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# ECONOMIC RESEARCH BULLETIN

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## EDITORIAL

This edition of the CNB Research Bulletin focuses on the topical issue of financial stability from a national as well as global perspective. The importance to the CNB of the questions under examination is highlighted by the fact that this is the third time in the past six years that the Bulletin has looked at questions of financial stability. First, in the 2005 edition, conceptual challenges in ensuring financial stability, focusing on the Czech banking sector, were discussed. Second, in the 2007 issue, the assessment of financial stability and the role of cross-country capital flows were examined. Now the Bulletin presents the results of CNB research in the financial stability area focusing on credit risk in the banking sector, monetary policy-making under financial instability and asset price co-movements due to financial market integration. The experience obtained during the current global financial crisis confirms not only the relevance of the research done in the CNB, but also hopefully its capacity to contribute to policies for coping with risks arising in the financial system.

The first article in this edition, employing stress-testing procedures, assesses the determinants of the ability of Czech banks as compared to German ones to withstand credit and macroeconomic risks. The second article scrutinises the role of quality of banks' management in bank failures, also testing whether there were differences between Czech-owned and foreign-owned banks. In the third article a modelling framework is proposed showing how the central bank's knowledge of the health of the financial system could be used for the optimal conduct of monetary policy. The last article empirically examines developments in the integration of stock markets in the Czech Republic, Hungary, Poland and Slovakia vis-à-vis the euro area.

Jan Frait

## IN THIS ISSUE

### Stress Testing Credit Risk: Is the Czech Republic Different from Germany?

Credit risk is one of the most important risks to banks. It is also a major threat to financial stability in the globalised financial world. This article investigates the credit risk environment of the two economies, focusing on the corporate and household sectors. A stress-testing framework for the evaluation of credit risk is proposed, suggesting that the economies may be considerably affected by macroeconomic shocks.

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### Bad Luck or Bad Management? Emerging Banking Market Experience

A large number of bank failures in transition countries were related to a rise in non-performing loans and cost inefficiency of banks. This study addresses the causality between non-performing loans and cost efficiency to examine whether either of these factors was the deep determinant of bank failures. The findings support the bad management hypothesis, according to which a rise in cost inefficiency precedes increases in non-performing loans.

Jiří Podpiera and Laurent Weill (on page 5)

### Monetary Policy Rules with Financial Instability

Financial instability is absent from most monetary policy rules and models. This article introduces financial instability into the standard, closed-economy monetary dynamic stochastic general equilibrium model, suggesting that if the central bank has privileged information about credit risk, it may be able to trade off more output and inflation instability today for a faster return to the trend. The welfare benefits of this strategy appear negligible, however.

Sofía Bauducco, Aleš Bulíř and Martin Čihák (on page 8)

### Stock Market Integration among New EU Member States and the Euro Area

In a monetary union, integration of financial markets plays the key role in assuring the effective transmission of a common monetary policy. This study considers the empirical dimension of financial integration among stock markets in four new EU member states in comparison with the euro area. Evidence of stock-market integration is found on both the national and sectoral levels.

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## Stress Testing Credit Risk: Is the Czech Republic Different from Germany?

Petr Jakubík and Christian Schmieder<sup>1</sup>

In quantitative terms, credit risk is the most important risk in banking books. This has recently been shown clearly again in the US subprime crisis. Moreover, the crisis occurred despite various improvements in credit risk management, for example progress in the field of credit risk analysis applied by banks on the portfolio level – spurred by Basel II<sup>2</sup> – as well as the increasing availability of a wide range of instruments that make credit risk more liquid, for example securitisation and credit derivatives. Hence, credit risk remains a major threat to financial stability in the globalised financial world, where cross-border contagion of crises particularly threatens countries with weak banking sectors.

