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Identifying Banking Crises Using Money Market Pressure: New Evidence For A Large Set of Countries

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Résumé/abstract

We construct a money market pressure index based on central bank reserves and the short-term nominal interest rate to identify banking crises, thereby extending the index proposed by Von Hagen and Ho (2007). We compare the crises identified by both indices with banking crises according to the benchmark of Laeven and Valencia (2010). Both indices identify more crises than these benchmarks. The crises identified by our index are more in line with the benchmark than the crises identified by the Von Hagen and Ho index, while our index also gives fewer false signals.

Mots clés/keywords : banking crises, money market pressure index.

Codes JEL *: C43, E44, G21*

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1. Introduction

Since the collapse of the Bretton Woods system, the frequency of financial crises has doubled (Bordo et al., 2001). Notably after the financial liberalization during the 1990s, the intensity of financial crises has increased. Recent research suggests that financial crises may have a permanent effect on potential output (Furceria et al., 2012).

In general, three types of financial crises may be distinguished: currency crises, banking crises and debt crises. Compared to other types, banking crises have a more serious impact on the economy (Hutchison et al., 2005). It is therefore important to prevent banking crises and to reduce the costs of banking crises once they occur (Caprio and Klingebiel 1996; Kaminsky and Reinhart 1999; Frydl 1999; Demirgüç-Kunt and Detragiache 1998, 2005; Duttagupta and Cashin 2008; and Davis et al. 2008a, 2008b).

A serious methodological challenge which researchers face is the identification of (systemic) banking crises. Most studies identify a (systemic) banking crisis based on exceptional events or policy interventions, such as bank closures, deposit freezes and government rescues (cf. Laeven and Valencia, 2008; 2010; 2013; and Reinhart and Rogoff, 2009). However, Von Hagen and Ho (2007) argue that this events methodology may be biased for several reasons. First, such interventions may refer to a few banks having problems rather than the whole banking sector. Second, it is hard to determine whether a particular policy intervention is taken because of a systemic banking crisis. Third, policy interventions mostly occur when a crisis has a significant impact on the financial system or the economy, which implies that the start of the banking crisis may

be identified too late. Finally, not each crisis leads to government interventions as central banks sometimes solve financial problems successfully. Therefore, there may be a selection bias when banking crises are identified based on interventions by government authorities.[1]

Drawing on the reasoning of Eichengreen et al. (1996a, 1996b), Von Hagen and Ho (2007) propose an index to identify banking crises based on money market pressure (which will be discussed in more detail in section 2). A monetary pressure index cannot offset all drawbacks of the events methodology, but advantages of a money market pressure index include that it is less subjective, available at a higher frequency and timelier. Although the Von Hagen-Ho index is very innovative, we argue that it can be improved upon by using nominal instead of real interest rates and by weighting its components differently. We propose a modified monetary pressure crises index to identify banking crises and compare it to Von Hagen and Ho's index. We construct the index for a much larger sample of countries than Von Hagen and Ho (2007). For comparison purposes we use the Laeven-Valencia (2010) database of banking crises, which is based on the events methodology. In our analysis we presume that this benchmark correctly identifies crises, even though there are good reasons to suspect that especially the timing of crises according to these benchmarks may be wrong. In our

[1] Likewise, Boyd et al. (2009) argue that the banking crisis indicators they examine—including those of Reinhart and Rogoff (2009) and Laeven and Valencia (2008)—actually measure lagged government responses to systemic bank shocks, rather than the occurrence of crises *per se*. After we had finished the research reported in this paper, Laeven and Valencia (2013) published an update of their dataset, which deviates sometimes substantially from their earlier dataset, further illustrating the intricacies of the events methodology.

comparison we take this timing issue into account by considering a signal given by the monetary pressure index to be correct also if it is two years earlier or one year later than the crisis period identified by the benchmarks. It turns out that the crises identified by our index are more in line with those of Laeven and Valencia (2010), while our index also identifies fewer banking crises that are not listed in the benchmark than the index of Von Hagen and Ho. This conclusion is robust when we use different samples or other becnhmarks. Our research also shows that money market pressure indexes, be it the original index of Von Hagen and Ho (2007) or our index, indicate many more banking crises than the events methodology. Further analysis shows that when our index gives a false signal (i.e. there is no crisis according to the benchmarks) there are frequently indications of financial stress.

The rest of the paper is organized as follows. Section 2 reviews previous research on identifying banking crises. Section 3 discusses the index proposed by Von Hagen and Ho (2007) and presents our proposed amendments. Section 4 describes the data and criteria for identifying banking crises. Section 5 compares crises identified by both indexes with crises according to the benchmarks, while section 6 offers a sensitivity analysis. Finally, section 7 concludes.

2. Identifying banking crises

2.1 The events method

The events method identifies banking crises based on the occurrence of certain events, such as bank runs, closures, mergers and government interventions (Demirgüç-Kunt

and Detragiache, 1998). Caprio and Klingebiel (1996) adopt information from supervisors and country experts to identify banking crises. In its World Economic Outlook, the IMF (1998, p.76) extends Caprio and Klingebiel's scheme and identifies a banking crisis as a situation in which actual or potential bank runs and failures lead banks to suspend the internal convertibility of their liabilities or compel the government to provide large-scale interventions in the banking sector.

Demirgüç-Kunt and Detragiache (1998, 2002, 2005) identify an event as a crisis if at least one of the following conditions holds:

(i) the ratio of non-performing assets to the banking system's total assets exceeds 10%;

(ii) the cost of the government's rescue operation is at least 2% of GDP;

(iii) banking sector problems result in a large-scale nationalization of banks;

(iv) extensive bank runs take place or emergency measures such as deposit freezes, prolonged bank holidays, or generalized deposit guarantees are enacted by the government in response to the crisis.

Laeven and Valencia (2008, 2010) adopt a somewhat different definition to identify banking crises. Laeven and Valencia (2008, p. 5) define a systemic banking crisis as an event where a "country's corporate and financial sectors experience a large number of defaults and financial institutions and corporations face great difficulties repaying contracts on time. This situation may be accompanied by depressed asset prices (such as equity and real estate prices) on the heels of run-ups before the crisis, sharp increases in real interest rates, and a slowdown or reversal in capital flows. In

some cases, the crisis is triggered by depositor runs on banks, though in most cases it is a general realization that systemically important financial institutions are in distress."

As pointed out in the Introduction, Von Hagen and Ho (2007) argue that the events method has several shortcomings. Therefore, they suggest an index based on pressure in the money market to identify banking crises.

2.2 Money market pressure index

The basic idea of the money market pressure index of Von Hagen and Ho (2007) is that in a crisis the banking sector will face difficulties, such as an increase in non-performing assets, withdrawals of deposits, and drying up of inter-bank lending, which will lead to a sharp increase in banks' demand for central bank liquidity. The central bank will react to this increased demand in two ways. If central bank reserves are the operating target of monetary policy, the supply of reserves will be constant and the short-term interest rate will rise. Otherwise, the central bank will sustain the level of the short-term interest rate and inject additional reserves into the banking sector. Thus, a banking crisis is generally characterized by a sharp increase of short-term interest rates, the stock of central bank reserves, or both.

Based on this logic, Von Hagen and Ho (2007) propose the following money market pressure index (MPI):

$$MPI_t = \frac{\Delta\gamma_t}{\sigma_{\Delta\gamma}} + \frac{\Delta r_t}{\sigma_{\Delta r}} \ , \qquad (1)$$

where Δ is the difference operator, γ is the ratio of central bank reserves to total bank deposits, r is the short-term interest rate, while $\sigma_{\Delta\gamma}$ and $\sigma_{\Delta r}$ are the standard deviations of $\Delta\gamma$ and Δr, respectively.

In identifying a banking crisis, Von Hagen and Ho (2007) apply two criteria. First, the MPI needs to exceed the 98.5 percentile of the sample distribution for the country under consideration. Second, the increase of the MPI from the previous period should at least be 5%. The first condition ensures that only exceptional events are treated as crises, and the second one is applied to avoid signaling crises in countries that did not experience a banking crisis.[2] Von Hagen and Ho quantify these criteria by selecting the combination of parameters that can best identify crises as listed by Caprio and Klingebiel (1996).

3. Modification of the money market pressure index

The money market pressure index constructed by Von Hagen and Ho (2007) is less subjective than the events methods. However, the index has some drawbacks as well. First, Von Hagen and Ho use the short-term real interest rate in their index instead of the short-term nominal interest rate while normally rising nominal rates indicate liquidity shortages in the money market. If the real interest rate decreases due to higher inflation, the money market pressure index will go down thereby wrongly indicating that the probability of a banking crisis has decreased. Previous research suggests that, if anything, inflation has a positive impact on banking crises (cf. Demirgüç-Kunt and

[2] These two criteria are similar to the extreme-value based identification of currency crises studied by Lestano and Jacobs (2007).

Detragiache 1998, 2002) and not a negative impact as implied by the index of Von Hagen and Ho.

Second, due to data limitations Von Hagen and Ho calculate standard deviations over the whole sample period thereby ignoring possible changes in monetary regimes. As we have sufficiently long samples—each country's sample exceeds 9 years—we apply rolling 24-month periods to calculate standard deviations.[3] As the ratio of central bank reserves to total bank deposits γ may be constant for a long time (which is the case in some countries) so that the standard deviation of $\Delta\gamma$ is equal to zero, the MPI index cannot be constructed.[4] Even if $\sigma_{\Delta\gamma}$ does not equal zero, it will generally be much smaller than the standard deviation of the short-term interest rate $\sigma_{\Delta r}$, so that the ratio of central bank reserves to total bank deposits γ receives more weight than the short-term interest rate r.

