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Macroprudential Research: Selected Issues
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EDITORIAL

Central banks significantly expanded their domain following the global financial crisis. Macroprudential policy, which marries the issues of financial stability and financial supervision with macroeconomic stabilisation, became its new core competence. This new competence needed a wide analytical basis. Therefore, the European System of Central Banks established the Macro-prudential Research Network (MaRs), which concluded its three-year existence in June 2014.

This edition of the Research Bulletin presents five articles that rank among the CNB's numerous contributions to the MaRs, covering diverse issues related to macroprudential policy. **The first** article provides a theoretical model of systemic risk arising from excessive collateral diversification. It shows that such diversification pitfalls can be avoided by means of a simple bail-in mechanism. **The second** article uses classification and regression trees to assess conditions preceding banking and currency crises in developed countries. It finds that the information provided by many early warning indicators is conditional on the levels of other indicators. **The third** article employs extreme value theory to identify the concurrence of crises and asset price misalignments on CEE asset markets. It shows that the potential for co-alignment in terms of crises and departures from equilibrium is high across both countries and markets in the CEE region. **The fourth** article studies the interlinkages between financial and real sectors in a small open economy. Employing a threshold Bayesian VAR the authors find that procyclicality of the financial sector affects the real economy, and non-linearity is in turn present in the responses of the financial sector to real shocks. **The last** article assesses the contagion risk in the Czech banking system using network analysis and simulations. It finds that the interbank market network is relatively sparse and highly heterogeneous and the system is resilient to contagion due to credit losses.

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IN THIS ISSUE

Collateral Diversification Pitfalls and Systemically Important Merchant Banks[1]

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It is both an empirical fact and a theoretical regularity justifiable by a host of financial intermediation models based on the notion of risk diversification (an early example is Woodford, 1990) that firms tend to hold cash and other liquid financial instruments in excess of working capital and other assets immediately linked to their business. Usually considered apt as financial reserves in terms of safety, low volatility and liquidity are fixed-income instruments issued by big multinational financial institutions. (We use an older term, *merchant banks*, to mark the advent of a new, post-Lehman state of the global financial industry in which investment banks in the narrow sense, as opposed to the business they conducted, practically ceased to exist. Alternatively, one sometimes talks about shadow banking, although the latter notion is much broader than what is under discussion here.) When a firm takes a loan, its activity-unrelated assets become part of the collateral (we call them *outside collateral*). If the loan is in default, the collateral is seized by the lender and put up for sale. In the outside collateral case, this means that selling pressure is exercised on financial instruments that have nothing to do with the defaulting firm itself. Spillover effects are a consequence.

In the process of channelling non-financial companies' free cash into presumably well-diversified products of investment banking, the financial intermediaries involved, usually through a chain of mutual exposures, end up holding claims on the same universe of producers. Since the latter partially finance their activities with commercial bank debt and, at the same time, are subject to both firm-specific and aggregate productivity shocks, merchant banks hold claims with lower seniority than commercial banks. Under an adverse productivity shock leading to a producer's default on a loan, the borrower's assets are seized by the commercial bank, whereas the merchant bank, being a residual claimant, gets nothing. Moreover, the failing borrower's assets include claims on the merchant banking sector. That is why, if the adverse shock is aggregate, the consolidated merchant banking sector balance sheet experiences a disproportional stress compared to the corporate sector. A merchant bank's probability of failure is then typically much higher than the default frequency of its non-financial partners, which include investors in its liabilities and companies in which it holds capital shares. The destiny of investment banks in the US in 2007–2009 provides a good example of this.

Accordingly, our research looks into the accumulation of systemic risk in the investment banking sector, which assists the corporate sector in diversifying firm-level risks. We examine the ways in which the heterogeneous ("diversified") collateral held by merchant banks can cause them to be fragile. This is a question earlier macroeconomic models have not covered sufficiently, and it

[1] This article is based on Derviz (2013, 2014).

requires financial assets and contracts to be specified in more detail than they are in those models. In a different strand of literature stressing the probabilistic side of the problem, diversification leading to the opposite of its initial goal, i.e. risk concentration, has been quantitatively examined by, for example, Ibragimov et al. (2011) and a host of earlier papers cited therein. In our approach, the diversification curse is accommodated in a standard choice-theoretic environment of a production economy.

The main adverse consequence of a merchant bank default is the associated shock wave of systemic illiquidity. In purely accounting terms, the loss on the merchant bank balance sheet resulting from an aggregate downturn in the producer sector may be quite small. However, as every observer of a financial firm resolution knows, the process is lengthy, subject to arbitrary legal tangles, and with an uncertain completion horizon. In the meantime, everything the merchant bank issued and sold to agents demanding outside collateral is affected by a substantial illiquidity discount. But, with less valuable outside collateral than before, more firms move closer to default, and a vicious circle connecting distressed financial and non-financial balance sheets can emerge.

This is why many regulators and the governments backing them resort to some sort of guarantee for the merchant bank liabilities under their jurisdiction. This policy (practised, for instance, both in the US and in several European countries, among them Ireland, during the crisis years 2008–2009) may fend off the immediate threat of systemic illiquidity, but it can create an enormous one-off burden on public finances around moments when some of the guarantees have to be honoured. The price of maintaining liquidity in the financial system may be too high for a government with an already precarious sovereign debt position, as the Irish and Spanish examples of the near past make clear. One needs policy alternatives that contain spates of illiquidity caused by default, instead of shifting them from sector to sector around the economy like a hot potato.