Credit risk analysis for the financial sector as a whole can be seen as a crucial means of preventing financial instability. This can be realised by means of a regular robustness test on a country's banking sector against credit risk, for example by means of stress tests carried out by supervisory bodies and central banks, providing hints for detecting financial system fragility.<sup>3</sup>

A key motivation for our study originates from the Basel II framework, concluded in 2006, which seeks to provide a more meaningful framework for the solvency of financial institutions and financial stability compared to the previous Basel Accord dating back to 1988.<sup>4</sup> Within this framework, our focus is on the investigation of business cycle effects on the aggregate default rate of corporates and households and the link to banks' capital requirements. Employing credit risk modelling and stress testing, we investigate two countries, a new EU member state – the Czech Republic – and the largest EU economy – Germany. We seek to provide answers to various questions, notably: which macroeconomic variables are the most important for explaining credit risk; whether there are country-specific differences; and what impact

unfavourable macroeconomic circumstances can have on the macro and micro (portfolio) level.

Why are these questions relevant? The recent financial crisis originated mainly from severe problems in the US household credit sector (the so-called US subprime crisis). It adds one more chapter to the history of past financial crises which have been caused primarily by an accumulation of non-bank credit losses, be it corporate or household debt. It is striking that despite the awareness that credit risk is the most important threat to financial stability, the complexity of this risk type is so high that crisis prevention remains a key challenge for the future. This results particularly from the increasing complexity of financial markets and their international dimensions, which requires worldwide cooperation.

Therefore, the purpose of this study is to add insights to the assessment of financial stability. Our study contributes to the recommendations issued in April 2008 by a key international forum for fostering financial stability, the Financial Stability Forum, which recommends a *strengthening of authorities' responsiveness to risks and an improvement of stress-testing practices and capital planning processes by banks*.

When it comes to credit risk analysis for the Central and Eastern European transition economies (and also for many other transformation economies and developing countries), a key limitation is the availability of data, as the time series are usually (still) relatively short and have various structural breaks. Accordingly, the data in this study were selected very carefully to prevent misinterpretation.<sup>5</sup> The data cover a period of eight years from 1998 to 2006 for the Czech Republic and twelve years from 1994 to 2006 for Germany. The investigated time period covers multiple periods of severe macroeconomic

<sup>1</sup> This article is based on Jakubík and Schmieder (2008).

<sup>2</sup> See BCBS (2006), European Commission (2006) and the national transpositions of Basel II.

<sup>3</sup> The importance of this mission is underlined, for example, by the fact that the Basel Committee on Banking Supervision has mandated a working group of the Research Task Force to further investigate stress testing.

<sup>4</sup> Another important catalyst for stress testing was the Financial Sector Assessment Program (FSAP) of the International Monetary Fund (IMF) and the World Bank initiated in the late 1990s.

<sup>5</sup> We draw on the findings of the analysis carried out by Jakubík (2007).

stress, namely the consequences of the Asian crisis in 1997 and the Russian crisis in 1998, as well as the crisis in the financial markets after 11 September 2001.

We seek to measure credit risk on the macroeconomic level by distinguishing the two major elements of non-bank credit in economies: corporate credit and household credit. For that purpose, we use a relatively simple credit model whereby credit losses can be explained by the development of key macroeconomic factors such as GDP growth and inflation.<sup>6</sup> Accordingly, we estimate separate models for corporate and household credit. We use a common indicator to explain credit risk, namely non-performing loans. We find that credit risk for firms can be modelled based on similar macroeconomic variables for both countries, despite fundamental differences in the default rate (time) pattern. Credit risk modelling for the household sector turns out to be more challenging for both countries, as there are apparently other variables than solely economic ones explaining the default rate pattern. This leaves some challenges for future research.

Next, we make use of the estimated models to predict potential future levels of credit losses for firms and households, commonly known as *stress testing*. We assess how future recessions could influence corporate credit and household credit losses by referring to historical stress scenarios. Based on the macroeconomic situation at the end of 2006, we predict an economic downturn for 2007 for both countries. We use stress levels of similar severity for both countries from a historical perspective, including the last decade, and find that even relatively light stress can lead to a substantial increase in the corporate default rate (more than 100% for the Czech Republic; up to 40% for Germany). As a caveat, the sensitivity of the corporate sector default

rates for the Czech Republic was driven by the high volatility of macroeconomic indicators during the transition period of the late 1990s, so the results have to be interpreted carefully; due to different magnitude of shocks in the past a direct comparison of the Czech and German responses is not possible. For households, sensitivity to the macroeconomic environment is less pronounced, unlike what the recent US subprime crisis might suggest, and seems to confirm the observation that the financial crisis has not had a considerable effect on the Czech and German household sector so far.