Third, the index of Von Hagen and Ho (2007) is driven by the most stable component. To avoid this problem, we change the weighting scheme and propose a Modified Monetary Pressure Index (MMPI):

$$MMPI_t = \omega_1 \Delta\gamma_t + \omega_2 \Delta r_t, \tag{2}$$

$$\omega_1 = \frac{\frac{1}{\sigma(\Delta\gamma)}}{\frac{1}{\sigma(\Delta\gamma)} + \frac{1}{\sigma(\Delta r)}}, \omega_2 = \frac{\frac{1}{\sigma(\Delta r)}}{\frac{1}{\sigma(\Delta\gamma)} + \frac{1}{\sigma(\Delta r)}}.$$

The weights fall in the interval (0, 1] and add up to one. To illustrate the difference between the two indices, we provide an intuitive example. We set the value

[3] To examine the sensitivity of our findings, we have experimented with different lengths of the moving window to calculate the standard deviations.

[4] If the value of a standard deviation in a particular window is zero, we use the minimum positive value instead.

of $\sigma_{\Delta\gamma}$ to 1, while the value of $\sigma_{\Delta r}$ varies from 1 to 100. Figure 1 shows the resulting values of the weights of MPI and MMPI. We find that the value of ω_1 is smaller than $\frac{1}{\sigma(\Delta\gamma)}$ and ω_2 is almost the same as $\frac{1}{\sigma(\Delta r)}$. In our sample (as discussed in the next section), the ratios of $\sigma_{\Delta r}$ to $\sigma_{\Delta\gamma}$ are in a range of [1, 50], so the weight of $\Delta\gamma$ in constructing MMPI is smaller than in constructing MPI. So our index is not driven by the most stable component.

[Insert Figure 1 here]

We deviate from the analysis of Von Hagen and Ho (2007) in two more ways. First, although Von Hagen and Ho (2007) consider both type I errors (i.e. the index does not signal a banking crisis when there is one according to some benchmark, missed crises from now on) and type II errors (i.e. the index signals a banking crisis when there is none according to the benchmark, false alarms from now on), we apply a quantitative method in assessing the performance of the indices more precisely.

Second, the sample of Von Hagen and Ho includes mostly countries which suffered from at least one banking crisis, while they include only few countries without banking crises. Therefore, there may be a sample selection bias and it is not clear whether the index is reliable in countries which did not experience banking crises. To avoid this bias, we include more countries with and without banking crises to investigate whether the index can identify banking crises in both types of countries.

4. Sample and criteria for identifying banking crises

4.1 Sample

We use monthly data from the IMF's International Financial Statistics, spanning the period 1975 to 2009, to construct money market pressure indices. Following Von Hagen and Ho (2007), total deposits consist of demand deposits, time and saving deposits and foreign liabilities of deposit money banks. Central bank reserves are defined as loans from monetary authorities. The nominal interest rate is the money market rate. If this variable is not available, we follow Von Hagen and Ho (2007) and use (successively) the Treasury bill rate, the government bond yield, the deposit rate, the lending rate, and the discount rate as substitutes. Changes in the consumer price index are used to measure inflation. In line with Von Hagen and Ho (2007), the real interest rate is defined as the nominal interest rate minus inflation.

We use five indices, namely VHH, RMPI, NMPI, RMMPI, and NMMPI. VHH, RMPI and RMMPI are based on real interests, while NMPI and NMMPI are constructed using nominal interest rates. These indices are defined in Table 1.

[Insert Table 1 here]

For illustrative purposes, we first zoom in on the results for a subsample of 10 countries which includes three industrial economies (Japan, Korea, and the United States), and seven developing and emerging economies (Argentina, Brazil, Indonesia, Malaysia, Mexico, Philippines, and Turkey). These 10 countries have experienced

banking crises during the last three decades.

Table 2 presents descriptive statistics of the five indices in these countries. The means and the standard deviations of RMPI and NMPI are much larger than those of RMMPI and NMMPI. The weights as used in Equation (2) are less than 1 while in Equation (1) they can be larger than 1, so that indices based on Equation (1) can become bigger. The average of VHH is mostly somewhere between the averages of MPI and MMPI.

[Insert Table 2 here]

Because VHH is different from the other four indices, Figure 2 shows only the other four indices for selected countries. The first graph for each country shows RMPI and NMPI, and the second one presents RMMPI and NMMPI. As these figures show, RMPI and NMPI are close to each other in Argentina and Brazil, while RMMPI and NMMPI are also very similar for these countries. In contrast, the indices differ for the other countries, and sometimes quite substantially. Specifically, compared to the indices based on nominal interest rates, those based on real interest rates often show a downward trend. Furthermore, it turns out that in some countries the signs of RMMPI and NMMPI are opposite. This difference is due to the effect of inflation. For instance, both inflation and the short-term interest rate were high in Indonesia in 1997, and the indices based on the nominal interest indicate a banking crisis, while those based on the real interest rate do not. According to Laeven and Valencia (2010), Indonesia

experienced a banking crisis in 1997.

[Insert Figure 2 here]

4.2 Assessing crisis signals

We assess the performance of the indices as follows. First, we use the Laeven and Valencia (2010) database as the benchmark when evaluating the results of the five indices. Due to data availability, the sample used for comparison purposes includes 136 countries with 75 banking crises. Column (2) in Appendix 1 lists all countries in our sample and their banking crises according to Laeven and Valencia (2010). Our sample includes 21 industrial economies and 115 developing economies having 11 and 64 banking crises, respectively. In addition, there are 11 industrial and 66 developing economies without a banking crisis.

Second, following Von Hagen and Ho (2007) there is a crisis if (i) the index exceeds the 98.5 percentile of the sample distribution for the country under consideration and (ii) the index increases by at least 5% compared to the previous period.

Third, we adopt Von Hagen and Ho (2007)'s rule to decide whether a signal identifies a banking crisis correctly. If the signal indicates a banking crisis at most two years prior to the start of the crisis according to the benchmark or if the signal indicates a banking crisis at most one year later than the benchmark, this signal is considered to

be correct.[5] If the index does not signal a banking crisis when there is one according to the benchmark, it is labeled as a missed crisis. If the index signals a banking crisis when there is none according to the benchmark, then it is labeled as a false alarm (see Table 3).

[Insert Table 3 here]

Finally, we consider type I errors (missed crises) and type II errors (false alarms). The frequency of missed crises is defined as the number of crises listed in the benchmark that are not signaled by the index compared to the total number of crises listed in the benchmark, while the frequency of false alarms is defined as the number of crises signaled by the index which are not listed in the benchmark compared to the total number of crises signaled by the index.

5. Results

5.1 Comparison of five indices

We first compare the five indices. Table 4 zooms in on missed crises and false alarms. The indices based on nominal interest rates have fewer missed crises than those based on real interest rates. Among the five indices, NMMPI has the lowest frequency of missed crises and false alarms, so that we prefer this index to the others.[6] Moreover,

[5] In the sensitivity analysis we also employ a window of (T-2, T+2) where T is the crisis period according to the benchmark.

[6] If we follow Von Hagen and Ho (2007) and use the standard deviations of the whole period to construct NMMPI, the results show that the index identifies one more correct crises, but 12 wrong crises according to the benchmark. If we use the crises database of Reinhart and Rogoff (2010) as an alternative

VHH performs worse than the other indices.

[Insert Table 4 here]

All indices have very high ratios of false alarms. However, these signals may not be all wrong. First, the benchmark of Laeven and Valencia (2010) may not identify all banking crises. Indeed, 24 crises 'wrongly' identified by NMMPI are crises identified by Reinhart and Rogoff (2009). And another 20 'false alarms' are in line with the crises database of Caprio and Klingebiel (1996) (see Appendix 2 for further details).

Second, many 'false alarms' identified by NMMPI may indicate events which are not severe enough to be identified as banking crisis by our benchmark or other crises databases. For example, even though in Algeria 4 out of 17 banks failed in 2005 our benchmark does not identify this as a systemic crisis. Likewise, in many other cases there are severe economic problems, such as currency devaluations or economic downturns, which can all lead to periods with high stress in the banking system even though our benchmark does not consider this stress as sufficient reason to consider the period as a banking crisis. Appendix 3 provides further details of these cases. In our view, most of the 'false alarms' indicate crises which are missed by our benchmark, a crisis not severe enough to be considered as systemic by our benchmark, or reflects stress in the banking sector.

Since RMMPI performs slightly better than VHH and RMPI, we select RMMPI

benchmark, the index identifies the same number of correct crises, but 10 more wrong crises. As a result, we conclude that NMMPI constructed with rolling standard deviations performs better than that based on standard deviations measured over the entire sample period.

for a more detailed comparison with NMMPI. It turns out that 45 crises correctly identified by NMMPI coincide with the benchmark, six have a 2-year lead, five have a 1-year lead, and four have a 1-year lag. RMMPI identifies 39 crises that coincide with crises identified by the benchmark, three have a 2-year lead, one has a 1-year lead, and four have a 1-year lag.