Going back to default treatment in the earlier mainstream microeconomics, a merchant bank default would be no problem at all if its pecuniary implications were transferred one-to-one to the ultimate creditors and did not receive an institutional spin in the form of a value-destroying bankruptcy procedure. In an environment without financial frictions, this could be achieved if the merchant bank were mandated to issue state-contingent liabilities only (i.e. the payout to the holder would depend on the realisation of some pre-defined indicator, such as the earnings of the issuer or the value of its assets, uncertain at the time of issue). However, in a less stylised model of the world, resembling the one we live in more accurately, the contingent liabilities of a merchant bank may be unsellable to firms for the reason already explained in Townsend's (1979) costly state verification (CSV) model: the impossibility for small shareholders to draw accurate implications from the imperfect information at their disposal in the case of a big and complex merchant bank. Therefore, we suggest an alternative, inspired in equal measure by Townsend (1979) and by the Black-Scholes (1973) and Merton (1974) treatment of risky company debt. Recall that under the Black-Scholes-Merton approach the company assets in default are transferred one to one to the creditor. The same thing happens under the debt contract considered in Townsend (1979). This is tantamount to the creditor becoming a shareholder. The resulting liability is a fixed-income debt instrument in good times and equity in bad times, i.e. essentially a convertible bond. An important formal difference from the classical understanding of the latter is that its covenant makes conversion the decision of the holder. In the setting considered in our paper, the conversion trigger is exogenously tied to the merchant bank's solvency (the current

model is sufficiently simple in this respect, so that one can assume automatic conversion whenever the bank is unable to pay the original deposit rate, without further procedural details). This means that we are interested in constructions that are, essentially, a variety of the so-called contingent convertible (CoCo) bond. In our view, the most important advantage of this bond covenant is that a shareholder of a living company has a much stronger legal standing in what concerns state verification than a creditor of a defaulting company. So, the key proposition we want to exemplify with the formal exercise under discussion is that an insolvent merchant bank should not be sent into bankruptcy, but rather should exchange its fixed income liabilities for shares and then distribute whatever (little) it actually earned among the old and new shareholders. In this way, the consequences of an adverse aggregate productivity shock will not be avoided. They will still be borne. However, under the said conditions of merchant bank bond conversion they only have a one-to-one impact on firm owners, whereas in a pure deposit-taking (or fixed income liability-issuing) merchant bank facing insolvency they are expanded. Additional losses emerge either because of a system-wide shock due to debt workout delays and destruction of value if the merchant bank is allowed to fail or because of a heavy fiscal burden if official deposit guarantees have to be honoured. Accordingly, risks will be diversified as long as they are really diversifiable and not just be different labels of an aggregate risk common to everybody (as in a systemic shock case), whereas the costs of the latter will be distributed predictably among the bank's claimholders without a legal breakdown.

The formal representation of the discussed research, building on an earlier model of financial frictions in a production economy with leverage (Derviz, 2012), offers a justification of the bail-in policy described above. The central element of the model is a firm that borrows from commercial banks and buys outside collateral from merchant banks. Stock in the firm is held by both an initial controlling shareholder and investors that acquire equity partnerships. A partnership is big enough for the owner to be aware of the consequence of its size on the quantity of physical capital employed in the firm. Typical partners are, again, merchant banks. This assumption of the model is justified by the observation that these banks, typically large international institutions with global linkages on both the asset and the liability side, have few choices with regard to investing the funds they raise. They can lend to other financial institutions (thereby adding to the aggregate stock of so-called non-core assets and making the financial system prone to cross-section, or network, disruptions in the case of deleveraging; see Shin and Shin, 2011) or invest in non-financial firms which already hold claims on some other institution in the merchant bank sector. The latter and the producer sector in this (semi-)closed global economy jointly create an additional source of leverage beside the better known one based on commercial bank lending.

In this model, if merchant banks issue liabilities in fixed income form, their sector is more vulnerable to insolvency in low-productivity states of nature than the non-financial sector. A hypothetical regulatory solution that would exclude merchant bank failures and give the loss absorption task back to non-financials would have to mandate merchant banks to fund their assets by equity. However, this policy is likely to be infeasible due to effects described by the theoretical financial intermediation literature: demand for merchant bank common stock does not necessarily exist if investors are unable to establish the appropriate value of the dividend the bank owes them in good times.

Instead of insisting on the unrealistic pure equity solution, we model a regulatory approach relying on the bail-in principle. This means that fixed income merchant bank liabilities receive a mandatory CoCo bond clause. Consequently, the outside collateral instruments provided to non-financials are standard fixed coupon bonds when the merchant bank generates enough revenue to repay, but convert to equity if it does not. Merchant bank failure is excluded by construction, meaning that legal uncertainty, illiquidity and other resolution costs do not apply any more. In the model, the impact of regime switch from official guarantees to the CoCo clause on macroeconomic fundamentals (bank credit, investment, output, interest rates, wages, etc.) turns out to be minimal, given that changes only concern adverse states of nature occurring with a small probability. Altogether, convertible bonds instead of government-insured deposits reduce fragility and public loss risk, but largely preserve the expected welfare level. Quantitatively, in our model firms holding merchant bank CoCos invest and produce almost identically to the earlier government guarantee case (this is, of course, a huge simplification due to our producer risk-neutrality assumption and the primitive merchant bank balance sheet structure), but the expected fiscal costs are now zero as opposed to nearly half of GDP under guarantees.

This line of regulatory policy may be particularly relevant to the containment of systemic events in globally leveraged economies serviced by big international banks outside host country prudential control.

In a small open economy, the adverse effect of international financial intermediary insolvency can be exacerbated if the real sector is the source of domestic GDP, whereas banks and their regulators are predominantly foreign, implying that they mostly care about gross investment and expected bank earnings on a consolidated basis. For this reason, macroprudential policies targeting a particular pattern of collateral diversification (in terms of the discussed model, this is the ratio of collateral value to equity and the structure of the portfolio in which collateral funds are invested) can be important for systemic event propagation. In practice, explicit regulation of the balance sheet composition of global systemically important financial institutions (SIFIs) is extremely cumbersome and costly for everyone, if possible at all. Therefore, an arrangement based on conversion into common stock can simplify things enormously for small claimants unable to bear legal representation costs in a multinational merchant bank resolution process. An international guarantee of their shareholder rights in the event of SIFI insolvency is much easier. One possibility would be to delegate shareholder rights on the nationality principle to an official fiduciary agent. That is, instead of a long and uncertain search for a satisfactory international systemic risk containment mechanism, as one can currently observe, for example, on the G20 level, stepwise international harmonisation based on support for standard shareholder rights seems a lot more feasible.

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Banking and Currency Crises: Differential Diagnostics for Developed Countries[2]

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The recent global financial crisis has reinvigorated interest in models capable of identifying the warning signs of crisis. However, common regression-based models are unable to capture important non-linearities and complex interactions between macroeconomic and financial variables that may exist in the run-up to crises. To address these issues we use the Classification and Regression Tree (CART) methodology and its generalisation, Random Forest (RF) analysis (Breiman et al., 1984). This method, which found extensive use mainly in fields such as medicine, allows for modelling explicitly non-linear interactions between variables and dealing with missing values and outliers, which are usually a problem for regression-based frameworks. The CART and RF frameworks provide crisis thresholds for key variables, thus significantly simplifying the interpretation of the results for decision-makers and non-technical audiences.