The outcome of macroeconomic stress testing is then used for predicting a stress scenario of a typical bank credit portfolio. In this way, our study takes a comprehensive view of credit risk. The stress scenarios for the two economies are applied to a hypothetical, but realistic average credit portfolio that could be held by a Czech or German bank. The credit risk models for both countries employ similar variables and the size of the shocks is calibrated according to the past development of the given time series. Based on the regulatory IRB capital requirements, the portfolio credit risk of an average bank would increase by up to 60% in the Czech case and by roughly 30% for Germany. However, we need to take into account the limitations of our analysis (mainly the transition period in the Czech case), which do not allow a full comparison of these numbers.

The methods and procedure presented in this study can be used by regulatory bodies to be able to take measures to safeguard financial stability. In the case of an adverse outcome either on the aggregate level or on the portfolio level of a bank with systemic relevance policy measures could be initiated. In this way, the framework can serve the purpose of an early warning system to detect and/or predict the severity of future crises.

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<sup>6</sup> Details on this model are provided by Gordy (2003). Such a model is also the basis for calculating the Basel II capital requirements for credit risk.

Likewise, the framework can also be used by commercial banks seeking to assess their specific situation and thereby contribute to the introduction of Basel II-type micro stress testing. In any case, future research is needed on the highly complex issues discussed in this paper.

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## Bad Luck or Bad Management? Emerging Banking Market Experience

Jiří Podpiera and Laurent Weill<sup>1</sup>

A large number of bank failures occurred in transition countries during the 1990s and, to a lesser degree, at the beginning of the current decade. In the Czech banking sector, for instance, out of the 48 banks operating in 1994 and another 6 licensed later on, 21 banks had failed by 2003. It is therefore of utmost interest to know which factors predict bank failures. The empirical literature identifies two main factors predicting bank failures. The first one is the volume of non-performing loans in the loan portfolio, since a large proportion of non-performing loans has been widely observed in failing banks. The second one is a low level of cost efficiency. The role of enhanced banking efficiency in reducing bank failures has been pointed out in studies in developed countries (e.g. Barr, Seiford and Siems, 1994) as well as in transition countries (Pruteanu-Podpiera and Podpiera, 2008). The underlying argument is that bad (less efficient) management increases the likelihood of bank failures. However, the big question is whether either of these factors is the deep determinant of bank failures. If one factor causes the other, it may therefore be considered the key determinant of bank failures – both through its direct impact and through its indirect influence via the other factor. As a consequence, the sense of causality between non-performing loans and cost efficiency is of utmost interest for the analysis of the causes of bank failures.

Following the empirical observation of a negative relationship between non-performing loans and cost efficiency, two assumptions have been proposed by Berger and DeYoung (1997). These differ on the direction of the causality. On the one hand, the bad luck hypothesis states that non-performing loans influence cost efficiency. The underlying argument is that external events such as economic slowdowns affect non-performing loans, resulting in banks incurring extra costs to deal with these loans, which, in

turn, weakens cost efficiency. On the other hand, the bad management hypothesis predicts that cost efficiency exerts an impact on non-performing loans, as bad managers do not monitor loan portfolios efficiently. The identification of the key determinant of bank failures is a fundamental issue for the authorities in charge of supervising the banking industry, as the implications for economic policy significantly differ depending on its origin. In particular, if non-performing loans influence cost efficiency, banking supervisors should limit banks' risk exposures by restricting loan concentration and favouring diversification. In contrast, an influence of cost efficiency on non-performing loans would suggest that the latter are caused internally. Therefore, banking regulators and supervisors should focus on improving cost efficiency standards through better education of bank managers and possibly through increased foreign ownership, as the latter element has been shown to favour cost efficiency, primarily through the transfer of know-how (Weill, 2003; Bonin, Hasan and Wachtel, 2005).

