) | (0.204) | (0.047) | (0.053) | (0.163) |
| Diversification | 0.021 | 0.012 | 0.192*** | −0.003 | 0.160* |
| | (0.030) | (0.069) | (0.047) | (0.023) | (0.087) |
| _cons | 1.371** | 1.358** | 1.239** | 1.672*** | 1.018* |
| | (0.598) | (0.588) | (0.590) | (0.588) | (0.596) |
| Other control variables | Yes | Yes | Yes | Yes | Yes |
| Time fixed effect | Yes | Yes | Yes | Yes | Yes |
| Bank fixed effect | Yes | Yes | Yes | Yes | Yes |
| N | 6305 | 6305 | 6305 | 6305 | 6305 |
| Adj. R-sq | 0.267 | 0.270 | 0.269 | 0.266 | 0.270 |

This table reports the panel regression results of the estimation of different regulations and systemic risk measure by MES. In Panel A, we introduce the interaction between the bank regulation stringency and Equity-to-Assets ratio. In Panel B, we introduce the interaction between the bank regulations and bank diversification. The standard errors for the regressions are estimated as heteroskedasticity-robust standard errors clustered for banks and are presented in brackets. *, **, and *** represent statistical significance at the 10%, 5%, and 1% significance level, respectively

We run the baseline regression by using SRISK as the systemic risk measure. The results are reported in Table 9. Overall, the results are consistent with the main results. We find that the coefficients for *Activity Restriction*, *Initial Capital Stringency*, *Prompt Corrective Action* and *Total Regulation Index* are still significantly positive, suggesting that the stringency of regulation and supervision have a positive impact on banks' systemic risk as measured by SRISK.

### 3.4 Heterogeneity effects

In previous sections, we present results of our main regression analyses and robustness tests, showing that stringent regulation and supervision can increase systemic risk through greater capital shortfall. In this section, we conduct further empirical tests to support our arguments by looking at two interaction terms.

First, if the increase in banks' systemic risk is due to their greater capital shortfall, we would expect that such an impact is likely to be alleviated for banks which hold more capital as capital can absorb the potential loss and thereby reduce capital shortfall. To validate this hypothesis, we introduce the interaction between regulatory variables and *Equity-to-Assets ratio*. The results are presented in Panel A of Table 10.

Overall, we observe that the interaction terms are significant and negative for the interaction between *Equity-to-Assets* and *Initial Capital Stringency/Prompt Corrective Action/Total Regulation Index*, indicating that the positive impact of regulation on systemic risk will be reduced if banks hold more capital. These results support our assumption that bank regulation increases systemic risk through banks having greater capital shortfall.

Second, if the capital shortfall is the channel through which regulation and supervision increase systemic risk, we would expect that diversification of banks can alleviate such impact. First, based on the portfolio theory, the combined cash flows from non-correlated revenue sources should be more stable than the constituent parts (Baele et al. 2007). If banks can maintain stable income flows, the likelihood of suffering capital shortage will be lower. In addition, diversification also provides more choices for banks to raise capital. In other words, banks who succeed in diversifying their business lines tend to have more channels to raise capital when they meet capital shortage, and thereby tend to be safer compared to their counterparts who rely on onefold source. We then introduce the interaction between regulatory variables and *Diversification* which is measured by non-interest income divided by total operating income. If our argument holds true, we would expect a negative relationship between the interaction term and the dependent variable in the regression models. Panel B of Table 10 shows the results of this heterogeneity test. We observe that the coefficients of interaction terms are negative and significant in columns (3) and (5). These results suggest that the positive influence of regulation and supervision on systemic risk can be alleviated for better diversified banks, which is consistent with our earlier expectation. Overall, our heterogeneity tests provide further evidence to support our main argument that stringent regulation and supervision can increase systemic risk and such an impact is likely to occur through intensified capital shortfall.