5.2 Weighting missed crises and false alarms

In evaluating indices, one needs to weight missed crises and false alarms. Inspired by Demirgüç-Kunt and Detragiache (2000), we use a loss function to calculate the combined costs of both types of errors and to evaluate the performance of RMMPI and NMMPI.[7]

First, we describe how to construct a loss function for NMMPI. Let H and w be the values of the threshold, i.e. the 98.5% percentile set by Von Hagen and Ho, and weights chosen by the decision-maker, respectively. Here, w= [w_1, w_2], w_1 and w_2 are the weights of the two components to construct NMMPI in Equation (2), respectively, where we assume that w_1+w_2=1. If the value of the index exceeds H, and its growth rate is larger than 5%, the index will issue a warning signal. Let $p(H, w)$ be the probability that the index issues a warning signal, and $a(H, w)$ be the probability of a missed crisis. Also, let c_1 be the cost of taking preventive actions when there is a warning signal, and let c_2 be the cost of a banking crisis if it is not predicted. Then, a simple expected loss

[7] An alternative way to introduce the trade-off between missed crises and false alarms is the receiver operating characteristic (ROC) as recently used in business cycle analysis (see Berger and Jorda, 2011).

function can be constructed as follows:

$$L(H,w) = p(H,w)c_1 + a(H,w)c_2 \quad . \tag{3}$$

In addition, let $b(H,w)$ be the probability of a false alarm, and let P_0 denote the (unconditional) probability of a banking crisis. Then, equation (3) can be rewritten as

$$\begin{aligned} L(H,w) &= c_1[(1-a(H,w))p_0 + b(H,w)(1-p_0)] + c_2 a(H,w)p_0 \\ &= p_0 c_1\left[1 + \left(\frac{c_2 - c_1}{c_1}\right)a(H,w) + \left(\frac{1-p_0}{p_0}\right)b(H,w)\right]. \end{aligned} \tag{4}$$

It follows that that the larger c_2 is relative to c_1, missed crises are considered more important than false alarms (and vice versa).

To estimate the values of the parameters, we can use in-sample frequencies. Specifically, we take P_0 to be equal to the frequency of banking crises in the whole sample, namely 0.077. $a(H,w)$ and $b(H,w)$ can be obtained when the thresholds and weights are determined. For example, if we set T=98.5, and w= [0.5, 0.5], then $a(0.985,[0.5, 0.5])$ is the associated probability of missed crises. Similarly, $b(0.985,[0.5, 0.5])$ is the probability of false alarms.

In our analysis we let the value of H range between 90% and 99% (with steps of 0.2%) to examine which value of the threshold gives the best performance of the indices.[8] Likewise, we set c_1 equal to 1 and let $(c_2 - c_1)$ vary from 5 to 50 in steps of 5.

Table 5 shows the loss for RMMPI and NMMPI in different scenarios. The table shows that the loss of RMMPI is larger than NMMPI in almost all cases, except in the case that (c_2-c_1) equals 5 and 10. In addition, the loss of RMMPI increases faster than that of NMMPI when the value of (c_2-c_1) varies from 5 to 50. We therefore conclude

[8] Changing the second condition, i.e. the index shows an increase compared to the previous period of at least 5%, has little impact on the empirical results. Results available on request.

that NMMPI has a smaller loss than RMMPI and this result is robust for increasing values of (c_2-c_1).

[Insert Table 5 here]

6. Sensitivity analysis

In this section we compare the performance of RMMPI and NMMPI for different samples of countries, sample periods, window lengths, and benchmarks.[9]

We first compare the performance of the two indices for different subsamples of countries. Table 6 shows the results of identifying banking crises in industrial economies and developing economies. According to the benchmark, there were 11 and 64 banking crises in industrial economies and developing economies, respectively. In industrial economies, both RMMPI and NMMPI can signal 8 out of 11 banking crises, while the frequency of false alarms of NMMPI is larger than that of RMMPI. Therefore, RMMPI performs better than NMMPI in industrial countries. In developing economies, NMMPI signals crises more accurately with fewer missed crises and false alarms than RMMPI.

[Insert Table 6 here]

To investigate the performance of our indices over time, we divide our sample

[9] We have done the sensitivity analysis using all indices. The results (available on request) show that RMMPI and NMMPI perform better than the other indices, so we do not show the results for the other indices.

period into three sub-periods: 1970-1989, 1990-1999, and 2000-2009. Table 7 shows that the frequency of missed crises and false alarms of NMMPI is lower than that of RMMPI in all three sub-periods.

[Insert Table 7 here]

Because the weights used in constructing the indices are based on the standard deviations of a certain time window, empirical results may differ if we use different window lengths. So, we compare the four indices over different time windows. In line with Von Hagen and Ho (2007), we choose windows of 12 months, 18 months, 30 months, and 36 months.[10] According to the results (available on request), NMMPI has the lowest frequency of missed crises and false alarms in all four cases.

As outlined in section 4, we have followed Von Hagen and Ho's (2007) rule to determine whether a signal correctly identifies a banking crisis, i.e. if the signal is in the window of (T-2, T+1) where T is the crisis period according to the benchmark it is considered as a correct signal. We have checked how sensitive our results are for this choice. It turns out that slightly enlarging the window to (T-2, T+2) hardly change the results. For illustrative purposes, Table 8 shows the outcomes for NMMPI.

[Insert Table 8 here]

[10] If the length of time window is too long, observations will be lost and the signal accuracy will be lower.

Finally, we check whether our results depend on the benchmark chosen. As an alternative benchmark, we use the banking crises listed by Reinhart and Rogoff (2009). According to the new benchmark, our sample includes 69 banking crises from 1977 to 2009.

As Table 9 shows, NMMPI still has the lowest frequency of missed crises and false alarms, in line with our previous findings. Particularly, NMMPI2 with a time window of 24 months signals banking crises more accurately than the other indices.[11]

[Insert Table 9 here]

7. Conclusion

The identification of banking crises is crucial for further research on banking crises. Different from the events methods, Von Hagen and Ho (2007) proposed an index of money market pressure to identify banking crises. We modify this index and apply it to a large set of countries. The main change is that in our modified index nominal interest rates are used instead of real interest rates as the former better capture money market stress, notably in developing countries. To avoid sample selection bias, our sample includes not only countries that suffered from one or more banking crises but also includes without banking crises. Our sample consists of 136 countries, including 22 industrial economies and 114 developing economies. We employ the database of banking crises in Laeven and Valencia (2010) as benchmark.

[11] If we compare the signals according to the Von Hagen and Ho (2007) index using the benchmark of Reinhart and Rogoff (2009), the results show that VHH can identify 42 crisis correctly and 183 wrongly. So NMMPI performs better than VHH.

Our findings suggest that our preferred index outperforms the index of Von Hagen and Ho (2007). The crises indentified by our index are more in line with the benchmark of Laeven and Valencia (2010), while the index also gives fewer false alarms. This conclusion is robust when we use different groups of countries, different periods and different time windows.

We also find that money market pressure indexes, be it the original index of Von Hagen and Ho (2007) or our modified index, suggest many more banking crises than those included in the database of Laeven and Valencia (2010). We argue that most of the 'false alarms' indicate crises which are missed by our benchmark, a crisis not severe enough to be considered as systemic by our benchmark, or reflects stress in the banking sector.

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References

Berge, T.J., Jorda, O. 2011. Evaluating the classification of economic activity into recessions and expansions American Economic Journal: Macroeconomics, 3, 246-277.

Bordo, M.D., Eichengreen, B., Klingebiel, D., Martinez-Peria, M.S. 2001. Is the crisis problem growing more severe? Economic Policy 16 (32), 51-82.

Boyd, J., De Nicolo, Loukoianova, E. 2009. Banking crises and crisis dating: Theory and evidence. IMF Working Paper 09/141.

Caprio, G., Klingebiel, D. 1996. Bank insolvencies: Cross-country experience. World Bank Policy Research Working Paper 1620.

Davis, E.P., Karima, D. (2008a). Comparing early warning systems for banking crises. Journal of Financial Stability 4 (2), 89-120.

Davis, E.P., Karima, D. (2008b). Could early warning systems have helped to predict the subprime crisis? National Institute Economic Review 206 (1), 25-37.

Demirgüç-Kunt, A., Detragiache, E. 1998. The determinants of banking crises in developed and developing countries. IMF Staff Papers 45 (1), 81-109.

Demirgüç-Kunt, A., Detragiache, E. 2000. Monitoring banking sector fragility: a multivariate logit approach. World Bank Economic Review 14 (2), 287–307.

Demirgüç-Kunt, A., Detragiache, E. 2002. Does deposit insurance increase banking sector fragility? Journal of Monetary Economics 49 (7), 1373-1406.

Demirgüç-Kunt, A., Detragiache, E. 2005. Cross-country empirical studies of systemic bank distress: A survey. IMF Working Paper 05/96.

Duttagupta, R., Cashin, P. 2008. The anatomy of banking crises. IMF Working Paper 08/93.

Eichengreen, B., Rose, A.K., Wyplosz, C. 1996a. Speculative attacks on pegged exchange rates: An empirical exploration with special reference to the European Monetary System. In: The New Transatlantic Economy, Canzoneri, M.B., Masson, P.R., Grilli, V.U. (eds.), pp. 191–228. Cambridge, Cambridge University Press.

Eichengreen, B., Rose, A.K., Wyplosz, C. 1996b. Contagious currency crises: First tests. Scandinavian Journal of Economics 98(4), 463–84.

Frydl, E. 1999. The length and cost of banking crises. IMF Working Paper 99/30.

