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# *Proliferation of Tail Risks and Policy Responses in the EU Financial Markets*

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## *Abstract*

This study draws attention to the proliferation of tail risks in financial markets prior to and during the course of the recent global financial crisis. It examines the level of tail risks in selected equity, interbank lending and foreign exchange markets in selected EU Member States in relation to the United States. The extent of tail risks is assessed by applying general error distribution (GED) parameterization in GARCH volatility tests of the examined variables. The empirical tests prove that tail risks were pronounced across all of the examined European financial markets throughout the crisis. They were also significant prior to the crisis outbreak. The analyzed interbank lending markets exhibited more extreme volatility outbursts than the equity and foreign exchange markets. Several countercyclical monetary and macroprudential policies aimed at abating tail risks are identified and discussed. Flexible capital adequacy and contingent capital requirements for financial institutions are advocated.

**JEL Classification: E44, G01.**

**Keywords:** tail risk, systemic risk, financial crisis, EU Member States

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## **I. Introduction**

The global financial crisis that began in mid-August 2007 has underscored the importance of tail risks embedded in the behaviour of key financial market variables. The primary examined variables are equity market indexes, interbank lending rates and exchange rates. The prevalence and scale of tail risks have contributed to the unprecedented depth, propagation and unpredictability of this crisis (Mishkin, 2009; Orłowski, 2008b). Ultimately, tail risks have engendered proliferation of systemic risk, i.e. a high probability of systemic financial collapse.

Tail risks stem from extreme outcomes and suggest that the data distribution of financial market variables is not normal but leptokurtic, which indicates high concentration of data around the mean at normal times and wide dispersion at turbulent periods. Elevated volatility, or fat tails in financial data distribution impair reliability of forecasts of these variables, particularly at times of financial distress. Fat tails arise from investor behaviour that is triggered by either excessive optimism or pessimism, leading to large market moves. As investors purchase securities in a steady stream being encouraged by herd behaviour that is not supported by economic fundamentals, a period of asset price appreciation yields to increased volatility. Eventually, a negative signal from fundamentals triggers a sudden sell-off of securities, reversing the herd actions, and amplifying price volatility. In essence, this herding behaviour and formation of asset-price bubbles leads to uncertainty of asset valuation, eventually resulting in high asset-price volatility, i.e., tail risks.

The analysis of tail risk conducted in this study is rooted within the context of selected theoretical models of financial crises, including the 'financial fragility', 'herd behaviour' and 'asset-price bubble' models. It argues that these concepts implicate prevalence of tail risks. Most of the analytical models applied in risk assessment and financial forecasting, such as the value-at-risk models, are based on an assumption of normal (Gaussian) data distribution. By ignoring leptokurtosis or tail risks, these models tend to overestimate volatility at normal periods and underestimate it at turbulent times.

This paper investigates prevalence of tail risks for the key financial variables that comprise market risk, i.e. equity market indexes, interbank lending rates and exchange rates relative to the euro. I aim to measure the extent of tail risks in equity, interbank credit and foreign exchange markets in the EU prior to and during the recent financial crisis. To reflect upon the variety of EU financial markets, the empirical analysis includes seven larger European countries. This group encompasses two dichotomies. The first distinguishes between incumbent and new EU Member States, and the second distinguishes between the eurozone members and the euro-candidates. Conditional volatility patterns of financial markets of the Czech Republic, France, Germany, Hungary, Poland, Sweden, and the United Kingdom are compared with those of the United States, where the crisis originated. The daily data series include 2540 observations for the sample period January 3, 2000-September 14, 2009. For the purpose of ascertaining tail risks, I employ GARCH-M tests augmented with general error distribution (GED) parameterization. The main advantage of looking at volatility dynamics using the GARCH-M-GED testing is that it allows for measuring the scope of tail risks. The ubiquitous character of extreme tail risks is empirically detected for all examined EU financial markets, as well as for the U.S. markets. It stems from increasingly risky capital inflows that have contributed in recent years to adverse feedback loops between increasingly volatile asset prices and the real economy slowdown. In all examined cases, the estimated GED parameters indicate significant fat-tails.