## 4 Conclusions

There has been increasing interest in academic research on bank regulation and supervision since the financial crisis of 2007–2009. However, the theoretical debates on whether bank regulation and supervision can help to maintain financial stability remain open due to limited evidence on the relationship between bank regulation and systemic risk. Hoque et al. (2015) argue that the correlation in the risk-taking behavior of banks is much more relevant than the absolute level of risk that individual banks take. The paper aims to investigate how some specific types of bank regulation and supervision affect individual banks' systemic risk across countries. Based on a new database developed by Barth et al. (2013a), we provide robust evidence on the impact of bank activity restriction, capital requirements, official supervision and deposit insurance on systemic risk in 65 countries during the period 2001–2013. We also develop a *Total Regulation Index* based on the four specific regulation variables in order to examine the combined effect of regulatory and supervisory policies.

We find that more stringent regulation and supervision lead to higher systemic risk. Specifically, countries with more restrictions on bank activities, higher initial capital stringency or stronger prompt correction power tend to suffer from higher systemic risk. We also find that the *Total Regulation Index* is positively related to the systemic index measure, confirming that increased systemic risk is more likely to happen in a stringent regulatory and supervisory environment. This is consistent with our expectation based on the view that systemic risk can be defined as the capital shortfall of a financial institution conditional on a severe market decline (Brownlees and Engle 2017; Acharya et al. 2017) and a bank is more likely to have capital shortfall when it is in an environment with more stringent regulation. To address the potential endogeneity issue, we employ Basel II staggered implementation across countries as exogenous event and use latitude for Instrument Variable analysis. Our findings appear to be robust after employing WLS to control the potential effect of unbalanced panel data, regressing on subsamples, using variables of a country's institutional quality indexes and alternative systemic risk measure. We also provide further evidence through examining interaction effects. By interacting regulatory variables with equity-to-asset ratio and diversification, we find the positive impact of bank regulation and supervision on systemic risk would be alleviated if the bank holds more capital and has a diversified income flow.

Our findings contribute to the limited understanding of the association between bank regulation and systemic stability, and have important implications for governments and regulators. Since the financial crisis of 2007–2009, we have seen a growing awareness of the need for a macroprudential approach to regulation (Arnold et al. 2012). Governments in different countries have introduced a variety of regulatory and supervisory polices to regulate the banking industry and manage the financial cycle. However, these stringent regulations have potential drawbacks. They may indeed decrease banks' standalone risks but fail to look at the correlated risks they take. Our findings show that, opposite to what governments and regulators have expected, stringent regulatory and supervisory policies result in less systemic stability, although such effect could be alleviated by the banks having a greater level of equity.

Our paper has important implications for policy makers. Despite the significant policy reforms introduced after the financial crisis, there have been increasing concerns on whether regulatory mechanisms designed according to stringent regulatory and supervisory policies, such as activity restrictions, based only on the perspective of individual bank risk, are effective in reducing the probability of systemic crises. Indeed, the "utopian" objective function of policy makers, that it, to maximize the expected value of a constrained social welfare function (Kane 1980, p. 199), has been long questioned due to influence of politic forces. Kane (1980) argues that effective policy control has three elements: policy instruments, intermediate policy targets and policy goals. In order to achieve long term policy goals, it is important for policy makers to have appropriate intermediate policy targets that can be tracked closely and are based on theoretical and empirical predictions. In this sense, timely empirical studies on the impact of bank regulation and systemic risk is in dire need. Our findings suggest that the currently designed tight regulation appears to have effects opposite to the expectations of governments. In order to sustain the stability of banking, regulatory and supervisory mechanisms should be designed based on inter-bank correlation. This is consistent with other researchers' call for prudential regulation that operates at a collective level (e.g., Acharya 2009).

**Funding** No funding was received for conducting this study.

## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.



## Appendix 1

See Tables 11.