Furceria, D., Mourouganeb, A. 2012. The effect of financial crises on potential output: New empirical evidence from OECD countries. Journal of Macroeconomics 34 (3), 822–832.

Hutchinson, M., Noy, I. 2005. How bad are the twins? Output costs of currency and banking crises. Journal of Money, Credit and Banking 37 (4), 725–752.

IMF. 1998. World Economic Outlook. Chapter IV: Financial crises: Characteristics and indicators of vulnerability. Washington DC, IMF.

Kaminsky, G.L., Reinhart, C.M. 1999. The twin crises: The causes of banking and balance-of-payments problems. American Economic Review 89 (3), 473-500.

Laeven, L., Valencia, F.V. 2008. System banking crises: A new database. IMF Working Paper 08/224.

Laeven, L., Valencia, F.V. 2010. Resolution of banking crises: The good, the bad, and the ugly. IMF Working Paper 10/146.

Laeven, L., Valencia, F.V. 2013. Systemic banking crisis database: An update. IMF Economic Review, 61, 225-270.

Lestano, Jacobs, J.P.A.M. 2007. Dating currency crises with ad hoc and extreme value based thresholds: East Asia 1970-2002. International Journal of Finance and Economics 12 (4), 371-388.

Reinhart, C.M., Rogoff, K. 2009. This Time is Different: Eight Centuries of Financial

Folly. Princeton, Princeton University Press.

Von Hagen, J., Ho, T. 2007. Money market pressure and the determinants of banking crises. Journal of Money, Credit and Banking 39 (5), 1037–1066.

Appendix 1. Summary of crises identified by different indicators

Country	(1) L&V (2010)	(2) NMMPI	(3) VHH (2007)	(4) VHH replicated in this paper
Albania	No	1997-1998		1997
Algeria	No	1998		1998-1999
		2005		
Angola	No	1999-2001		1999
				2009
Antigua and Barbuda	No	2001		2001
		2009		2009
Argentina	1980-1982	1983		1982
	1989-1991	1989-1990	1989-1990	1989-1991
	1995			
	2001-2003			
Armenia	No	1999		1999
				2008
Aruba	No	1995-1999		1988
				1995-1997
Austria	No	1977-1981		1977-1981
		1988		
Azerbaijan	No	2009		2002-2006
Bahamas, The	No			1978-1980
		1983-1987		1984-1988
		1990		
Bangladesh	No	1996		1996
		2006-2008		2008
Barbados	No	1981-1983		1981-1983
		1989-1992		1989-1991
Belarus	No	1998-2000		1997-1998
Benin	No	2007-2008		2008
Bolivia	No	2002-2003		2002-2004
Botswana	No	2004		2005
Brazil	1990-1994	1994-1998	1989	1990
	1994-1998			1997
				2001
Bulgaria	1996-1997	1996		1995-1996
Burkina Faso		1979-1981		1979-1981
	1990-1994	1992		
		2007		

Country	(1) L&V (2010)	(2) NMMPI	(3) VHH (2007)	(4) VHH replicated in this paper
Burundi				1991
	1994-1998	1995-1996		1995-1996
		2001		
Cambodia	No	2003		1999-2003
Cameroon				1984
	1987-1991	1988-1990		1987-1990
	1995-1997	1994-1997		
Canada	No			1979-1980
		1985-1986		1985-1986
		1991-1992		
Cape Verde	No	2000-2003		2000-2003
Central African Republic				1983-1985
	1995-1996	1994-1996		1994
		1998		1999
Chad	1992-1996	1990-1994		1988-1989
				1997
				1998
Chile	No		1984	
		2004		2004
China, P.R.: Macao	No	1997-2000		2000-2004
				2009
Colombia	1998-2000	1999		
				2005-2007
Congo, Republic of	1992-1994	1994-1995		1995
				1998-2000
Costa Rica	1987-1991	1986-1990		1985-1986
	1994-1995	1994-1995		1994
				1997
				2003
Cote d'Ivoire	No	1979-1982	1980	1981-1985
		1992		
			1995	1997-1998
Croatia	1998-1999			2001
		2008-2009		2009
Cyprus	No	1998		
		2006		2004-2006
Czech Republic	1996-2000	1997-1998		
		2005		2005-2008

Country	(1) L&V (2010)	(2) NMMPI	(3) VHH (2007)	(4) VHH replicated in this paper
Denmark		1978-1982	1982	
		1993	1993	1993-1995
				2001-2004
	2008-2009			2008
Djibouti	No	2008		2008-2009
Dominica		1988-1993		1993
		2001		1999-2000
	2003-2004			2005
Dominican Republic	No	2003-2004		2003
				2009
Ecuador	1982-1986			
		1992-1993		1992
	1998-2002	1998		1998-1999
Egypt	No	2004-2008		2007
El Salvador	No	1999		1999
Equatorial Guinea	No	1990-1994		1989-1991
		1996		
Estonia	No	1997		1996
				2005-2006
Fiji	No	1994-1996		1994-1997
		2000		
Finland		1986	1989	
	1991-1995	1991-1992		1991-1995
				1997
France	No	1979-1982		1978-1979
		1992		1992-1993
Gabon	No	1994-1998		1992-1995
				2002
Gambia, The	No	1987-1990		1988
		2002		
				2008
Georgia	No	2003-2006		2004-2006
Greece	No		1984	
		1991		
		1997		1997-2000
Grenada	No	1987-1989		1988-1989
		2001		
				2008
Guatemala	No	2001		2001

Country	(1) L&V (2010)	(2) NMMPI	(3) VHH (2007)	(4) VHH replicated in this paper
Guinea-Bissau	1995-1998	1992		1993
		2008		2008
Haiti	1994-1998			
		2000-2003		2000-2003
Honduras	No			1987-1991
		1994-1995		
Hungary	1991-1995	1993		
				2001
	2008-2009	2008		2006-2008
Iceland	No	2001-2002		2002-2005
Indonesia			1985	
				1990-1993
	1997-2001	1997-1998		1998
				2005
Israel	No	1988-1991		1989-1993
Italy	No	1979		
		1992-1995	1992	
				1998
Jamaica	No	2002		2000
		2009		2009
Japan		1979-1980	1980	
			1985	
		1995		1995
	1997-2001			2003-2004
		2006		
Jordan	No	2004-2006		2004-2005
Kazakhstan		1999		
				2003-2004
	2008-2009	2007		
Kenya				1978
	1985	1982		
	1992-1994	1993-1994	1993	1992-1994
		2002		2002-2003
Korea, Republic of		1984-1988		1984-1988
		1990-1992		1992
	1997-1998	1997		1997
Kuwait	No	1995-1998		1998-2000
				2009
Kyrgyz Republic	1995-1999	1998		1999-2000

Country	(1) L&V (2010)	(2) NMMPI	(3) VHH (2007)	(4) VHH replicated in this paper
Lao, P.D.R.	No	2001		2001
				2009
Latvia	1995-1996			
		2001		1999-2001
	2008	2009		2008
Liberia	No	2008		2008
Lithuania	1995-1996	1996		
		1999		1998-1999
Macedonia, FYR	No	1996		
		2006		2006-2007
Madagascar	No	2005-2008		2008
Malawi	No	1992		1992-1996
		2006-2008		2006-2008
Malaysia	1997-1999	1997-1998		1997
				2001
				2008
Mali	1987-1991	1992		
				1996-1998
		2008		2007
Mauritius	No	1983		1981
		1993-1994		1993
		2001		2001
		2008		2008
Mexico	1981-1985			
	1994-1996	1994-1995		1994
		1998-1999		
				2005-2009
Moldova	No	1998		
		2006		2009
Mongolia		1997-1998		1998
	2008-2009	2008		2008
Morocco	No	2001-2005		
				2008-2009
Mozambique	No	2001-2005		2001-2005
Myanmar	No	1996		
		2001-2003		2001-2003
Namibia	No	2007		2006

Country	(1) L&V (2010)	(2) NMMPI	(3) VHH (2007)	(4) VHH replicated in this paper
Nepal				1985
	1988	1989-1990		1988
		2005-2008		2004-2008
Netherlands	No	1978-1979		
			1981	1983-1984
		1988	1986	
				1990-1994
Nicaragua	1990-1993	1990		1990
	2000-2001			
Niger		1979		1979
	1983-1985	1981		1987
		1992-1994		1994-1998
				2009
Nigeria			1989	
	1991-1995	1994-1995	1996	1995
		1999		2002
Norway		1982-1986		1986-1987
	1991-1993	1992		
				2004-2006
Oman	No	2004		2004
Pakistan	No	1981-1985		1981
		1991-1992		
		1996-2000		1997-2000
				2003-2006
Panama	No	2006		2005
Paraguay	1995	1997		1997
				2005-2006
		2009		
Peru	No	1998		
		2008		2005-2008
Philippines		1989-1990		1990
	1997-2001	2001		2000-2001
Poland	1992-1994	1993-1994		
				1997-2002
				2008
Portugal	No		1985	
		1990-1992	1991	
				1993-1994