A couple of papers have investigated this issue for developed countries. Berger and DeYoung (1997) provide some support for both hypotheses on a sample of US banks, as they observe that the relationship runs in both directions. Williams (2004) concludes in favour of the bad management hypothesis on a sample of European savings banks. However, this question is of greater importance in transition countries, owing to the importance of the bank failure phenomenon in these countries. In spite of this aspect, no study has yet been published providing a thorough investigation of the causality between non-performing loans and cost efficiency in transition countries. To our knowledge, the only paper on this topic is Rossi, Schwaiger and Winkler (2005), which concludes in favour of the bad luck hypothesis on a sample of banks from nine transition countries.

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<sup>1</sup> The article is based on Podpiera and Weill (2007, 2008).

Our aim is to provide empirical evidence on the source of bank failures in transition countries by investigating the causality between cost efficiency and non-performing loans for the Czech banking industry. The Czech banking industry constitutes a relevant illustration of what has happened in a transition country. Although the Czech Republic was considered a particularly successful country at the beginning of the transition period, it later faced similar problems of numerous bank failures and increasing non-performing loans. We use an exhaustive dataset for all Czech banks from 1994 to 2005, which avoids any sample selection bias and any bias resulting from the adoption of proxy variables. We extend the Granger causality framework used by Berger and DeYoung (1997) and Williams (2004) by applying generalised method-of-moments (GMM) dynamic panel estimators (Arellano and Bond, 1991). These estimators are specifically designed to address the econometric problems induced by unobserved bank-specific effects and joint endogeneity of the explanatory variables in lagged-dependent variable models such as the one adopted to test Granger causality.

We observe that the total effect of non-performing loans on cost efficiency is not significant, which speaks in favour of the hypothesis that changes in non-performing loans do not Granger-cause changes in cost efficiency. This finding is inconsistent with the bad luck hypothesis, in which non-performing loans influence cost efficiency. However, we observe at the same time a significant and negative total effect of cost efficiency on non-performing loans. The total effect of a change in efficiency scores on the change in non-performing loans is  $-0.1$ , which implies that a reduction in cost efficiency by one standard deviation (0.24) leads to an increase in the share of non-performing loans in total loans by 2.4%. Our finding is in accordance

with the bad management hypothesis, according to which deteriorating cost efficiency exerts an impact on the accumulation of non-performing loans. However one might wonder whether this finding is observed for each category of banks, regardless of banks' ownership, and during all subperiods. Below, we summarise the results of a sensitivity analysis that explores the robustness of our findings for all banks and all subperiods.

To examine the sensitivity of the findings, we test whether they are robust to a specific sample period and the type of bank ownership. Indeed, as mentioned above, the transition period in the Czech Republic was marked by two very different subperiods, one with many bank failures between 1994 and 2000 and the other with only two bank failures thereafter. Furthermore, we can wonder whether the increasing share of foreign investors in the banking industry exerts an influence on the findings, in the sense that "bad management" might be observed only in one category of banks among the domestic-owned and foreign-owned banks.

The result of the estimation, which tests the dependence of the findings on the specific period, is based on two subperiods. Namely, we consider a "troubled" subperiod from 1994 to 2000 and a "quiet" subperiod from 2001 to 2005. We use the interaction terms of non-performing loans and cost efficiency interacted with a dummy variable which is equal to one if the observation belongs to the "quiet" subperiod and zero otherwise. We find, however, that the sums of the additional terms for non-performing loans and cost efficiency are not significant. As a consequence, the findings obtained in the baseline estimation appear robust to the difference in subperiods. The next set of results of the estimation was obtained by testing the dependence of the findings on the type of ownership. The period of our

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study was marked by a major change in bank ownership from a banking industry almost fully owned by Czech investors in 1994 to an industry almost fully owned by foreign investors in 2005. One may therefore wonder whether this exerts an influence on our finding of bad management. Indeed, this hypothesis might have been caused by a predominance of only one category of banks among Czech-owned and foreign-owned banks. Consequently, we investigated the sign and sense of the causality between non-performing loans and cost efficiency by including the interaction terms of these items interacted with a special dummy variable which is equal to one if the observation is Czech-owned and zero otherwise. We point out the lack of significance of the sums of the additional terms for non-performing loans and for cost efficiency. We can therefore conclude that the findings of the baseline estimation are robust to the type of ownership as well.