This paper contributes to the existing literature in several ways. It identifies the roots of tail risks within the main theories of financial crisis, it provides specific estimates of the magnitude of these risks in selected financial markets, and it suggests several policy solutions for containment of these risks. It argues that extreme volatility of financial market variables is a source of systemic risk. At times of financial distress, volatility of the analyzed financial variables is intensified, manifesting itself as an extreme leptokurtic distribution. Such extreme volatility is most pronounced in the case of interbank rates and somewhat less significant for equity market indexes and exchange rates, which is the main empirical finding of this paper. These disparities have been particularly magnified during the recent global financial crisis.

Prior to this crisis, the potential for outbursts in volatility of financial market variables had been largely underestimated, which was a major contributing factor to the unexpected scale of this crisis. Therefore, monitoring tail risks has emerged as a prerequisite for devising appropriate monetary and macroprudential policies aimed at containing speculation and mitigating systemic risk. In general, policies aimed at mitigating extreme risks ought to be countercyclical and sufficiently flexible, allowing for appropriate responses during tranquil market periods as well as at times of financial distress.

Section II discusses basic theoretical concepts that explain the recent crisis within the context of tail risk proliferation of key monetary and financial variables. Section III explains the impact of several risk categories faced by financial institutions and monetary policy-makers on systemic risk. An empirical approach to tail risk analysis is laid out in Section IV. Empirical tests demonstrating the impact of the recent crisis on volatility of equity market indexes are presented and discussed in Section V. Volatility of interbank interest rates is analyzed in Section VI and of exchange rates in Section VII. Monetary and macroprudential policy responses aimed at mitigating tail risks within a broader policy framework for managing systemic risk are outlined in Section VIII. Section IX summarizes the main arguments and findings.

## **II. Tail Risks in Financial Crisis Theories**

The depth and the global scope of the recent financial crisis has taken the majority of economists and financial analysts by surprise, because the prevailing risk assessment and forecasting models were based on the assumption of normal data distribution. These models have proven to be flawed because they disregard the potential for leptokurtic distributions among financial variables.

Although a comprehensive theoretical framework for analyzing financial crises is yet to be developed, a number of existing theories of financial fragility and crises could have been used to identify the potential for tail risks. Chief among them is the Kindleberger-Minsky theoretical framework of *financial fragility*, which they consider an inherent attribute of market economies. According to Minsky (1982a, 1982b), high financial fragility leads to a higher risk of financial crisis. When there are first signs of the so-called 'Minsky moment', which is an abrupt reversal of investor confidence, appropriate economic policy decisions are needed to avoid the transition from "normal" to high fragility (i.e. to a debt-deflation process). At these times, the intensity of decline depends on the relative proportion of three categories of financing identified by Minsky, i.e. hedge finance, speculative finance and Ponzi finance. The most stabilizing among them is hedge finance, in which both the principal and interest

payments on loans are paid in every period. With speculative finance, income flows cover interest payments only, forcing a borrower to roll over at least some portion of debt. The most destabilizing is Ponzi finance, which takes place when expected income is not sufficient to cover interest costs, forcing the borrower to incur more loans or to sell off assets to service the debt.