**Table 11** Definition of variables

| Variable name | Description |
|---|---|
| MES | Average return on sample banks conditioned on 5% worse returns on the market |
| Activity restriction | A measure of a bank's ability to conduct activities in the business area of securities underwriting, insurance, and real estate. A value of 1–4 is added if an activity is (1) "unrestricted" and coded as a score of 1 if a full range of activities can be conducted directly; (2) "permitted" and coded as a score of 2 if the full range of activities can be conducted, but some or all must be conducted in subsidiaries; (3) "restricted" and counted as a score of 3 if less than a full range of activities can be conducted in a bank or subsidiaries; and (4) "prohibited" and counted as a score of 4 if the activity cannot be conducted in either the bank or subsidiaries. Activity restriction is calculated by adding the answers to these questions together then divided by 12. Greater values indicate more restrictions (Barth et al. 2004, 2013b) |
| Initial capital stringency | A variable used to measure whether regulatory capital in a country can include assets other than cash or government securities and borrowed funds and whether the sources of capital is verified by the regulatory supervisory authorities. It is an index based on the following question (for question (1), Yes = 1 No = 0; for question (2) and (3), Yes = 0 No = 1): (1) Are the sources of funds to be used as capital verified by the regulatory/supervisory authorities? (2) Can the initial disbursement or subsequent injections of capital be performed with assets other than cash or government securities? (3) Can the initial disbursement of capital be performed with borrowed funds? We then add answers to these questions together and divide it by 3 to calculate the initial capital stringency index. Higher values indicate greater stringency (Barth et al. 2004, 2013b) |
| Prompt corrective action | A variable that measures whether supervisors in a country have the requisite and suitable powers to force automatic enforcement actions based on predetermined levels of bank solvency deterioration. It is constructed based on the following questions (Yes = 1, No = 0): (1) Can the supervisory authority force a bank to change its internal organizational structure? (2) Are there any mechanisms of cease and desist-type orders, whose infraction leads to the automatic imposition of civil and penal sanctions against the bank's directors and managers? (3) Can the supervisory agency order the bank's directors or management to constitute provisions to cover actual or potential losses? (4) Can the supervisory agency suspend the director's decision to distribute dividends? (5) Can the supervisory agency suspend the director's decision to distribute bonuses? (6) Can the supervisory agency suspend the director's decision to distribute management fees? Prompt corrective action is calculated as the sum of the score counted for each question and divided by 6. A higher value indicates greater supervisory power (Barth et al. 2004, 2013b) |
| Deposit insurer power | The deposit insurer power scheme is an index that measures each country's deposit insurance regime and evolution from 1999 to 2011. This index is based on the answer to the following questions (Yes = 1, No = 0): (1) Does the deposit insurance authority make the decision to intervene in a bank? (2)Can the deposit insurance agency/fund take legal action for violations of laws, regulations, and bylaws (of the deposit insurance agency) against bank directors or other bank officials? (3)Has the deposit insurance agency/fund ever taken legal action for violations of laws, regulations, and bylaws (of the deposit insurance agency) against bank directors or other bank officials? (4)Were any deposits not explicitly covered by the deposit insurance at the time of the failure compensated when the bank failed (excluding funds later paid out in liquidation procedures)? Deposit insurer power is equal to $\{[(1)+(2)+(3)]/3+(4)\}/2$. This variable ranges from 0 to 1, where higher values indicate more power (Barth et al. 2004, 2013b) |