years. Our results are only partially similar to those obtained by Berger and DeYoung (1997) for US banks, which support causality in both directions between non-performing loans and cost efficiency, but agree with those derived by Williams (2004), which support only the bad management hypothesis in the case of European savings banks. It may appear surprising at first glance that our results differ the most from those of Rossi, Schwaiger and Winkler (2005), who observed the bad luck hypothesis on a sample of banks from transition countries. However, their work differs from ours with regard to the sample of countries, the use of the Bankscope dataset, and the adoption of a proxy variable for the non-performing loan ratio. All the papers nevertheless agree with our finding of a negative relationship between non-performing loans and cost efficiency. This finding rejects the skimping hypothesis, which avers that greater cost efficiency should enhance non-performing loans.

In summary, our results in the sensitivity analysis clearly support the baseline findings in favour of the bad management hypothesis, according to which cost efficiency exerts a negative influence on non-performing loans. Therefore, our major conclusion is support for the bad management hypothesis for Czech banks during the transition

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## Monetary Policy Rules with Financial Instability

Sofia Bauducco, Aleš Bulíř and Martin Čihák<sup>1</sup>

Standard monetary policy rules explain monetary policy decisions well. For example, the basic Taylor rule (Taylor, 1993), that is, a reaction function in which the real funds rate changes by roughly equal amounts in response to deviations of inflation from a target of 2 per cent and to deviations of actual from potential output, “describes reasonably well” what the US Fed has been doing since the mid-1980s (Yellen, 1995).

Such a rule, however, leaves much to be desired. In general, simple instrument rules, such as the Taylor rule, explain at most two-thirds of the variance of interest rate changes (Svensson, 2003). While the unexplained part may include discretionary policy-making, it can also be seen as measure of our ignorance about the actual objective of policy makers, in particular their attitude towards financial sector instability. We argue that a financial sector focus is missing from the simple monetary rules, as central banks have recognised the importance of timely response to financial instability and have devoted substantial resources to monitoring financial stability, often with the help of confidential supervisory data.

The massive liquidity injections and other dramatic measures taken by many central banks during the 2007–2009 global financial crisis have brought financial instability and its impact on monetary policy to the spotlight. These actions are difficult to explain by the standard monetary policy response functions, which have largely ignored the interaction between financial instability and central bank behaviour.

How should changes in financial sector soundness affect monetary policy? Bauducco, Bulíř and Čihák (2009) answer this question by addressing the following two issues in the context of the standard, closed-economy monetary dynamic stochastic general equilibrium (DSGE) model. The first issue is the omission of a financial system.

We address this by enriching the standard new Keynesian model with a financial system and firms that require external financing.

The second issue addressed in the paper is the omission of forward-looking variables in the Taylor (policy) rule in most theoretical models (such variables have always been present in applied forecasting models used by central banks, however). We address this by introducing a forward-looking element into the policy rule. Under this augmented policy rule, the central bank monitors the financial system, responding to deterioration in the financial system balance sheet with instant monetary loosening. To the best of our knowledge, our paper is the first one to model the central bank response to financial instability in a general equilibrium context.

In the model, the central bank has privileged information about the health of the financial system, a reasonable assumption given that many central banks are involved in financial sector supervision, and even those that are not have access to payment system data. Individual financial institutions would normally have better information about their financial health and the financial health of their clients, but they would lack such information at the systemic level. In contrast, the central bank’s unique role in the payment system and usually also in prudential supervision gives it access to superior information about the health of the financial system as a whole (e.g. Padoa-Schioppa, 2002).

Our simulation results show that if the central bank responds to a deterioration in financial system credit risk by a monetary easing, such a “preemptive strike” stabilises inflation and output better in the short run than the simple Taylor rule that is usually employed in the DSGE models. In other words, well-informed, forward-looking discretionary policy-making, which

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<sup>1</sup> This article is based on Bauducco, Bulíř and Čihák (2009).