This framework has both advantages and disadvantages compared with other common early-warning methods. On the one hand, it allows explicitly for the fact that not all crises are alike and accommodates non-linearities by including conditional thresholds. On the other hand, it is a non-parametric approach that cannot estimate the marginal contributions of each explanatory variable or confidence intervals for the estimated thresholds.

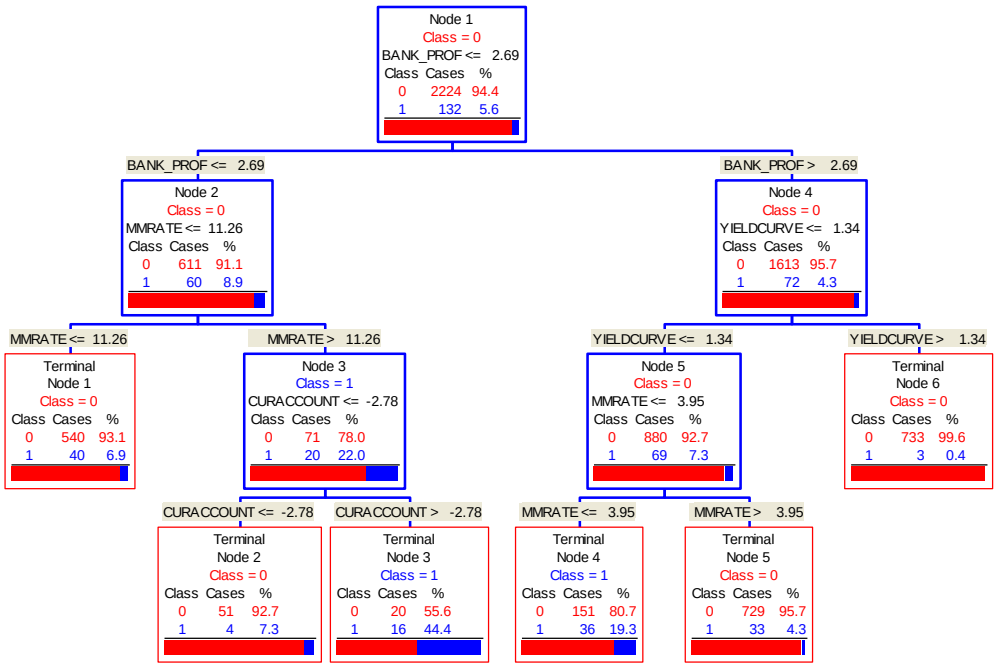
We apply the CART and RF techniques on an unbalanced panel dataset consisting of 36 advanced countries between 1970 and 2010 (see Joy et al., 2014 for details). We investigate what macroeconomic, financial and structural conditions prevailed in the economies in the periods ahead of banking and currency crises. Specifically, we try to identify variables that showed abnormal developments in periods that preceded crises as opposed to those that did not. In the baseline case we analyse the developments of domestic variables 1–2 years ahead of crisis onsets. Consequently, we enlarge the set of potential crisis predictors by including variables tracking domestic structural characteristics, which evolve only very slowly over time, as well as international variables, which in turn evolved across time but are common to all countries in the sample. Finally, we perform these exercises at a longer prediction horizon of 2–3 years ahead.

For banking crises, we find that both short-term domestic economic factors (low banking-sector net interest rate spreads; a shallow yield curve, see Figure 1) and longer-term structural

[2] This article is based on Joy et al. (2014).

characteristics (financial development and trade openness) are important indicators of crisis. The importance of structural characteristics is a new finding. Other studies assume that advanced economies, for the purposes of crisis prediction, can be considered structurally homogeneous. Typically, the assumption is made that advanced economies are structurally distinct only from emerging economies, not from each other. However, we find that structural differences between advanced economies offer important information on how vulnerable a country is to a banking crisis, with economies that are more financially developed being sometimes but not always more vulnerable (depending on a number of prevailing macroeconomic factors), and likewise with trade openness – more open can mean more vulnerable if the government yield curve is shallow. The parallels with emerging economies are, in other words, stronger than we may have previously presumed (Eichengreen, 2010). We also find that international developments, specifically the phase of the world business cycle, are key preconditions for banking crises. Specifically, the occurrence of banking crises is much more likely when world GDP growth is well above its normal value. When we perform this analysis for the longer prediction horizon (2–3 years ahead of identified banking crisis onsets) house prices turn out to be the most important domestic predictors.

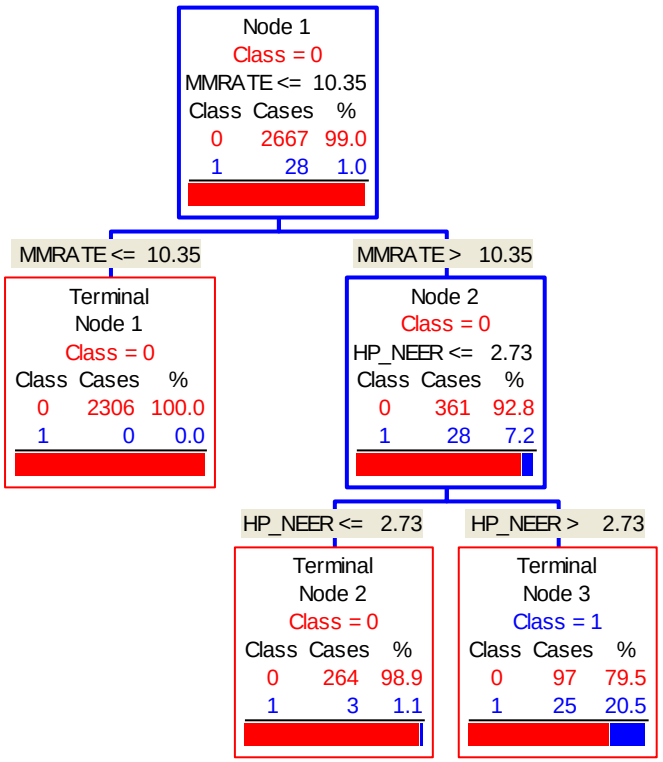
Figure 1. Banking crises within 4–8 quarters – binary tree (cost of missing crisis 7, best tree within 1 standard errors, data priors, tree size depth 3)



Notes: The tree separates the observations into nodes. The CART algorithm starts with the root node, which is further split into two child nodes based on classification rules, in our case yes/no questions. The nodes continue to be split until a terminal node is reached. For example, Terminal Node 1 describes all the outcomes in the branch where short-term interest rates are less than or equal to 11.26%. This node is a terminal node, which means that it cannot optimally be split any further. 540 observations in this node (93.1%) are non-crisis episodes and 40 observations (6.9%) are crisis episodes. The bar shows visually the proportion of non-crisis and crisis observations.