Country	(1) L&V (2010)	(2) NMMPI	(3) VHH (2007)	(4) VHH replicated in this paper
Romania	No	1999		
				2008-2009
Russian Federation	1998	1998		
	2008-2009	2008		2008
Rwanda	No	2005		2005
Samoa	No	1985-1987		
				1989-1992
Sao Tome and Principe	No	2000-2004		2000-2004
Senegal		1981-1983		
	1988-1991			1987-1988
		1992-1993		
			1995	1994-1998
Seychelles	No	1981-1985		1981-1985
		2004-2008		2004
Sierra Leone	1990-1994			
		1996		1996
		2008-2009		2008-2009
Slovak Republic	1998-2002			
		2006		2006
Slovenia	No	1995-1999		
				2001-2002
Solomon Islands	No	1986-1990		1985-1989
		2006		2008
South Africa	No	1981-1983		
		1989		
		2001		2001-2002
				2007
Spain	1977-1981	1978		
		1983-1987	1983	
			1993	1990-1993
Sri Lanka		1981-1983		1981-1983
	1989-1991	1989-1990		1990
				2005-2009
St. Kitts and Nevis	No	1988-1992		1988
		2001-2005		2001-2005
St. Lucia	No			1994
		1999-2001		1999-2003
		2005		
St. Vincent and the Grenadines	No	2001-2005		2001-2005

Country	(1) L&V (2010)	(2) NMMPI	(3) VHH (2007)	(4) VHH replicated in this paper
Suriname	No	1994-1995		1995
Swaziland	1995-1999	1998		
		2004-2006		2004-2006
Sweden			1992	
	2008-2009	2008		2008
Syrian Arab Republic	No			1995-1998
		2005-2008		
Tanzania	No	1997-1998		1997-1998
Thailand	1983	1985	1981	
	1997-2000	1997		1997-2001
Togo		1979-1981		1979
	1993-1994	1992		
				1996-1999
		2008		
Tonga	No	1993-1995		1995
Trinidad and Tobago	No	1986-1989		1986-1988
		1991-1995		1991-1994
Tunisia	1991	1989-1991		
		1994		1994-1996
				2001-2004
Turkey		1994	1996	
	2000-2001	2000-2001		1999-2001
Uganda	1994			
		2001-2005		2001-2005
Ukraine	1998-1999			
	2008-2009	2008-2009		2008
United States		1978-1980		
	1988			
	2007-2009	2008		2008
Uruguay	2002-2005	1998	1981-1984	1998
		2002		2007-2008
		2008		
Venezuela	1994-1998	2002-2003	1988-1990	2002-2003
Yemen, Republic of	No	2009		2009
Zambia	1995-1998	1993-1995		1990
				1995
Zimbabwe	1995-1999	2003-2004		2003-2004

Note: This table shows banking crises according to Laeven and Valencia (2010), and signalled crises according to several pressure indexes for all countries in our sample. Column (1) shows the crises listed in Laeven and Valencia (2010), where “No” indicates that there is no crisis. Column (2) shows all crises

identified by our preferred index, *NMMPI*. Column (3) shows the crises according to the index of Von Hagen and Ho (2007), while column (4) shows the crises if we apply the method of Von Hagen and Ho (2007) to our data.

Appendix 2. Signaled crises according to NMMPI that are in line with crises according to Reinhart and Rogoff (2009) and/or Caprio and Klingebiel (1996)

Country	Signaled crises	Crises periods in the literature
Angola	1999-2001	1992-1998
Bahamas, The	1983-1987; 1990	Late 1980s
Belarus	1998	1995-?
Canada	1985-1986	1983-1985
Central African Rep	1998	1988-1999
China, P.R.: Macao	1997-2000	1992-1999
Cote d'Ivoire	1992	1988-1991
Dominican Rep	2003-2004	2003
Estonia	1997	1998
France	1992	1994-1995
Gabon	1994-1998	1995-?
Gambia, The	1987-1990	1985-1992
Greece	1991	1991-1995
Guatemala	2001	2001
Guinea-Bissau	1992	1995-?
Italy	1992-1995	1990-1995
Kenya	1982	1985-1989
Kenya	2002	1996-2002
Korea, Rep	1984-1988	1983-1988
Latvia	2001	1995-2002
Macedonia, FYR	1996	1993-1994
Mexico	1998-1999	1994-2000
Myanmar	1996	1996
Myanmar	2001-2003	1996-?
Nepal	1990	1988
Niger	1992-1994	Late 1980s
Nigeria	1999	2001-2002
Norway	1982-1986	1988-1993
Paraguay	1997	1995-2002
Peru	1998	1999
Philippines	1989-1990	1981-1987
Romania	1999	1990-2002
Sao Tome and Principe	2000-2004	1980s-1990s
Senegal	1993	1988-1991
Sierra Leone	1996	1990-2002
Spain	1983-1987	1977-1985
Tanzania	1997-1998	Late 1980s; 1990s
Thailand	1985	1980-1987
Tunisia	1994	1991-1995
Turkey	1994	1994

Country	Signaled crises	Crises periods in the literature
Uganda	2001-2005	1994-2002
Venezuela	2002-2003	1994-2002
Zimbabwe	2003-2004	1995-2008

Note: This table summarizes the crises identified by NMMPI that are not in line with the database of Laeven and Valencia (2010), while they are in line with the crises periods as identified by Reinhart and Rogoff (2009) and Caprio and Klingebiel (1996). The second column indicates the crises periods identified by NMMPI. The third column indicates the crises periods given by Reinhart and Rogoff (2009) and/or Caprio and Klingebiel (1996).

Appendix 3. Signals which coincide with stress

Country	Signaled crises:	Events:	Source:
Albania	1997-1998	In 1997, the Rural Commercial Bank, a state-owned bank, was closed.	http://www.bankofalbania.org/web/Brief_History_of_Banking_Supervision_in_Albania_52_2.php
Algeria	1998; 2005	Public banks' losses averaged over 4 percent of GDP each year from 1991 to 2002. Financial restructuring of banks occurred in 1991-94, 1995-98, and 2001.	http://www.imf.org/external/pubs/ft/scr/2004/cr04138.pdf
Armenia	1999	In 2000, RNPL reached a peak of 17.5%	http://www.financebycountry.com/Armenia/indicator-non_performing_loans/
Bangladesh	1996	All banks had high levels of non-performing loans. In 1998, the RNPL reached 40%.	http://www.apu.ac.jp/rcaps/uploads/fckeditor/publications/journal/RJAPS_V29_Uddin.pdf
Bolivia	2002-2003	The average RNPL for 2001-03 is about 17%.	http://www.financebycountry.com/Bolivia/indicator-non_performing_loans/
Cambodia	2003	The average RNPL to total assets in 2002-2003 is about 14%.	http://www.acledabank.com.kh/kh/assets/pdf_zip/Conference2007_05.pdf
Canada	1991-1992	In 1991-1992, 9 financial companies collapsed.	http://en.wikipedia.org/wiki/Canada_Deposit_Insurance_Corporation#List_of_financial_collapses_since_1967
Chile	2004	Affected by the crisis in Argentina in 2002.	http://www.eclac.cl/cgi-bin/getProd.asp?xml=/prensa/noticias/comunicados/9/10739/P10739.xml&xsl=/prensa/tpl-i/p6f.xsl&base=/tpl/top-bottom.xslt
Czech Republic	2005	The average RNPL in 2001-03 is about 8.5%.	http://www.financebycountry.com/Czech-Republic/indicator-non_performing_loans/
Denmark	1993	Crises occurred in 1987-1992	Von Hagen and Ho (2007)
El Salvador	1999	Two bank failures in 1997 and 1998.	http://www.frbatlanta.org/filelegacydocs/erq306_quispe.pdf

Country	Signaled crises:	Events:	Source:
Finland	1986	The incompatibility of prudential regulation with the more competitive environment of the late 1980 was a reason for the fragility of the banks which was revealed in the Finnish banking crisis of the early 1990s.	http://www.bancaditalia.it/studiricerche/convegni/atti/Financial_Market_Regulation/sessione_a/paper_TARKKA.pdf
Fiji	1994-1996	State-owned banks failed in the 1990s, requiring restructuring and recapitalization.	http://www.microfinance-pasifika.org/assets/newsitefiles/reports/ADB_Pacific_Financial_Sector_Review_Vol_1.pdf
Georgia	2003-2006	The average RNPL for 2001-02 is about 10.3%.	http://www.financebycountry.com/Georgia/indicator-non_performing_loans/
Greece	1997	Up to the second half of the 1990s almost 2/3 of Greek banks were controlled by the State and were moreover, badly run.	http://www.bis.org/review/r060907c.pdf
Honduras	1994-1995	The average RNPL for 1998-2000 is about 11%.	http://www.financebycountry.com/Honduras/indicator-non_performing_loans/
Iceland	2001-2002	In 2001 the banking system was deregulated in Iceland. The big and aggressive growth of Iceland's banks started to become remarkable, because of the small economy of Iceland.	http://www.studymode.com/essays/Icelandic-Bank-System-972315.html
Israel	1988-1991	In 1986, the Sheqel's link to the U.S. Dollar was broken.	http://intl.econ.cuhk.edu.hk/exchange_rate_regime/index.php?cid=24
Jamaica	2002	From1996-2002, the banking system had a negative asset growth rate and the RNPL was 12.43%.	http://boj.org.jm/uploads/pdf/papers_pamphlets/papers_pamphlets_An_Early_Warning_Model_of_Bank_Failure_in_Jamaica__An_Information_Theoretic_Approach.pdf
Kazakhstan	1999	Between 1998 and 2001 the number of banks decreased from 71 to 48 due to bank regulation.	http://images.mofcom.gov.cn/ozs/table/kaza/banking.pdf
Kuwait	1995-1998	From 1998 to 2000, the RNPL increase from 10.3% to 19.2%.	http://www.financebycountry.com/Kuwait/indicator-non_performing_loans/
Macedonia, FYR	2006	The average RNPL for 2002-05 is about 20%.	http://www.financebycountry.com/Macedonia/indicator-non_performing_loans/
Moldova	1998	Affected by the crisis in Russia in 1998.	http://en.wikipedia.org/wiki/Economy_of_Moldova
Mongolia	1997-1998	There was a banking crisis in 1998-1999.	http://www.mongolbank.mn/eng/listfinstability.aspx?did=5
Morocco	2001-2005	The average RNPL for 2001-03 is about 20%.	http://www.financebycountry.com/Morocco/indicator-non_performing_loans/
Mozambique	2001-2005	The average RNPL for 2001-05 is about 17.5%.	http://www.financebycountry.com/Mozambique/indicator-non_performing_loans