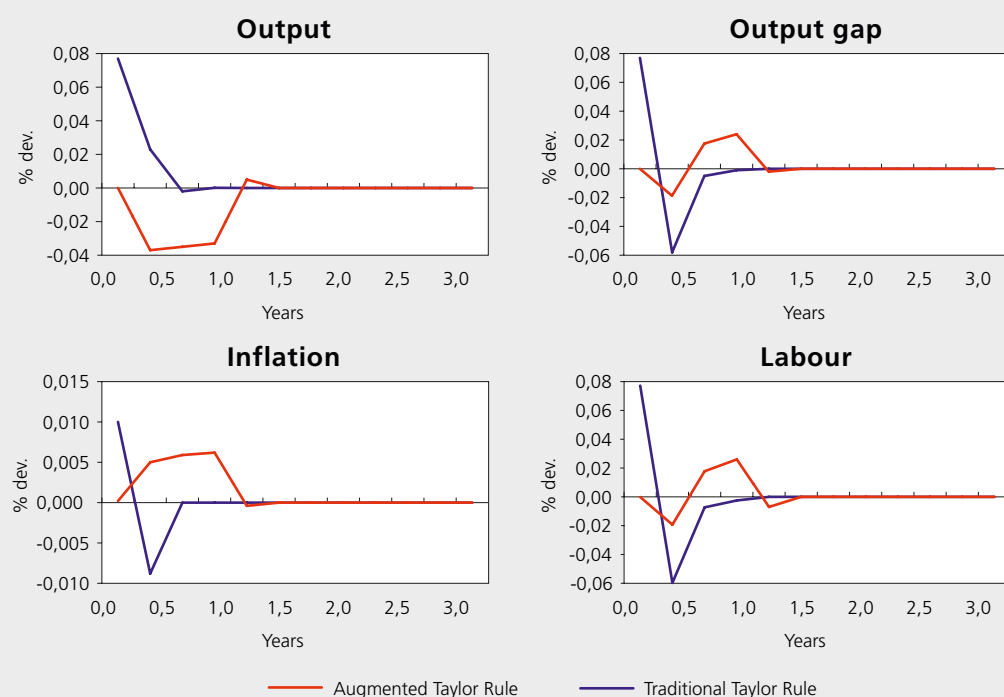
takes into account the default rate of financial intermediaries' lending projects and its impact on future output developments, is preferable to backward-looking policy-making in the short run. However, after the initial output stabilisation, the economy is subsequently faced with more output volatility and higher inflation as compared to the Taylor rule.

The findings provide model justification for the well-known central bank practice of "leaning against financial shocks". The simple Taylor rule is an inaccurate description of central bank behaviour

to the extent it has underestimated actual policy rate adjustments in such situations. A central bank that follows the augmented policy rule trades off more output and inflation instability today for a faster return to the trend path tomorrow. This is illustrated in Figure 1: in our simulations there are larger initial two-period departures from the trend in both output and the output gap under the augmented rule than under the Taylor rule. The introduction of the financial sector and shocks thereto in the DSGE model does not change the nature of monetary policy; it only brings forward the eventual policy reaction.

FIGURE 1

**Response of output, output gap, inflation and labour to a credit risk shock (modelled as a one standard deviation shock in default probability in the corporate sector)**



The simulations also suggest limits to the use of monetary policy instruments for financial system stabilisation. The central bank seems capable of a faster reaction to the financial instability shock. However, the impact of monetary policy on the economy remains unchanged. Specifically, long-run consumption volatility remains practically identical under both rules. Moreover, one would expect that monetary easing is unlikely to work in highly open economies with either fixed exchange rates or a strong exchange rate channel of monetary transmission.

The setup of the model fits the stylised facts of modern central banking, namely the attention paid to monitoring of the economy and financial system, collecting information that would allow the central bank to respond rapidly to forthcoming financial instability shocks well before these shocks are transmitted into headline inflation, output and other macroeconomic aggregates. The underlying financial shock and its transmission

mechanism are integrated into the model, rather than being treated as ad hoc factors as in the earlier literature.