For currency crises we find that the most important signals are short-term and country-specific: high money market rates and an overvalued currency (Figure 2) turn out to be the most important predictors of crisis. Interestingly, we find that although the resulting tree is very sparse, i.e. it features two variables only, the fit of the model is very decent (i.e. we are able to distinguish between crisis-prone and non-crisis-prone situations to get very homogeneous nodes). This is feasible given that currency crises were far less common in developed countries and therefore the tree is not subject to overfitting. Another notable feature of currency crises is that they are much more scattered across time and countries. Consequently, we indeed find that unlike for banking crises, for currency crises structural characteristics of the domestic economy are not important, nor are international factors, such as the global business cycle (see Joy et al., 2014). The results obtained for the longer horizon (2–3 years) are entirely consistent with the baseline horizon (1–2 years).

Figure 2. Currency crises within 4–8 quarters – binary tree (cost of missing crisis 7, best tree within 1 standard errors, data priors, tree size depth 3)



Notes: See the note for Figure 1.

While we believe our results corroborate many of the findings of other researchers, it is important to note where they do not. For instance, the credit-to-GDP gap, which is perhaps the single most important indicator of banking crises identified in empirical research (e.g. Babecký et al., 2014; Drehmann and Juselius, 2014), does not play an important role in our models of crises. This may

be explained in part by differences in country and time span as well as differences in prediction horizons. A more fundamental cause of disagreement is that the credit-to-GDP gap is in other studies commonly assumed to be an unconditional signal of crisis. On the contrary, our work finds that signals are highly conditional: one country may have a booming banking sector but have a negligible probability of banking crisis; another may have an equally frothy banking sector but may be running a high risk of crisis. The reason is that the risk of crisis is conditional on other factors, namely the steepness of the yield curve, the level of short-term interest rates and, in some instances, the size of the current account balance. While unconditional early warning signals such as the credit gap can offer valuable information on crisis prediction, they underplay the importance of interaction effects and non-linearities in explaining crises.

These results can also be compared with previous studies using the CART methodology for analysing banking and currency crises in emerging market economies (Dattagupta and Cashin, 2011; Davis et al., 2011; Ghosh and Ghosh, 2003). For banking crises we confirm the importance of falling banking-sector profitability in terms of net interest rate spreads as well as a high level of financial intermediation but discard the relevance of some other indicators such as high inflation or deposit dollarisation. These developments were much less common in advanced countries. For currency crises, our findings do not confirm the relevance of the current account balance but rather point to a combination of high short-term interest rates and previous currency overvaluation.

Our findings have implications for the recent debate on macroprudential policy. First, our results in a broad sense suggest that not all early warning indicators are reliable all the time for all countries and estimated thresholds can be conditional (on other thresholds). This suggests that an indicator's conditionality and broader country-specific characteristics should be taken into account by supranational financial stability surveillance bodies such as the Financial Stability Board (FSB) and the European Systemic Risk Board (ESRB). For example, we found that bank net interest rate spreads often indicated forthcoming banking crisis, but looking at this indicator unconditionally can be misleading because numerous banking crises also occurred when net interest rate spreads were high. Second, although we provide thresholds for several indicators, it should also be kept in mind that any threshold is subject to substantial uncertainty. Therefore, there is no sharp cutting edge between crisis-prone and non-crisis-prone situations. Finally, our results suggest that information on the domestic credit gap, which has been suggested by the Basel Committee on Banking Supervision (BCBS) as a key tool to activate the countercyclical capital buffer (CCCB), should be used with caution. Specifically, this indicator does not flash as a core leading indicator of crises (either banking or currency) when conditionality is taken into account, and it is impossible to find any reliable threshold for it.

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Asset Price Misalignments on Financial Markets[3]

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Recent developments in financial markets have shown that crises can have quick and often devastating effects in areas far beyond their epicentre. The speed with which the recent US subprime crisis reached a global dimension took the majority of economists and policy makers by surprise. It proved that the global nature of the current market interlinkages makes the transmission of disequilibria across markets and regions a very likely outcome.

In this paper we look at disequilibrium transmission within the foreign exchange, government bond and stock markets of three Central European countries (the Czech Republic, Hungary and Poland) and the euro area. We analyse the potential for co-alignment of crises in this region. However, the main aim of the paper is methodological, i.e. to extend the standard analysis of financial crises by looking at alignment during episodes of significant departure from equilibrium asset values. This offers an insight into how likely it is that this type of disequilibrium will be transmitted in a coordinated manner across the above-mentioned markets in this area.

Concurrence of crises across regions/markets is formalised as the occurrence of joint extreme events and is assessed with a measure of asymptotic tail dependence among the distributions examined. *Crisis concurrence* among financial markets is assessed in a standard way by focusing on the extremes of asset return distributions. *Disequilibrium concurrence* is examined by firstly linking representative assets to their fundamentals using a cointegration approach. This gives the equilibrium values of assets at a coarser (monthly) frequency. Next, the data are considered at daily frequency and the extreme values of the differences between the actual daily asset values and their monthly equilibrium values determine the episodes associated with large departures from equilibrium. Consequently, an extreme value theory (EVT)-based approach is applied to these departures from equilibrium distributions.

The empirical analysis undertaken in this paper draws intensively on cointegration and the vast amount of EVT literature relating to financial crises and contagion. In the EVT approach, financial crises are viewed as rare and extreme events whose occurrence is governed by different

[3] This article is based on Kadlčáková et al. (2013).

laws than those governing the entire domain of asset return distributions studied. The focus is on the tails of the distributions. This allows the avoidance of some typical misassumptions, of which the most commonly made are that (a) the analysed empirical distributions follow normal distributions, and (b) the Pearson correlation is a good measure of crisis dependence.