Country	Signaled crises:	Events:	Source:
Oman	2004	The average RNPL for 2003-04 peaked at about 12%.	http://www.financebycountry.com/Oman/indicator-non_performing_loans/
Pakistan	1991-1992; 1996-2000	The banking sector of Pakistan went through major reforms since 1990; at the end of the 1990s loan default rates increased.	http://www.ukessays.com/essays/economics/how-privatization-effects-banking-sector-of-pakistan-economics-essay.php#ixzz2enUEcGaB
Portugal	1990-1992	Crises occurred in 1986-1989.	Demirgüç-Kunt and Detragiache (2005)
Rwanda	2005	The average RNPL for 2001-05 is about 45%.	http://www.financebycountry.com/Rwanda/indicator-non_performing_loans/
Slovenia	1995-1999	The only bankruptcy in the banking system in Slovenia took place in the year 1996.	http://www.oecd.org/finance/financial-markets/49497940.pdf
South Africa	1981-1983	Financial crises occurred due to default of foreign banks in 1985.	Demirgüç-Kunt and Detragiache (2005)
South Africa	2001	Three banks failed in 2001-2002.	http://www.resbank.co.za/Publications/Reports/Documents/Annual%20Report%202001.pdf
Suriname	1994-1995	In 1994 the inflation rate was over 400%.	http://www.encyclopedia.com/topic/Suriname.aspx
Syrian Arab Republic	2005-2008	In 2004-2005, the fast-paced credit expansion is likely to have weakened the quality of banks' loan portfolios —given weak risk management practices—and made banks run into liquidity problems.	http://www.bi-me.com/main.php?id=5344&t=1&c=6&cg=2&mset=
Tonga	1993-1995	One foreign-owned bank was in trouble.	http://www.microfinance-pasifika.org/assets/newsitefiles/reports/ADB_Pacific_Financial_Sector_Review_Vol_1.pdf
United States	1978-1980	Crises occurred in 1980-1992.	Von Hagen and Ho (2007)
Uruguay	2002-2005	Affected by the crisis in Argentina at 2002.	http://www.eclac.cl/cgi-bin/getProd.asp?xml=/prensa/noticias/comunicados/9/10739/P10739.xml&xsl=/prensa/tpl-i/p6f.xsl&base=/tpl/top-bottom.xslt

Note: This table indicates important events during the periods identified by NMMPI. The second column lists the crises periods, the third column lists the important events, and the last column lists the resources from where we collect the information. "RNPL" denotes the ratio of non-performing loans to total assets.

Table 1. Definition of indices used

Index	Definition
VHH	MPI proposed by Von Hagen and Ho (2007)
RMPI	MPI constructed using real interest rates and 24-months moving window for standard deviation
NMPI	MPI constructed using nominal interest rates and 24-months moving window for standard deviation
RMMPI	MMPI (equation 2) constructed by using real interest rates and 24-months moving window for standard deviation
NMMPI	MMPI (equation 2) constructed by using nominal interest rates and 24-months moving window for standard deviation

Note: This table shows the definitions of five indices used in the empirical tests.

Table 2. Summary of money market pressure indices for 10 countries

Country	Index	Mean	Max	Min	Median	S.D	N	Number of crises
Argentina	VHH	-0.062	8.628	-11.26	-0.013	1.423	345	4
	RMPI	6.355	215.571	-16.03	-0.166	115.874	345	
	NMPI	12.524	419.15	-16.053	-0.107	225.876	345	
	RMMPI	0.08	27.864	-0.368	-0.001	1.501	345	
	NMMPI	0.166	54.305	-0.528	-0.001	2.925	345	
Brazil	VHH	-0.051	7.866	-7.622	-0.005	1.409	230	2
	RMPI	-0.204	11.785	-21.236	-0.224	2.235	230	
	NMPI	0.034	15.297	-16.027	-0.122	2.232	230	
	RMMPI	0	0.105	-0.031	-0.001	0.01	230	
	NMMPI	0	0.098	-0.054	-0.001	0.01	230	
Indonesia	VHH	-1.228	3.072	-6.885	-0.785	1.376	271	1
	RMPI	-4.423	7.314	-48.022	-4.085	3.979	271	
	NMPI	0.063	41.452	-7.458	-0.15	3.134	271	
	RMMPI	-0.038	0.025	-0.215	-0.024	0.04	271	
	NMMPI	0	0.115	-0.059	-0.001	0.014	271	
Japan	VHH	-0.926	19.478	-4.327	-0.763	1.441	388	1
	RMPI	-5.604	2.829	-50.172	-3.2	6.328	388	
	NMPI	0.117	43.066	-6.697	-0.012	2.796	388	
	RMMPI	-0.002	0.001	-0.01	-0.001	0.002	388	
	NMMPI	0	0.002	-0.002	0	0	388	
Korea	VHH	-1.012	13.575	-5.258	-0.762	1.372	383	1
	RMPI	-9.222	15.794	-35.366	-8.735	6.08	383	
	NMPI	-0.096	32.47	-4.658	-0.184	2.356	383	
	RMMPI	-0.044	0.079	-0.181	-0.037	0.036	383	
	NMMPI	0	0.134	-0.026	0	0.01	383	
Malaysia	VHH	-1.775	1.563	-13.506	-1.239	1.450	183	1

Country	Index	Mean	Max	Min	Median	S.D	N	Number of crises
	RMPI	-22.825	-0.475	-89.082	-11.758	23.471	183	
	NMPI	0.269	36.948	-18.293	-0.016	4.373	183	
	RMMPI	-0.014	0	-0.071	-0.011	0.013	183	
	NMMPI	0	0.031	-0.033	0	0.005	183	
Mexico	VHH	-0.396	5.771	-5.999	-0.122	1.431	316	2
	RMMPI	-5.282	6.477	-72.358	-2.801	10.708	316	
	NMMPI	0.142	11.002	-14.671	0.008	2.165	316	
	RMMPI	-0.02	0.019	-0.108	-0.013	0.02	316	
	NMMPI	0	0.093	-0.021	0	0.008	316	
Philippines	VHH	-1.523	3.820	-13.054	-1.186	1.491	230	1
	RMPI	-8.653	2.943	-43.279	-3.83	10.48	230	
	NMPI	-0.072	11.063	-7.978	-0.188	1.962	230	
	RMMPI	-0.013	0.005	-0.057	-0.008	0.01	230	
	NMMPI	0	0.04	-0.032	0	0.005	230	
	RMPI	-2.564	21.27	-12.883	-1.655	3.564	255	
Turkey	VHH	-0.495	6.421	-9.067	-0.092	1.451	255	1
	NMPI	0.074	23.182	-8.574	-0.081	2.763	255	
	RMMPI	-0.013	0.042	-0.116	-0.009	0.016	255	
	NMMPI	0	0.186	-0.115	0	0.019	255	
United States	VHH	-1.163	5.553	-8.289	-0.841	1.431	389	2
	RMPI	-8.475	59.435	-63.06	-6.506	10.467	389	
	NMPI	0.321	60.412	-9.103	0.118	3.56	389	
	RMMPI	-0.002	0.005	-0.012	-0.002	0.003	389	
	NMMPI	0	0.007	-0.007	0	0.001	389	

Table 3. Contingency table for concepts in assessing crisis signals

Crises	Identified in the benchmark	Not identified in the benchmark
Identified in this paper	Correct crises	False alarms
Not identified in this paper	Missed crises	

Table 4. Assessing the predictive power of the indices

Index	VHH	RMPI	RMMPI	NMPI	NMMPI
Total number of crises in the benchmark	75	75	75	75	75
Correct crises	40	49	47	53	54
Type I error (missed crises)	35	26	28	22	21
Type II error (false alarms)	181	181	158	218	166
Frequency of Type I error	46.67%	34.67%	37.33%	29.33%	28.00%
Frequency of Type II error	81.90%	78.70%	77.07%	80.44%	75.45%

Note: This table shows the predictive power of five monetary pressure indices (see Table 1 for their definition), and zooms in on type I and type II errors in identifying banking crises. “Correct crises” is the number of crises identified correctly according to the benchmark of Laeven and Valencia (2010).