A key trigger of the crisis outburst in the Minsky-Kindleberger theoretical framework (Minsky, 1982a, 1982b; Kindleberger, 1988, 1996) is an exogenous shock to the macroeconomic system, labelled by Minsky as a 'displacement'. Such a shock can be induced by various types of systemic interruptions (wars, supply or demand shocks, drastic regulatory changes or other 'policy-switching causes inducing financial instability). One such cause that is particularly relevant to the recent global financial crisis is the expansion of bank credit to increasingly risky borrowers, which was incited by the rapid growth of credit derivatives. As argued by Minsky (1982a), an expansion of bank credit usually follows an economic boom. Such expansion enlarges money supply and leads gradually to a speculative mania that accompanies infinitely growing personal credit. This in turn spurs the development of new credit instruments and a further expansion of personal credit outside the banking sector. Such growth in liquid funds engenders supply of both traditional and new types of financial assets that generate strong profits for investors. Solid profits trigger further demand for financial assets in spite of rising assets prices, which results in a 'bandwagon effect' that becomes increasingly speculative as less-qualified and more risky investors join the game. This process ultimately leads to the formation of an asset-price bubble. Such speculative 'euphoria' (as it is called by Minsky), or 'over-trading' (as termed by Adam Smith) leads to a situation of 'revulsion' when economic agents realize that markets cannot go higher any more. At this stage, a single exogenous shock is all that it takes to trigger a stampede, a burst of a speculative bubble. In the Minsky-Kindleberger conceptual framework, relative stability or 'tranquillity' is restored if one or more of the following conditions take place: (a) investors move to less liquid assets, (b) trade is constrained by limits on price declines, or, perhaps most importantly, (c) the lender-of-last-resort provides sufficient liquidity to financial markets (Kindleberger, 1996). In sum, the Minsky-Kindleberger model is useful for understanding both the creation of a speculative bubble and the prevalence of leptokurtosis in the time series of asset prices. During the bubble-growing period, asset price volatility is likely to be contained around the mean. However, during the crisis period asset-prices are subject to significant, unexpected gyrations.

Investor *herd behaviour* is a second plausible factor contributing to the asset price bubble cycle. In integrated financial markets, information flow is fast and unrestrained, allowing investors to learn from each other and form expectations about future asset-price trends. Herding models assume that investors are acting rationally by following their peers as they buy certain types of assets, presumably because the other players have some additional, yet to be disclosed positive information about these assets. However, in the framework of 'adaptive learning' models, investors are imperfectly rational, as their buying decisions are based on presumed information of others that asset prices will rise further (Froot, et.al 1992). In some extreme cases when asset prices are proven to rise for some time, investors following the 'herd' buying decisions may develop a perception that the price increase is more permanent and a price correction is unlikely. This leads directly to a formation of asset price bubbles. Such perceptions and the herd behaviour related to them are particularly pervasive when full information about asset prices is restricted and not widely available. This phenomenon has been confirmed in several recent studies. Among them, Cipriani/Guarino (2009) demonstrate that herding behaviour of investors prevails under the market scenario

with a high event (price) uncertainty, while the proportion of herd decisions is low in the absence of similar uncertainty. Nevertheless, recent herding behaviour models have also been exposed to some criticism. They have been viewed as ineffective for explaining financial crisis episodes if they assume that investors are allowed to trade assets with market-determined prices and when investors are bound to follow pre-specified orders. Chari and Kehoe (2004) show that once these two rigorous assumptions are waived, herd behaviour re-enters these models. Within the context of the recent crisis, herding actions of investors have contributed sequentially to the formation of the housing market bubble in the U.S. and some regions of Europe, the mortgage and other consumer debt bubbles, the derivatives' bubble (mainly collateralized debt obligations or CDOs), the crude oil futures bubble, and perhaps the emerging market currencies bubble (Mizen, 2008; Orlowski, 2008b; Akerlof/Shiller, 2009).