In fact, it is a common finding in the economic literature that asset returns significantly depart from the normal distribution in the majority of countries and asset types studied. As a rule, empirical asset returns display fat tails, implying that the probability of extreme events is higher than studies based on the normal distribution usually assume. Additionally, asymptotic dependence or tail-based dependence measures are usually quite different from linear dependence measures proxied by Pearson correlation. Embrechts et al. (2002) and de Vries (2005), for instance, proved that tail dependence may still be significant among variables with a zero Pearson correlation. It is also true that asymptotic dependence is zero in the case of bivariate normal distributions with a non-zero but less than one Pearson correlation.

We draw inspiration from several papers employing EVT in the crisis context. Cumperayot and Kouwenberg (2011) used EVT to search for asymptotic dependence between exchange rates and several macroeconomic variables in an attempt to find early warning systems for currency crises. Their methodology was based on the approach of Poon et al. (2004), who were the first to formalise two measures of asymptotic dependence/independence for two random variables, which we also used in our paper.

The first measure (χ) is rather intuitive. It represents the conditional probability that one variable takes extreme values given that the second variable is taking such values. If the limit of such a conditional probability goes to zero when we move more deeply into the tails of the distributions, then the two variables are said to be asymptotically independent. Otherwise, if the limit is non-zero, they are considered to be asymptotically dependent.

The second measure ($\bar{\chi}$) is a measure of extreme association in the tails. It shows the speed at which the above-mentioned conditional probability decays to zero. It has been proven (Ledford and Tawn, 1996) that this second measure equals one for all asymptotically dependent variables but is less than one for asymptotically independent ones.

Bilateral country asymptotic dependence measures would assess the potential for cross-country crisis concurrence in each of the three financial markets studied – bonds, equity and exchange rates. Additionally, cross-asset concurrence within individual countries was considered, and this separately envisaged the co-movement and flight to quality scenarios as in Hartman et al. (2004).

As an example, the estimations of the parameters χ and $\bar{\chi}$ for the exchange rate variables are shown in Table 1. The results suggest that significant tail dependence is present among all the pairs of exchange rate variables considered in this paper.

Table 1. Measures of bilateral asymptotic dependence for exchange rates at the 5% tail threshold

a) Deviations from equilibrium series

	Depreciation (right tail)			**Appreciation (left tail)**		
	$\overline{\chi}$	Hypothesis $\overline{\chi}=1$	χ	$\overline{\chi}$	Hypothesis $\overline{\chi}=1$	χ
CZ_EA	0.8445	Rejected	-	0.8789	Not rejected	0.9323
CZ_HU	0.8900	Not rejected	0.9431	0.888	Not rejected	0.9323
CZ_PL	0.9384	Not rejected	0.9431	0.8816	Not rejected	0.9323
HU_EA	0.9537	Not rejected	0.9408	0.9724	Not rejected	0.9478
PL_EA	0.9307	Not rejected	0.9408	0.9613	Not rejected	0.9469
HU_PL	0.9501	Not rejected	0.948	0.9654	Not rejected	0.9469

Notes: CZ – Czech Republic, HU – Hungary, PL – Poland, EA – euro area.

b) Exchange rate return series

	Depreciation (right tail)			**Appreciation (left tail)**		
	$\overline{\chi}$	Hypothesis $\overline{\chi}=1$	χ	$\overline{\chi}$	Hypothesis $\overline{\chi}=1$	χ
CZ_EA	0.9846	Not rejected	0.9343	0.9569	Not rejected	0.9374
CZ_HU	0.9547	Not rejected	0.9425	0.9643	Not rejected	0.94
CZ_PL	0.9257	Not rejected	0.8928	0.9584	Not rejected	0.9374
HU_EA	0.9464	Not rejected	0.9343	0.9472	Not rejected	0.9381
PL_EA	0.8994	Not rejected	0.8928	0.9433	Not rejected	0.9381
HU_PL	0.9573	Not rejected	0.8928	0.9623	Not rejected	0.9455

Notes: CZ – Czech Republic, HU – Hungary, PL – Poland, EA – euro area.

Overall, the findings of the paper show that the potential for co-alignment in terms of crises and departures from equilibrium in this region is particularly high across both countries and markets. In almost all cases we found high values of asymptotic dependence on both the upward/depreciation and downward/appreciation side.

Another interesting result of the paper is that support for cointegration was found, as a rule, among the asset variables and the small set of macro variables that we proposed as fundamentals.[4] This result shows that these markets function in accordance with basic theoretical models, if not on a standalone basis, then at least as the interplay of multiple factors. Based on cointegration we were also able to distinguish episodes of extreme misalignments from equilibrium. It is worth noting that the evidence for persistent disequilibrium formation in the exchange rates was very weak. However, such evidence was stronger in the equity markets, predominantly in 2005–2006 for Hungary and the Czech Republic and in 2003 for the euro area. Such evidence was also found in the government bond markets, although the misalignment was much less synchronised in these markets.

[4] These fundamentals differ slightly across different classes of assets. For example, for the exchange rate market they are the money supply, industrial production as a proxy for output, the consumer price index and the money market interest rate.

Our results expand the mosaic of understanding of behaviour regarding segments of the financial markets of Central European Countries (CEC) based on co-movement analysis of financial asset returns. Similarly, Babecký, Komárková and Komárek (2013) have provided an empirical analysis based on financial asset returns in terms of the speed (beta-convergence) and level (sigma-convergence) of financial integration of inflation-targeting Central European economies (the Czech Republic, Hungary and Poland) and advanced Western European economies (Sweden and the UK) in comparison with the euro area, regarding foreign exchange, money, bond and stock markets. The results for the CEC reveal that a process of increasing financial integration has been going on steadily since the end of the 1990s and also that the financial crisis caused only temporary price divergence of the CEC financial markets from the euro area market. Likewise, Adam and Benecká (2013) add some supportive evidence showing how the transmission of financial stress from the euro area to the Czech Republic has evolved over time. This analysis was made by means of a composite indicator of systemic stress based on information from the foreign exchange, stock and bond markets, as well as financial intermediaries. It shows that the degree of spillover between financial markets, based on the constructed composite indicator of systemic stress, is heavily dependent on the stress level, and that this mechanism is significant.

Our results imply that financial stability policy makers should take into account the interlinkages identified between different parts of national financial markets. These interlinkages may manifest themselves only in the "tails", as during the financial crisis. Similarly, the potential for increased cross-border linkages could be strong in crisis periods. Therefore, policy makers should closely monitor not only their own national financial markets, but also financial markets in other relevant countries.