We find that an augmented policy rule, whereby a central bank lowers its policy rate in response to financial sector instability, yields different short-term outcomes in terms of output and inflation than the Taylor rule. Our model illustrates that as long as the financial instability shock is short-lived and of reasonable magnitude, a forward-looking central bank can prop up the banking system with monetary easing, limiting the short-term fall in the level of output and consumption as compared to the Taylor rule. In doing so, however, the central bank that follows the augmented rule trades off more output and inflation instability today for a faster return to the trend path tomorrow. The long-run welfare impact depends on the parameterisation of the model and on the type of the welfare function. However, the welfare benefits of the augmented rule appear to be negligible.

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## Stock Market Integration among New EU Member States and the Euro Area

Jan Babecký, Luboš Komárek and Zlata Komárková<sup>1</sup>

In a monetary union, integration of financial markets plays the key role in assuring the effective transmission of the common monetary policy. The importance of conducting an assessment of the degree of financial integration across the euro area member countries is stressed by both central banks and academic institutions. The more integrated financial markets are, the more effectively monetary policy is transmitted through the financial system. Joining the euro area without a sufficient degree of financial market integration can cause problems in terms of transmission of the common monetary policy and common shocks. A high degree of financial market integration implies that euro area-wide shocks dominate; hence, the common monetary policy can be effectively applied to react to common shocks. On the other hand, in the case of weak financial market integration, local (i.e. country-specific) shocks prevail, which diminishes the effectiveness of the common monetary policy. In the case of new EU member states, which are committed to adopting the euro at some point, it is especially important to analyse the alignment of their markets, including the financial ones, with those of the euro area countries.

Our article focuses on financial integration among stock markets in four new EU member states (the Czech Republic, Hungary, Poland and Slovakia) in comparison with the euro area. As stock markets grow in size, they represent an increasingly important but not yet well-examined segment of the financial system. Our main objective is to test for the existence and determine the degree of stock market integration of the selected new member states relative to the euro area. Furthermore, we investigate the extent to which stock market integration is determined by sector rather than country effects. Our empirical analysis is hence

conducted at the country level (using national stock exchange indices) and at the sectoral level (considering banking, chemical, electricity and telecommunications indices).

How can the degree of financial market integration be measured in practice? Financial market integration is a broad concept. Baele et al. (2004) propose to quantify financial integration using three main dimensions, namely (i) price-based, (ii) news-based and (iii) quantity-based measures. The first class of measures could be viewed as a direct check of the law of one price on the condition that the compared assets have similar characteristics. Price-based measures can then be quantified by means of, for example, beta and sigma convergence. The second class of measures makes it possible to identify existing market imperfections such as frictions and barriers, because in the integrated area new information of a local character should have a smaller impact on particular assets than global news. The third class of measures quantifies the effects of mainly legal and other non-price frictions and barriers from both the supply and demand sides of the investment decision-taking process.

Following Adam et al. (2002) and Baele et al. (2004), in our article we make use of the price-based approach to measure stock market integration. Stock market integration takes place when shares having the same risk factor and yield are priced identically by the markets no matter where they are traded. This follows from the law of one price.<sup>2</sup> The more, for example, the Czech stock market becomes integrated with the euro area market, the more share prices will be affected by global (euro area) factors associated with symmetric shocks rather than by local (national) effects associated with asymmetric shocks. Such shocks may be due

<sup>1</sup> This article is based on Babecký, Komárek and Komárková (2007a,b).

<sup>2</sup> If the law of one price did not apply, there would be room for arbitrage. If we assume a fully integrated market with no barriers (economic, legal, cultural, etc.), then any investor will be able to use this arbitrage opportunity, causing the law of one price to apply again.

to any factors capable of affecting share prices (yields). It can be assumed that with increasing integration the stock market will become a less likely source of asymmetric shocks.