Table 5.Values of the loss function in Equation (4) for different values of (c_2-c_1)

(c_2-c_1)	NMMPI	RMMPI	Difference
5	2.339	2.300	0.039
10	2.346	2.330	0.016
15	2.352	2.361	-0.009
20	2.358	2.392	-0.034
25	2.365	2.423	-0.058
30	2.371	2.454	-0.083
35	2.377	2.487	-0.110
40	2.384	2.519	-0.135
45	2.390	2.552	-0.162
50	2.397	2.585	-0.188

Table 6. Results for different samples of countries

	NMMPI	RMMPI
Industrial countries		
Total crises in the benchmark	11	11
Correct crises	8	8
Type I error (missed crises)	3	3
Type II error (false alarms)	30	24
Frequency of Type I error	27.27%	27.27%
Frequency of Type II error	78.95%	75.00%
Developing countries		
Total crises in the benchmark	64	64
Correct crises	46	39
Type I error (missed crises)	18	25
Type II error (false alarms)	136	134
Frequency of Type I error	28.13%	39.06%
Frequency of Type II error	74.73%	77.46%

Note: See Table 4.

Table 7. Results for different periods

Index:	Period:	1970-1989	1990-1999	2000-2009
	Total crises in the benchmark	15	46	14
NMMPI	Correct crises	9	34	11
	Type I error	6	12	3
	Type II error	42	54	70
	Frequency of Type I errors	40.00%	26.09%	21.43%
	Frequency of Type II errors	82.35%	61.36%	86.42%
RMMPI	Correct crises	4	33	10
	Type I error	11	13	4
	Type II error	20	48	90
	Frequency of Type I errors	73.33%	28.26%	28.57%
	Frequency of Type II errors	83.33%	59.26%	90.00%

Note: See Table 4.

Table 8. Two types of errors for different crises periods

	Missed crises	False alarms
NMMPI	21	166
NMMPI with different window	17	161

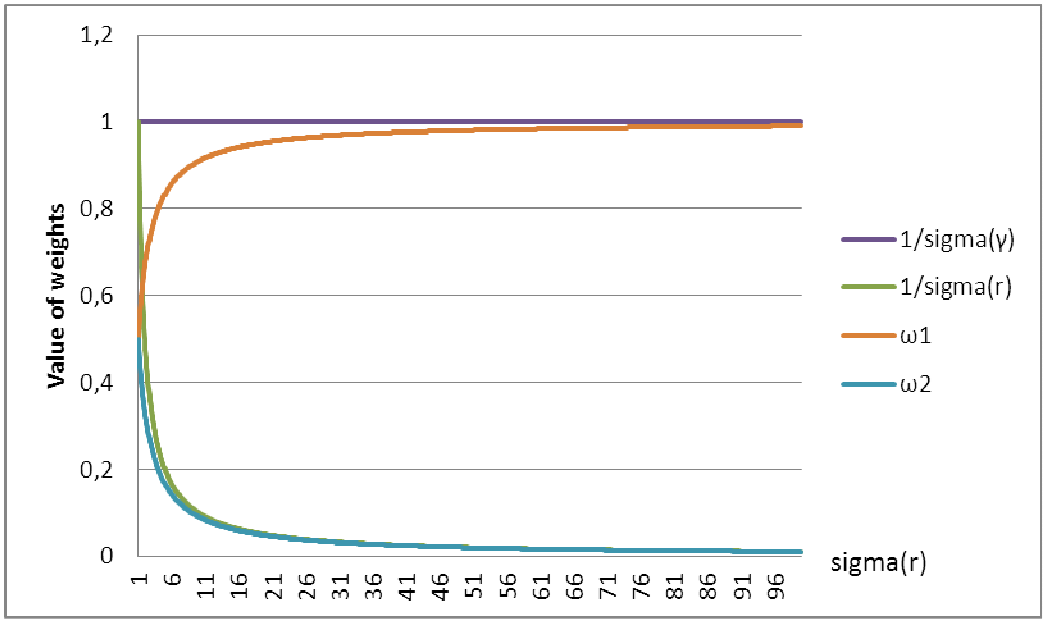
Note：This table shows the two types of errors for two indices. If there is a crisis at time T in the benchmark, the signal of NMMPI is correct if it falls in the period of [T-2, T+1]. In the alternative this period is set at [T-2, T+2].

Table 9. Robustness test using the benchmark of Reinhart and Rogoff (2009)

Index:	RMPI	RMMPI	NMPI	NMMPI
Window=12 Months				
Total crises in the benchmark	71	71	71	71
Correct crises	46	42	51	49
Type I error (missed crises)	25	29	20	22
Type II error (false alarms)	194	179	221	167
Frequency of Type I errors	35.21%	40.85%	28.17%	30.99%
Frequency of Type II errors	80.83%	81.00%	81.25%	77.31%
Window=18 Months				
Total crises in the benchmark	71	71	71	71
Correct crises	43	42	45	49
Type I error (missed crises)	28	29	26	22
Type II error (false alarms)	191	173	230	170
Frequency of Type I errors	39.44%	40.85%	36.62%	30.99%
Frequency of Type II errors	81.62%	80.47%	83.64%	77.63%
Window=24 Months				
Total crises in the benchmark	69	69	69	69
Correct crises	44	41	43	49
Type I error (missed crises)	25	28	26	20
Type II error (false alarms)	181	160	221	163
Frequency of Type I errors	36.23%	40.58%	37.68%	28.99%
Frequency of Type II errors	80.44%	79.60%	83.71%	76.89%
Window=30 Months				
Total crises in the benchmark	68	68	68	68
Correct crises	41	38	42	47
Type I error (missed crises)	27	30	26	21
Type II error (false alarms)	180	165	207	160
Frequency of Type I errors	39.71%	44.12%	38.24%	30.88%
Frequency of Type II errors	81.45%	81.28%	83.13%	77.29%
Window=36 Months				
Total crises in the benchmark	65	65	65	65
Correct crises	40	38	40	45
Type I error (missed crises)	25	27	25	20
Type II error (false alarms)	176	155	209	167
Frequency of Type I errors	38.46%	41.54%	38.46%	30.77%
Frequency of Type II errors	81.48%	80.31%	83.94%	78.77%

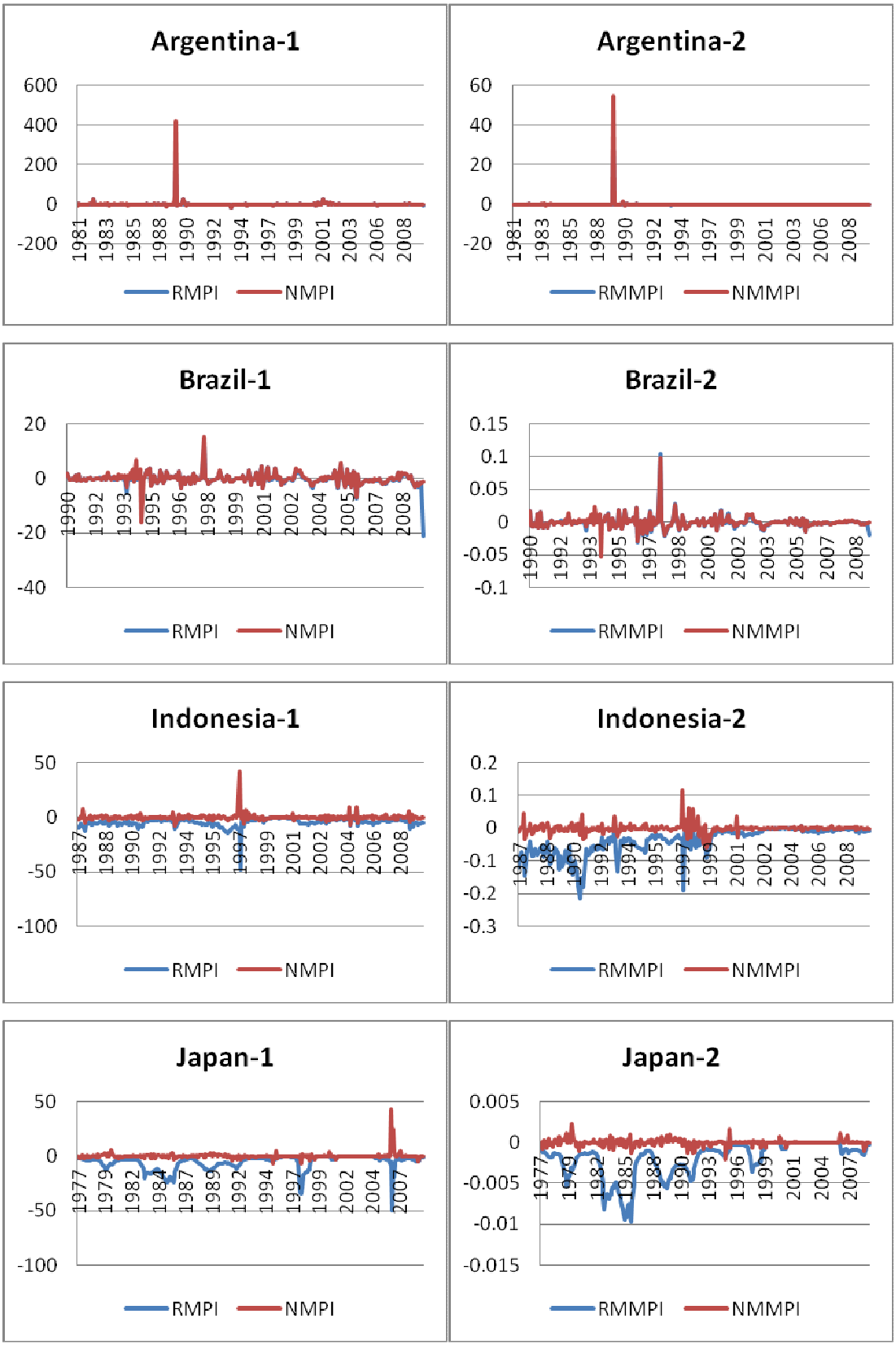
Note: This table shows the results of four indices with the benchmark given by Reinhart and Rogoff (2009). In this table, we show the results with the rolling time window of 12, 18, 24, 30, and 36 months for calculating the standard deviations. “Correct crises” is the number of crises the index identifies correctly according the benchmark.