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Evaluating the Links Between the Financial and Real Sectors in a Small Open Economy: The Case of the Czech Republic[5]

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The persisting climate of financial market vulnerability in Europe has raised pressing questions about the viable options for policy makers and the operability of "traditional" policy instruments. Given the recent crisis and post-crisis experience, the momentum of the debate has from the outset centred on the interactions between the real and financial sectors. The efforts by researchers, industry experts and policy makers have ultimately transformed into a number of both theoretical and empirical studies (for a detailed survey see, for example, BIS, 2011), which either build upon existing channels or develop novel ones linking the real and financial sides of the economy. The influential balance sheet or "financial accelerator" framework of Bernanke and Gertler (1995) emphasises capital market frictions, including moral hazard, asymmetric information and imperfect contract enforcement problems, and the subsequent need for collateral to access credit. As a result, shocks to collateral value arising in the real economy might in turn feed back from the banking sector into real economic activity.[6] The bank lending and bank capital channels instead focus on banks' asset and liability structure. The former channel relies on the inability of banks to fully substitute for lost liabilities in the event of a monetary contraction (Bernanke and Blinder, 1988), while the latter reflects banks' incentives given exogenous shocks to capital and interactions of capital with regulatory requirements. In such a setting, adverse changes to bank capital can have a pronounced impact on the lending of less capitalised banks (Van den Heuvel, 2002; Meh and Moran, 2010). The literature on capital requirements has identified additional feedback effects of regulation through shifts in risk-weighted assets in the capital-asset ratio (Borio et al., 2001; Goodhart et al., 2004). The liquidity channel, as discussed, for example, by Brunnermeier and Pedersen (2009), has received considerable attention, especially due to the spillover mechanisms amplifying the recent financial crisis.[7]

While the empirical literature spans a long list of macro-studies on feedback effects between the real economy and the banking sector, the role of non-linearities (between the former two) has been studied to a somewhat lesser extent. As the precise nature of the non-linearities in most situations is not known, authors have opted for diverse estimation frameworks. Among the most prominent are the threshold and Markov-switching VAR models (TVAR and MS-VAR respectively). A frequently cited study by Balke (2000) adopts a structural TVAR model with

[5] This article is based on Konečný and Babecká Kucharčuková (2013, 2014).

[6] Given the dominant position of bank credit in the financing of Czech corporates and households, the authors use the terms banking sector and financial sector interchangeably.

[7] Other studies on market and funding liquidity include Wagner (2010) and Strahan (2008).

tight and regular credit regimes using the quarterly US GDP data over 1960–1997. It finds a larger effect of monetary policy shocks on output in the "tight" credit regime and a more pronounced effect of contractionary monetary shocks compared to expansionary ones. Atanasova (2003) in a similar TVAR exercise for the UK supports the evidence on the asymmetry of monetary policy effects in credit constrained and unconstrained regimes as well as different output effects of monetary contractions and expansions. Finally, Calza and Sousa (2006) employ Balke's framework to investigate the role of credit shocks in the euro area and conclude that while present, the non-linearities and asymmetric responses seem to be less pronounced than those found by Balke (2000) for the US.

The contribution of our study is threefold. First, it aims to gauge the non-linear interactions both within and between the real sector and the financial sector. We estimate a standard monetary policy model for a small open economy augmented by financial sector aggregates as a Bayesian threshold VAR (BTVAR). By allowing for endogenous regime shifts depending on credit market conditions, we impose greater flexibility than in the case of a linear system, so that the potential non-linearities in the transmission of shocks from the financial system can be evaluated. The second contribution is methodological, as we extend the single-equation Bayesian threshold model by Chen and Lee (1995) into the multiple-equation setting with block restrictions to account for external factors in a small open economy. Third, given that most of the related empirical studies have focused on developed economies (Çatik and Martin, 2012 being the sole exception), the study provides complementary evidence on the role of non-linearities for a small emerging economy.

The study combines standard macroeconomic variables with information on aggregate credit and non-performing loans (NPLs) in the Czech Republic over the period 2004m1–2012m3. Our results indicate that the omission of non-linearities might lead to an imprecise understanding of the interactions and transmission mechanisms between the real economy and the financial sector. The estimated thresholds obtained from the BTVAR identify different cut-off values for the credit spread, indicating the importance of the initial two and a half years of the crisis for credit developments and the pronounced impact of the financial crisis on banks' credit losses extending over the whole post-2009 period. Despite the absence of asymmetries in the effects of positive and negative shocks, the magnitude and, less frequently, the timing of the impulse responses differ in the high (large credit) and low (small credit) credit spread regimes. We find that procyclicality of the financial sector matters for the real economy. A positive shock to credit (Figure 1) and a negative shock to NPLs (Figure 3) support industrial production over the entire time horizon, yet the responses to credit shocks do not differ substantially across credit spread regimes. This finding differs from the results of other studies employing the threshold VAR framework, which report asymmetric feedback from credit to the real economy. Asymmetries are nonetheless present in the responses of the real economy to shocks to NPLs, which differ in both size and timing and are probably aligned with cyclical factors. As the financial sector in the Czech Republic is largely bank-based and funded predominantly by domestic deposits, the direct impact of foreign factors on lending seems to be rather limited and credit volumes tend to be affected indirectly through the situation in the production sector of the economy.

Figure 1. Impulse response functions from real sector variables to credit.

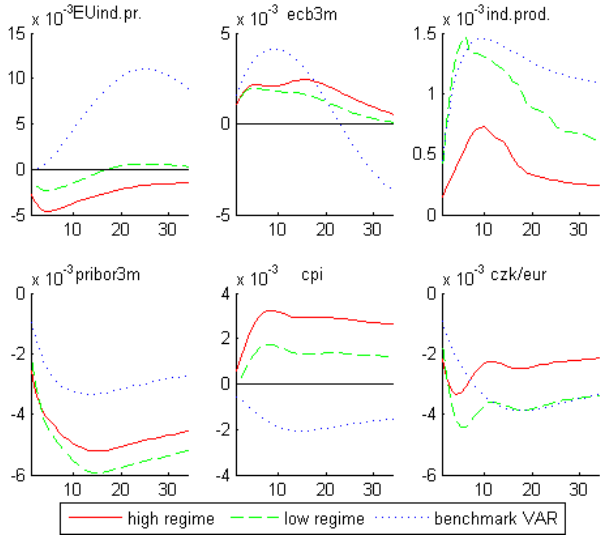


Figure 2. Impulse response functions from credit to real sector variables.