The massive liquidity in global money and capital markets is re-allocated into different asset classes in response to various economic signals, i.e. changes in interest rates, exchange rates, income and inflation expectations, etc. (Akerlof/Shiller, 2009). The process of global capital re-allocations between different asset classes during the course of the recent crisis has been examined by Orlowski (2008b) and labelled as a “*wandering asset-price bubble*”, which is the third useful framework for explaining prevalence of tail risks. An outburst of financial crisis always engenders a large-scale correction of asset prices and a bank credit freeze due to a rapid increase of both liquidity and counter-party risks (rapidly depreciating assets cannot be easily liquidated and the likelihood of default by the parties entangled in contractual obligations increases). This prescription has been endemic for the present financial crisis (Hellwig, 2008; Orlowski, 2008b). As home prices in the US started to decline in the early 2006, demand for mortgages by qualified prime borrowers began to recede. Eager to sustain their previous profits, mortgage companies engaged in aggressive lending to high-risk borrowers (as much as 40 percent of new mortgages in 2006 were granted to subprime or near-prime US borrowers). The banks were unwavering in securitization efforts of these high-risk loans, resulting in the issuance of financial derivatives, mainly collateralized debt obligations. The further corrections in home values in 2007 and 2008 led to a negative equity position for many mortgage loans (i.e., the value of an underlying property falling below the outstanding balance of the mortgage loan), making mortgage derivatives non-marketable and thus difficult to price. Moreover, a perpetual cycle of asset depreciation coupled with rising demand for more collateral developed (Brunnermeier, 2009). As asset prices entered a declining mode and lenders demanded more collateral, borrowers had to liquidate risky assets, which in turn led to a further decline in their market values and even higher demand for collateral. These processes ultimately led to the collapse of derivative securities and to a mounting market risk that gradually reverberated into: global credit risk, a wide-spread credit freeze, correction of nearly all international financial markets, and a world-wide economic recession.

The absence of relevant risk variables in financial models, particularly the measures of liquidity risk, has contributed to their failure to predict the recent global financial crisis. The models that were commonly used prior to this crisis focused mainly on the expected returns of individual assets and their default risk, but largely ignored the liquidity and the counter-party risks. Therefore, the process of asset value deterioration, in which declining trust in counter-parties freezes up markets and disables market pricing, has not been captured by the standard risk models. The exclusion of liquidity risk from these models is perplexing given that the calls for adequate measuring of liquidity risk are not new. Among others, Bangia, et. al

(2002) showed some parsimonious measures of liquidity risk and argued for its inclusion in market risk modelling<sup>2</sup>.

The prevalence of leptokurtosis in the time series distribution of financial variables has been well-known and documented in the literature. Most of the empirical studies addressing this problem have employed the extreme value method based on out-of-sample value-at-risk (VaR) computations. Applications of the VaR methodology have been routinely based on normal distribution. Thus, the reduced-form VaR model has failed to adequately evaluate risk and determine portfolio investment losses when markets are subject to extreme volatility outbursts. Among others, Danielsson (2002) shows empirically that VaR tests with normal distribution provide improper guidance to investors at times of excessive volatility and are likely to exacerbate both idiosyncratic and systemic risk in turbulent periods. To circumvent this problem, Longin (2000 and 2005) proposes VaR tests that rely on out-of-sample extreme value computations by generating better-fitting distribution tails, particularly at times of elevated market volatility. Similarly, Gençay/ Selçuk (2004) use VaR with extreme value estimates for daily returns in a number of emerging stock markets, proving that their distributions have very different moment properties at their right and left tails. These studies were published prior to the extreme volatility outbursts associated with the recent (2007-2009) global financial crisis, the scope of which has questioned applicability of VaR tests (even those relying on extreme value computations) for an accurate market risk assessment. Recognizing the drawbacks of VaR methodology, this study extends the analysis of extreme risks by employing GARCH conditional volatility with GED parameterization for the identification of leptokurtosis. This allows for investigating the dramatic market vicissitudes engendered by the recent crisis.

The prevalence of tail risks made interactions between different types of financial risk (liquidity, credit, default, interest rate, market, exchange rate risks, etc.) during the course of the recent crisis exceptionally intense. Their comprehensive empirical assessment remains a task for future research. I attempt to contribute to it by examining the impact of the main components of market risk on systemic risk.

### **III. Market Risk and Its Impact on Systemic Risk**

The underlying assumption for this analysis is that systemic risk stems from propagation of market risk. I further assume that market risk is proxied by volatility and forecasting uncertainty of key market variables, such as equity market indexes, interest rates and exchange rates. Thus, market risk is composed of *equity market risk*, *interest rate risk* and *exchange rate risk*. Unexpected precipitation of these risks may lead to systemic risk. Elevated market risk makes asset, liability and risk management at financial institutions more difficult. It also complicates the strategy and conduct of monetary policy.