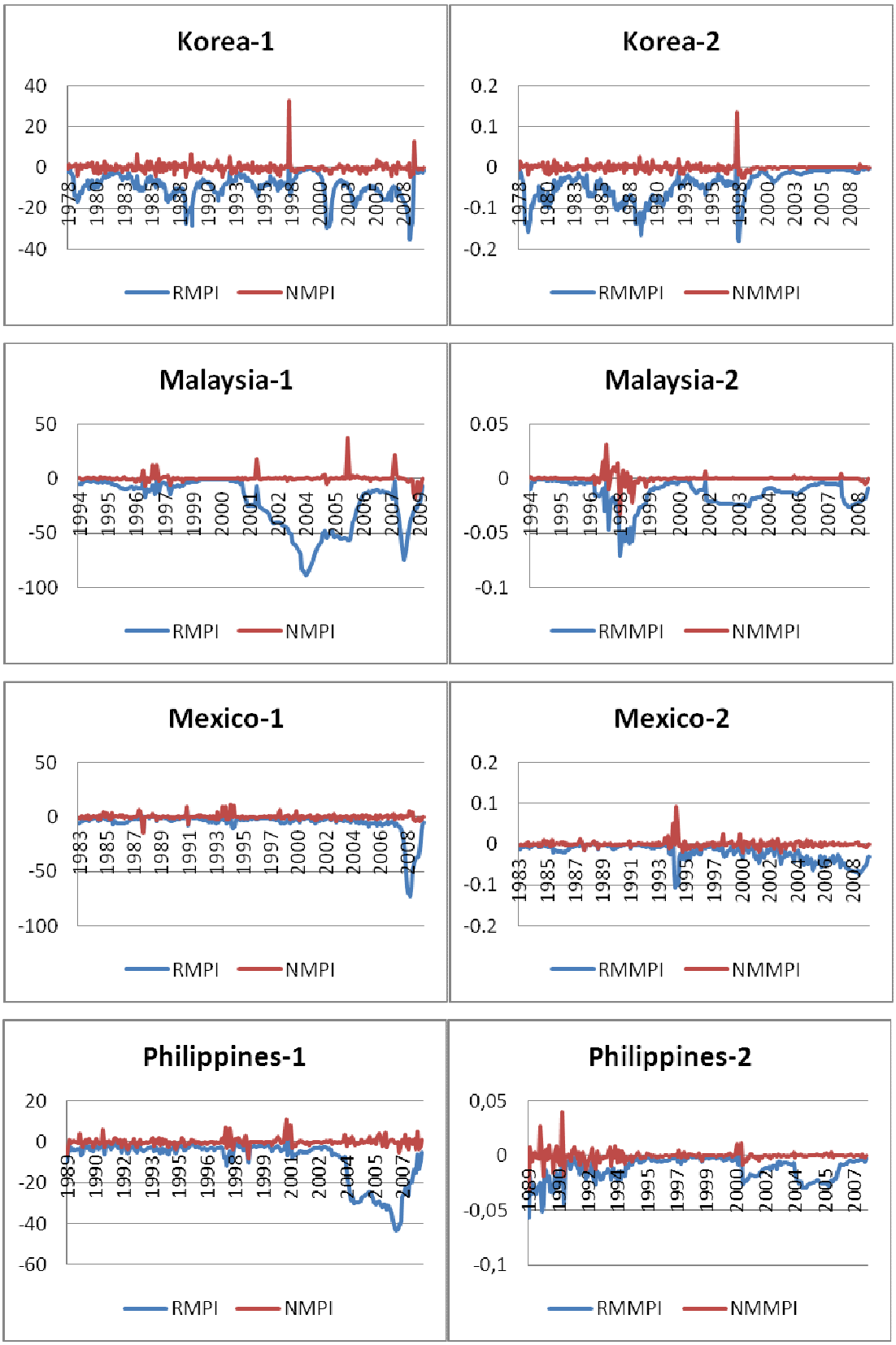
Figure 1. MPI and MMPI for different weights for two components

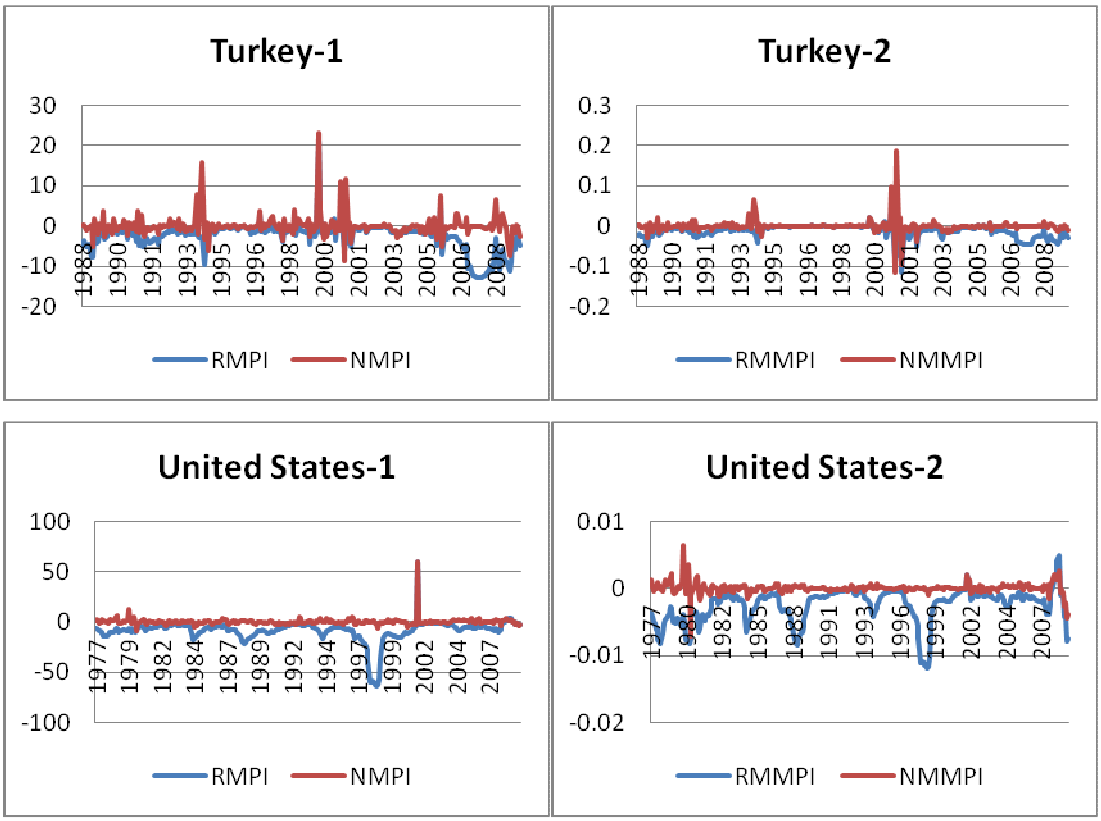


Note: This figure shows the differences between weights in equation (1) and (2). Sigma(γ) and sigma(r) are the weights in equation (1), and ω1 and ω2 are the weights in equation (2). In this figure, we set the value of sigma(γ) to 1 while the value of sigma(r) varies from 1 to 100.

Figure 2. Money market pressure indices of money market pressure in 10 countries




Korea-1
40
20
0
-20
-40
1978 1980 1983 1985 1988 1990 1993 1995 1998 2000 2003 2005 2008
RMPI
NMPI
Korea-2
0.2
0.1
0
-0.1
-0.2
1978 1980 1983 1985 1988 1990 1993 1995 1998 2000 2003 2005 2008
RMMPI
NMMPI
Malaysia-1
50
0
-50
-100
1994 1995 1996 1997 1999 2000 2001 2002 2004 2005 2006 2007 2009
RMPI
NMPI
Malaysia-2
0.05
0
-0.05
-0.1
1994 1995 1996 1998 1999 2000 2002 2003 2004 2006 2007 2008
RMMPI
NMMPI
Mexico-1
50
0
-50
-100
1983 1985 1987 1989 1991 1993 1995 1997 2000 2002 2004 2006 2008
RMPI
NMPI
Mexico-2
0.2
0.1
0
-0.1
-0.2
1983 1985 1987 1989 1991 1993 1995 1997 2000 2002 2004 2006 2008
RMMPI
NMMPI
Philippines-1
20
0
-20
-40
-60
1989 1990 1992 1993 1995 1996 1998 1999 2001 2002 2004 2005 2007
RMPI
NMPI
Philippines-2
0,05
0
-0,05
-0,1
1989 1990 1992 1994 1995 1997 1999 2000 2002 2004 2005 2007
RMMPI
NMMPI



Note: This figure plots four money market pressure indices for the selected countries. The first graph for each country shows RMPI and NMPI constructed according to equation (1), and the second one presents RMMPI and NMMPI constructed according to equation (2).