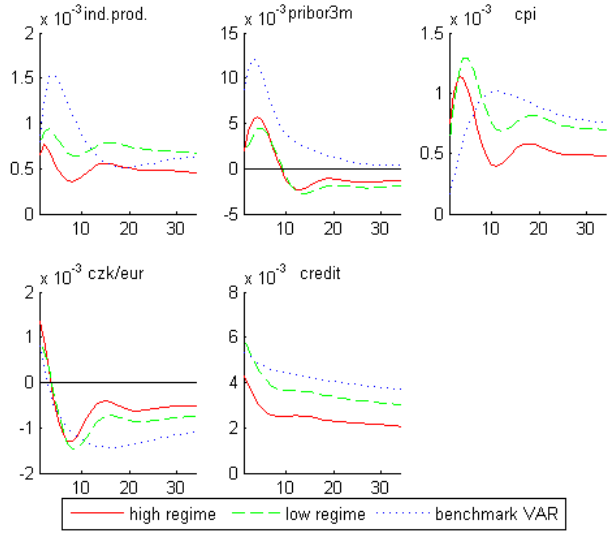


Figure 3. Impulse response functions from real sector variables to non-performing loans.

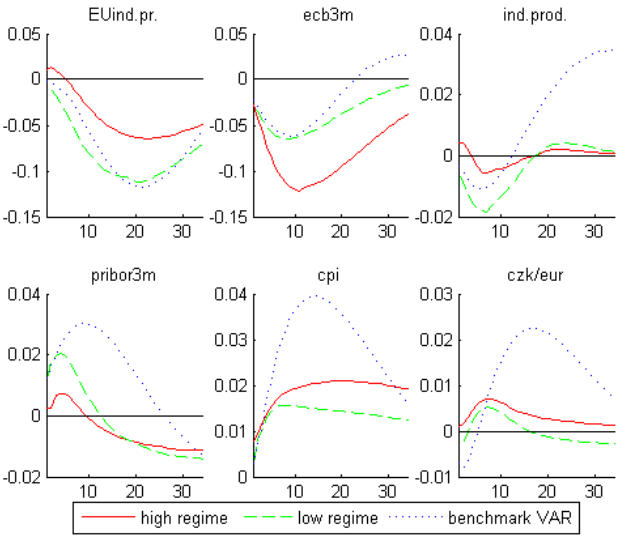
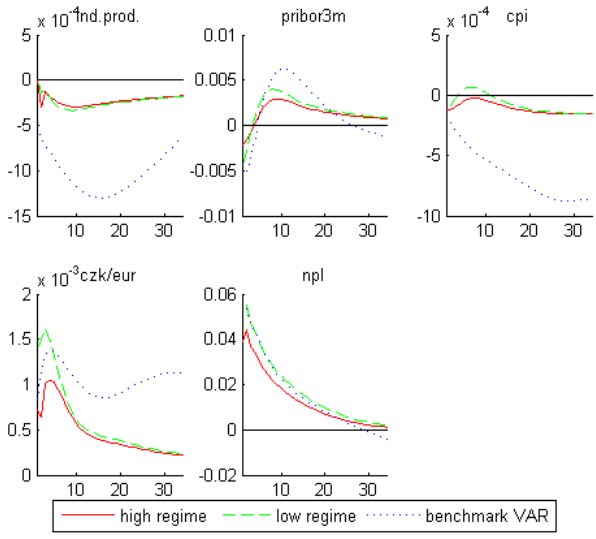


Figure 4. Impulse response functions from NPLs to real sector variables.



Note: ind.pr is the industrial production index, ecb3m is the 3-month Euribor, pribor3m is the 3-month Pribor, cpi is the consumer price index and czk/eur is the Czech koruna-euro exchange rate.

The magnitude and, in some cases, even the direction of the impulse responses differ in the benchmark and BTVAR frameworks. Furthermore, the impulse responses are in some cases strongly dependent on the initial state. This relates in particular to the tamed response of aggregate credit to a positive shock to industrial production in the *high* credit spread (Figure 2). The responses to credit shocks are roughly similar across regimes, with the exception of the policy reaction of the monetary authority, which is more pronounced in the *low* regime. This finding differs from the results of other studies employing the threshold VAR framework, which

report asymmetric feedback from credit to the real economy. Asymmetries are likewise absent from the responses of the real economy to shocks to NPLs (Figure 4). The complementary investigation of non-performing loans reveals weak procyclicality of NPLs, which, however, vanishes after approximately 18 months. The economic recovery thus needs to be sufficiently robust to translate into lower NPLs.

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Contagion Risk in the Czech Financial System: A Network Analysis and Simulation Approach[8]

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The current global financial crisis has shown that the stability of individual institutions and the stability of the system as a whole do not necessarily overlap, since there are important financial linkages between individual institutions making the system more complex. The interconnectedness of financial institutions can be direct (via direct exposures such as loans, cross-holdings of securities, etc.) or indirect (via common exposures to a particular class of assets or even to the very same debtor). Both types of exposures create channels for potential contagion within the financial system.

In our paper, we assess the resilience of the Czech banking system to interbank contagion. We develop an agent-based computational model of interbank contagion which analyses the effect of three potential channels of interbank contagion – a credit channel, a liquidity channel and an asset price channel – and takes into account the specific characteristics of the Czech banking system. Despite the fact that the Czech banking system is characterised by a strong capital position, stable profitability and liquidity (CNB, 2012), there is still heterogeneity among individual institutions, leaving some potential for credit and liquidity risk contagion in the system and thus making contagion analysis a relevant part of financial stability assessment.

In normal times, the interbank market ensures efficient liquidity redistribution from banks with surplus liquidity to banks with a shortage of liquidity and thus serves as an absorber of idiosyncratic liquidity shocks. In turbulent times, however, interbank markets can become a channel for liquidity contagion due to liquidity hoarding by banks and/or credit risk contagion due to credit losses on interbank exposures.