**Table 11** (continued)

| Variable name | Description |
|---|---|
| Total regulation | A single measure of bank regulation that is constructed using factor analysis based on the four regulation measures. The following equation is employed: $Y_{i,s,t} = \beta_i$ Regulation$_{s,s,t} + \varepsilon_{i,t}$, where the subscripts i, s, and t refer denote for countries, the four regulation variables and years, respectively. $Y_{i,s,t}$ is the value of four regulation measures, Regulation is the observation on the common factor, and $\beta$ is the factor loadings. Next, we normalize variable $Y_{i,s,t}$, to have a mean of zero and a variance of one. Following the Eq. (1), we estimate the factors ($Regulation_{ist}$) and their loadings$\beta_i$. The results shows that around 55% of variance for the variable are explained by the common factors. We use the factor with greatest explanatory power as our measure of total regulation, where larger value indicates greater stringency |
| LgTA | A natural logarithm of total assets denominated in US dollars |
| ROAA | Return on average asset. Net income/total assets in % |
| MTBV | Market-to-book value, measured as market value of equity/Book value of equity |
| LLP | Loan loss provision ratio, measured as total loan loss provision/net loan in % |
| GDP growth | The log value of annual growth rate of GDP |
| Inflation | The percentage change of GDP deflator |
| Basel II Dummy | A dummy variable which equals to one for the time after the country adopted Basel II and 0 otherwise |
| SRISK | An individual financial institution's contribution to the systemic risk, measured in billion dollar value |
| Economic freedom | Proxy for the overall level of economic freedom from Heritage Foundation. It is a composite index that including business freedom, trade freedom, fiscal freedom, government spending, monetary freedom, investment freedom, financial freedom. property rights, labour freedom |
| Equity/assets | Total equity to total assets ratio |
| Diversification | Non-interest income divided by total operating income in % |
| Latitude | The absolute value of the latitude of the country and normalized to take value between 0 and 1 |
| Control of corruption | The perception of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption. As well as "capture" of the state by elites and private interests. Higher value indicates a better control of corruption (Data source: World Bank World Governance Indicator database) |
| Overall governance index | The overall political and institutional quality of a country, measured as the arithmetic average of six indicators, including Governance effectiveness, Political stability, Regulatory Quality, Rule of law, Voice and accountability, as well as Control of corruption. Higher value of this index indicates a better institutional environment (Data source: World Bank World Governance Indicator database) |

## Appendix 2

See Tables 12.

**Table 12** Robustness test: includes US and UK banks

| | (1) Activity restriction | (2) Initial capital stringency | (3) Prompt corrective action | (4) Deposit insurer power | (5) Regulation total |
|---|---|---|---|---|---|
| Regulation | 0.843*** | 1.027*** | 0.696*** | −0.024 | 0.200*** |
| | (0.109) | (0.096) | (0.094) | (0.050) | (0.022) |
| MTBV | 0.143** | 0.142** | 0.146** | 0.146** | 0.145** |
| | (0.070) | (0.069) | (0.071) | (0.071) | (0.071) |
| lgTA | −0.151** | −0.227*** | −0.142** | −0.180*** | −0.082 |
| | (0.065) | (0.064) | (0.064) | (0.068) | (0.067) |
| LLP | −0.007 | −0.009 | −0.008 | −0.008 | −0.006 |
| | (0.006) | (0.006) | (0.007) | (0.007) | (0.006) |
| ROA | −0.025*** | −0.023*** | −0.026*** | −0.026*** | −0.027*** |
| | (0.007) | (0.007) | (0.007) | (0.007) | (0.007) |
| GDP growth | 0.059*** | 0.054*** | 0.058*** | 0.056*** | 0.057*** |
| | (0.008) | (0.007) | (0.008) | (0.008) | (0.008) |
| Inflation | 0.021*** | 0.023*** | 0.022*** | 0.019*** | 0.021*** |
| | (0.004) | (0.004) | (0.004) | (0.004) | (0.004) |
| Economic freedom | −0.000 | −0.016** | −0.002 | 0.000 | 0.008 |
| | (0.007) | (0.007) | (0.007) | (0.007) | (0.007) |
| _cons | 1.289 | 2.961*** | 1.162 | 1.909** | 0.287 |
| | (0.839) | (0.829) | (0.842) | (0.922) | (0.858) |
| Bank-fixed effect | Yes | Yes | Yes | Yes | Yes |
| Time-fixed effect | Yes | Yes | Yes | Yes | Yes |
| N | 9559 | 9559 | 9559 | 9559 | 9559 |
| Adj. R-sq | 0.089 | 0.094 | 0.088 | 0.084 | 0.091 |

This table reports the panel regression results of the estimation of different regulations and systemic risk from 67 countries, including US and UK banks for the period from 2001 to 2013. The dependent variable is the systemic risk measure by MES. Control variables include MTBV, lgTA, LLP, ROAA, GDP Growth, Inflation and Economic Freedom. Detailed definitions of the variables can be found in "Appendix 1 of Table 11". Bank fixed effect and year fixed effects are both included. The standard errors for the regressions are estimated as heteroskedasticity-robust standard errors clustered for banks and are presented in brackets *, **, and *** represent statistical significance at the 10%, 5%, and 1% significance level, respectively

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