We address the following three main questions, similar to those raised earlier by Adam et al. (2002) with respect to the euro area: (i) Is there convergence of stock markets between the Czech Republic, Hungary, Poland and Slovakia on one side and the euro area on the other side? (ii) If there is convergence, how fast is it? (iii) How does the degree of financial market convergence change over time at the national and sectoral levels? In particular, are there any effects related to the announcement of EU enlargement or to EU enlargement itself?

Our empirical evaluation consists of (1) an analysis of alignment (by means of standard and rolling correlation analysis) to outline the overall pattern of integration; (2) the application of the concept of beta convergence (through the use of time series, panel and state-space techniques) to identify the speed of integration; and (3) the application of so-called sigma convergence to measure the degree of integration. The calculations were carried out on weekly data (daily data averages) drawn from Thomson DataStream, covering the period from 1995 to 2006.

*Analysis of alignment* is the first step towards obtaining an outlook for stock market integration. This analysis indicates the strength of the linear relationships between the variables. The concept of *beta convergence*, which originated in growth literature (Barro and Sala-i-Martin, 1992), enables identification of the speed at which stock markets achieve integration over time. A negative beta coefficient signals the existence of convergence, and the magnitude of the beta coefficient expresses the speed of convergence,

i.e. the speed of elimination of shocks to the yield differential vis-à-vis the euro area. The concept of *sigma convergence*, which was also originally used in the growth literature, identifies the degree of convergence achieved between stock markets at a given point in time. Application of sigma convergence to stock markets involves calculating the cross-section dispersion in the return spread of specific assets (national or sectoral stock exchange indices) as a measure of the degree of integration. Sigma convergence arises if and when the cross-sectional distribution collapses to a single point. Since beta convergence may be accompanied by sigma divergence, both concepts must be tracked concurrently in order to assess the degree of financial integration.

Overall, we find evidence of stock market integration on both the national and sectoral levels between the Czech Republic, Hungary, Poland, and the euro area. Yet some diverging increase in volatility is observed since 2005. The results unambiguously point to the existence of beta convergence of the stock markets under review at the national and sectoral levels. Moreover, the speed at which shocks dissipate is quite high – less than half of a week. Notice, however, there are still more differences between countries than sectors in terms of the speed and degree of convergence. For example, the Slovak stock market is characterised by the lowest degree of beta convergence.<sup>3</sup> We do not find a major impact of either EU enlargement or the announcement thereof on beta convergence. In fact, the high speed of beta convergence was achieved much earlier, during the 1990s. Furthermore, the dynamics of the sigma convergence for the EU-4 block suggest overall convergence during 1995–2004, yet some diverging increase in volatility afterwards. Since 2005 the stock markets of the Czech Republic, Hungary and Poland have

3 The Slovak stock market is much smaller and, from the perspective of investors and stock issuers, may seem less attractive than the markets of the other new EU member states under review. For example, in 2006 the Czech market capitalisation was € 58 billion, as against only € 4 billion in the Slovak case. Similarly, the Czech average daily trade amount (€ 123 million) was much higher than that for Slovakia (€ 0.31 million), and also the Czech trade volume was 1,072 million units, as compared to 5 million in Slovakia.

diverged from the euro area stock market. This result is not surprising given the fact that these stock markets experienced high growth exceeding the growth of the benchmark eurozone index. Hungary – followed by Poland – has the lowest degree of stock market integration with the euro area at the end of the period under review.<sup>4</sup> On the sectoral level, the dynamics of beta and sigma convergence for banking, chemicals, and electricity is fairly similar. The telecommunication sector, which had above-average volatility (sigma divergence) in the past,

has converged to the other three sectors since the end of 2002. Similar to the national indices, there are signs of sigma divergence since 2005.

In conclusion, when evaluating the degree of stock market integration between euro-candidates and the euro area one should bear in mind that this is a relatively small, yet important, segment of the financial markets. In our subsequent research we deal with a broader examination of integration of the money, bond and credit markets in the enlarged EU (see Czech National Bank, 2008).

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4 Although the stock market in Slovakia displays convergence, this result should be interpreted with caution given the moderate state of development of the Slovak stock market.

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