Contagion due to losses on interbank credit exposures is possible only in banking sectors that have a high share of interbank assets relative to the available capital. In the event of a failure of a bank in the system, the bank's equity is wiped out and the bank is no longer able to fully repay its liabilities. Depending on the relative importance of the initial shock, further rounds of solvency contagion can occur. While this channel seems to be relevant, for example, in Belgium (Degryse and Nguyen, 2007), Germany (Upper and Worms, 2004), Italy (Mistrulli, 2011) and the UK (Wells, 2004), it is estimated to be less important in Hungary (Lublóy, 2004), the Netherlands (van Lelyveld and Liedorp, 2006) and Switzerland (Sheldon and Maurer, 1998).

In addition to the credit channel, Müller (2006) assumes that a bank can go bankrupt for illiquidity reasons and shows that the liquidity channel is stronger in the case of the Swiss

[8] This article is based on Hausenblas et al. (2012, 2015).

banking sector. Moreover, she suggests that credit lines, which are arranged between banks to ensure provision of liquidity when needed, represent an additional contagion channel.

Adrian and Shin (2008) point out that the simple domino model is unlikely to explain financial contagion in a modern market-based financial system, where any unusual volumes of trading in financial assets directly influence the market value of these assets and consequently the net worth of financial institutions. The effect of the asset price channel is analysed by Cifuentes et al. (2005), Nier et al. (2007) and Bluhm and Krahnen (2011).

In the first part of our study, network analysis is employed in order to understand the structure of the Czech interbank market. Banks and their interbank exposures create a so-called interbank network, where banks represent the nodes and financial exposures create the links between those nodes. The results of the analysis indicate that the network in the Czech banking system is relatively sparse and highly heterogeneous. It points to several banks important for the stability of the network whose failure could potentially have systemic consequences. Nevertheless, not only the structure of the interbank links within the network, but also the financial soundness of individual banks might be crucial for the resilience of the network to external shocks and consequent contagion (Nier et al., 2007; Gai and Kapadia, 2010).

The exploratory data analysis is followed by an agent-based computational model of interbank contagion which combines information on the stability of individual banks, bilateral interbank exposures and the structure of the interbank network. The resilience of the system is assessed using a simulation approach where the initial shocks have the form of either individual or multiple bank failures. More specifically, we assume three potential channels of interbank contagion: a credit channel, a liquidity channel and an asset price channel.

- The credit channel is active when banks in the system are defaulting due to credit losses on interbank exposures. A bank defaults in the model whenever its capital adequacy ratio falls below 1/3 of the regulatory minimum of 8%.

- Additionally, a bank might default in the model when it is illiquid, i.e. when liquid assets such as cash, central bank balances, interbank lending and domestic government bonds are not sufficient to cover short-term interbank liabilities.

- Finally, the asset price channel is activated in the model when domestic government bonds are no longer considered to be highly liquid assets, hence it is not possible to exchange these bonds in the market for cash without a price discount. The simulations incorporating the asset price channel represent a theoretical exercise where banks selling government bonds in the market face less than perfectly elastic demand for government bonds. The higher is the volume of government bonds placed on the market, the more the price decreases and the higher are the losses due to revaluation of these assets in the balance sheets of all banks holding government bonds. Considering that Czech banks have non-negligible exposure to domestic government securities, even banks with no direct interbank exposures can default in this setting.

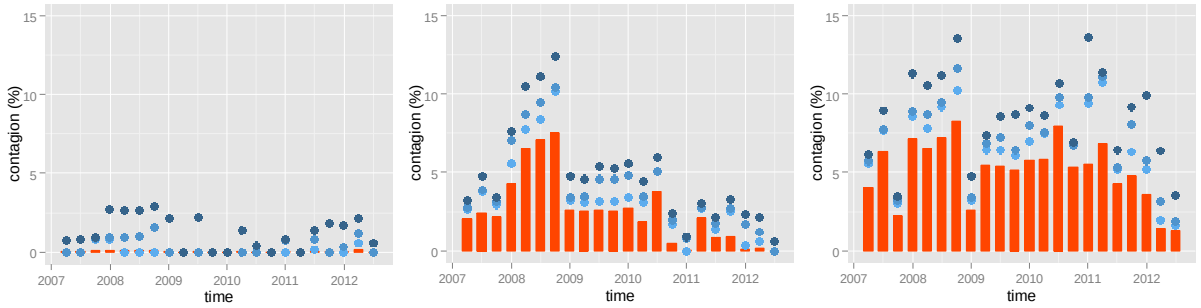
Plugging these channels additively into the simulation resulted in three different model specifications. Figure 1 summarises the results of the idiosyncratic shock simulations for each model specification.

Figure 1. Contagion losses relative to potential losses

Benchmark model
Credit channel

Extended model A
Credit and liquidity channels

Extended model B
Credit, liquidity and asset-price channels



Note: The red bars represent the average contagion and the blue dots are the three worst-case scenarios, i.e. the scenarios with the worst contagion impact (y-axis). Contagion is measured as the ratio of the losses due to the initial shock to the value of the total assets remaining after the initial shock.
Source: Authors' computations

The potential for contagion in the Czech banking system was assessed over the period from March 2007 to June 2012. The simulation results for the idiosyncratic shock suggest very low potential for interbank contagion across scenarios due to pure credit losses on interbank exposures in the Czech banking sector. The contagion amounted to 3% of the remaining banking sector assets after the initial idiosyncratic shock in the worst-case scenarios over the period in focus. After the introduction of the liquidity condition into the simulations, the average contagion was below 3.8% of the remaining banking sector assets, with the exception of the period from December 2007 to September 2008. Activation of the asset price channel further increases the losses due to interbank contagion, showing that liquidity of government bonds would be essential for the stability of Czech banks in stress situations. Finally, the simulation results for both idiosyncratic and multiple bank failure shocks suggest that the potential for contagion in the Czech banking system has decreased since the onset of the global financial crisis.

Besides the empirical findings relevant to the Czech Republic our paper might contribute on the methodological level, especially to future research on banking systems in Central and Eastern European countries with less developed financial systems, where the methods and findings of the existing literature focusing on developed financial centres are less applicable.

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Call for Research Projects 2016

The CNB Economic Research Department will announce its regular Call for Research Projects 2016 on **15 April 2015**. Follow the link: http://www.cnb.cz/en/research/research_projects/.

CNB Research Open Day

The eleventh CNB Research Open Day will be held in the Czech National Bank's Commodity Exchange (Plodinová Burza) building on **Monday, 18 May 2015**. This half-day conference will provide an opportunity to see some of the best of the CNB's current economic research work, to learn about the CNB Call for Research Projects 2016 and to meet CNB researchers and research coordinators informally.

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