Monitoring market risk is critical for the assessment of financial stability because market risk affects the valuation of risk of various types of financial assets. Under elevated market risk conditions, the flow of accurate information between lenders and borrowers is disrupted, leading to greater information asymmetry. Increasing market volatility impairs asset price valuation, making it more difficult for lenders or issuers of credit and its derivatives to estimate the de facto credit risk associated with these instruments as well as the

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<sup>2</sup> Bangia, et al. (2002) claim that ignoring liquidity risk leads to underestimation of market risk in emerging markets by approximately 30 percent.



default risk of borrowers. As a result, the high risk environment leads to reluctance to purchase assets, which epitomizes financial crisis episodes (Mishkin, 2009). The difficulties to estimate the de facto value of a security, coupled with higher default risk and counter-party risk, ultimately lead to a credit freeze and, with some impact lag, to lower consumption, investment and economic growth. Moreover, an economic downturn may further exacerbate market risk as the value of assets may decrease due to changing market factors, which may generate an adverse feedback loop from financial disruption to economic slowdown. This process, known in the literature as the ‘financial accelerator’ (Bernanke, et.al, 1999), is found to amplify demand shocks on investment and to dampen supply shocks (Christensen/Dib, 2008).

For the above reasons, *equity market risk*, as it affects valuation of liquid assets is a crucial component of market risk. It is the risk that is common to an entire class of equity securities and is attributable to stock market volatility. Equity market risk has proven to be an important source of volatility of other asset classes, particularly at times of financial distress (Fleming, et.al, 1998). Daily changes in equity prices normally have a moderate causal impact on the direction of bond prices, exchange rates and commodity prices. This causal relationship has been magnified during the recent financial crisis that caused banks lose their capital. In response, many financial institutions were forced to sell various types of assets, as part of deleveraging strategies (reducing asset to equity ratios). Deleveraging pressure and fire sale of assets resulted in steep asset-price declines. Thus, volatile and declining equity prices induced a significant correction of other asset prices and contributed to systemic risk. Therefore, tail risks embedded in the behaviour of equity markets need to be accounted for in risk models.

The *interest rate risk* component of market risk is critical for asset/liability management at financial institutions, as it affects the duration gap, i.e. the disparity between rate sensitive assets and rate sensitive liabilities. Prior to this financial crisis the duration gap expanded substantially, in part due to an unprecedented increase in the leverage of major financial institutions. This type of risk needs to be monitored closely by monetary policy-makers. Elevated instability of short-term interest rates requires a departure from standard instrumentalization venues, i.e. adjustments of interest rates. Since unstable rates increase the gap between (more volatile) nominal interest rates and the rate implied by an instrument rule, such as a simple or an open-economy Taylor rule, continuous reliance on an unremitting Taylor rule is likely to be inadequate. The presence of higher interest rate risk would lead to either a suboptimal choice of the policy instrument, with some costs to financial stability and social welfare, or to frequent adjustments of the interest rate target to the rule-implied rate, which would inhibit policy predictability and transparency. For these reasons, in periods of financial crisis and elevated interest rate risk, monetary policy should become more discretionary by departing from rigid instrument rules that are normally designed for tranquil economic conditions.<sup>3</sup> Furthermore, during turbulent market periods policy instrumentalization and signalling may suffer additional impairments, such as the recent de-

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<sup>3</sup> This notion follows the critique of Taylor rules by Svensson (2003) that at times of elevated interest rate risk compliance with such rules becomes implausible. In addition, Woodford (2001) points out that a time-invariant Taylor rule may distort the relation between nominal interest rate and the inflation- and output gaps when real economy shocks are present. Inapplicability of Taylor rules for the euro-candidate countries at times of financial distress is expressed by Gabrisch (2009) and Orłowski (2010). In support of a rule-based policy, Taylor (2009) calls for a prompt return to ‘the set of principles for setting interest rates that worked well during the Great Moderation’, in the aftermath of the present financial crisis. In a similar vein, Ahrend (2008) attributes the risk propagation during the recent crisis to excessive easing of monetary policies by the US Federal Reserve and other central banks that maintained the reference interest rates considerably below the Taylor rule-implied levels.

coupling of long-term and short-term interest rates. This distortion stems from weak markets for assets backed by securitized loans (unless such assets were guaranteed by government agencies) and interest rate swaps. They can also be attributed to novel central banks' policy actions, such as the long-term lending facility and direct loans to banks by the Federal Reserve or private debt purchases by the Bank of Japan. Nevertheless, these technical difficulties do not imply that central banks should entirely abandon short-term interest rate adjustments as a policy instrument in their interest rate risk mitigating attempts (Jobst, 2008; Mishkin, 2009). In sum, the prevalence of tail risks embedded in interest rate movements calls for more discretionary, unconventional monetary policies. Sticking to a rule-based policy course may increase probability of systemic risk.

Identification and management of *exchange rate risk* is important for both financial institutions and monetary authorities. Rapid increases in exchange rate volatility impede the valuation of assets and the assessment of borrowing costs at financial institutions and other economic agents exposed to foreign currency translations. Sudden increases in exchange rate risk necessitate application of more sophisticated methods of asset/liability management at financial institutions. For policy-makers, excessive volatility of exchange rates distorts information about the exchange rate channel of monetary policy transmission<sup>4</sup>. In essence, unexpected increases in exchange rate volatility inhibit effective implementation of monetary policy and normally lead to higher interest rate on domestic credit, as financial institutions translate a higher cost of foreign currency borrowings into a higher credit risk premium.

In hindsight, precipitation of tail risks embedded in the behaviour of equity markets, interest rates and exchange rates may lead to systemic risk. It obfuscates asset/liability management at financial institutions and hinders monetary policy implementation.

#### **IV. Empirical Analysis of Tail Risks**

The focus of empirical analysis is on the proliferation of tail risks for the key financial variables that comprise market risk, i.e. equity market indexes, interest rates as approximated by inter-bank lending rates, and exchange rates relative to the euro. I aim to determine the magnitude and precipitation of tail risks in selected European countries prior to and during the course of recent financial crisis. To reflect upon variety of EU financial markets, I select a group of seven larger countries. This group encompasses two dichotomies. The first distinguishes between the incumbent and the new EU members, as defined on the basis of the 2004 enlargement, and the second distinguishes between the eurozone and the euro-candidates. I choose the larger countries that follow more autonomous monetary policies with flexible exchange rates in order to account for the dynamics of exchange rate risk. The examined group of countries includes the three largest new EU members who are expected to join the euro – the Czech Republic, Hungary and Poland; the two largest EU and eurozone members – France and Germany; and two incumbent EU members pursuing autonomous monetary policies outside the eurozone – Sweden and the United Kingdom. I then compare these countries results with those for the United States, where the crisis has originated. The tests are based on daily average market data for the sample period January 3, 2000-September 14, 2009 (2540 observations).

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<sup>4</sup> This channel has been proven to play a particularly important role in the economies converging to the euro since it has a relatively short impact lag translating currency appreciation (depreciation) into disinflation (inflation) through pass-through effects of import prices (Golinelli/Rovelli, 2005; Orłowski, 2005; Kočenda/Poghosyan, 2009).

Prior to conducting the econometric tests, I scan the examined variables for leptokurtosis. The results of this scanning are shown in Table 1. The data distribution of daily changes of all equity market indexes, interbank rates and exchange rates is highly leptokurtic, since all kurtosis coefficients are greater than 3. In some cases, namely of the German DAX market index and the Hungarian and Swedish interbank rates, leptokurtosis is extreme indicating high probability of very large shocks at times of financial instability. The obtained kurtosis measures suggest a potential flaw in econometric models that assume a normal distribution of these variables, because such models are likely to underestimate volatility or tail risks at turbulent periods.

**Table 1:** Kurtosis coefficients of financial market variables

<i>Country (market)</i>	<i>Δlog of stock market indexes</i>	<i>Δ of interbank lending rates</i>	<i>Δlog of exchange rates vis-à-vis EUR</i>
Czech Republic	15.71	117.18	10.26
France	8.10	66.84	-
Germany	607.29	66.84	-
Hungary	9.40	235.04	14.30
Poland	9.18	34.57	7.81
Sweden	5.97	436.38	7.73
United Kingdom	7.49	169.64	7.72
United States	21.98	58.45	6.12

*Notes:* January 3, 2000-September 14, 2009 sample period. Equity market indexes: Prague SEPX, Paris CAC40, German DAX40, Budapest BUDEX, Warsaw WIG20, Stockholm SMIALL, UK FTALL, US S&P500; three-month interbank rates: Prague-Pribor, Euribor, Budapest Bibor, Warsaw-Wibor, Stockholm-Stibor, London-Libor, USD Libor; the kurtosis coefficient  $k > 3$  indicates leptokurtic data distribution.

*Source:* Author's own estimation based on Datastream data.

I therefore proceed to econometric testing of conditional volatility that accounts for tail risks. For this purpose, I employ the generalized auto-regressive conditional heteroscedasticity method with in-mean conditional variance and generalized error distribution parameterization (GARCH-M-GED). I do not aim to find the best-fit forecast functions; instead, I emphasize the pattern of noise, or volatility gyrations particularly during the course of the recent crisis. I use a parsimonious GARCH(1,1) specification to ascertain the overall risk compression. Such compression takes place when the sum of ARCH (innovations to volatility) and GARCH (persistence in volatility) estimated coefficients is below unity; when it exceeds unity, the risk dispersion occurs. To determine whether the return on a financial asset is positive or negative, I include the (log of) GARCH conditional variance in the conditional mean equation. Most importantly, my analytical objective is to demonstrate that the volatility pattern follows a leptokurtic distribution, which occurs when the estimated GED parameter is less than 2.

To capture the degree of leptokurtosis exhibited by financial market variables, I use a two-step GARCH(1,1)-M-GED process represented by two equations. The first one consists of general specification of the conditional mean equation:

$$Y_{i|t} = \beta_0 + \beta_1 \log \sigma_{t-1}^2 + \varepsilon_t \quad (1)$$

where  $Y_{t|rt}$  is a regressant that is treated respectively as either the equity market index, the interbank interest rate or exchange rate. The conditional mean equation includes the log of GARCH conditional variance  $\log \sigma_{t-1}^2$  as a regressor. The second equation is the corresponding GARCH(1,1) conditional variance specification

$$\sigma_t^2 = h_0 + h_1 \varepsilon_{t-1}^2 + \gamma_1 \sigma_{t-1}^2 \quad (2)$$

The ARCH(1) term denoted by  $\varepsilon_{t-1}^2$  represents the impact of the previous-period news, or ‘innovations’ to volatility on current volatility. The GARCH(1) term  $\sigma_{t-1}^2$  reflects persistency in volatility.

## V. Equity Market Risk

To analyze the developments in equity market risk, I look at the return process  $r_t$  of daily percentage changes in domestic stock market index as a regressant in the conditional mean equation, which is  $Y_{t|rt} = \log E_{t|rt}$ . The conditional volatility testing of the percentage changes in stock market indexes is conducted for: S&P500 (the United States), DAX40 (Germany), CAC40 (France), FTALL (the United Kingdom), SMIALL (Sweden), WIG20 (Poland), SEPX (Czech Republic) and BUDEX (Hungary). The empirical results of the GARCH series of daily percentage changes ( $\Delta \log$ s) in these indexes are shown in Table 2.

**Table 2:** GARCH(1,1)-M-GED estimation of percentage changes ( $\Delta \log$ s) in stock market indexes

	<i>Czech R.</i>	<i>France</i>	<i>Germany</i>	<i>Hungary</i>	<i>Poland</i>	<i>Sweden</i>	<i>U.K.</i>	<i>U.S.</i>
<u>Cond. Mean Eq.</u>								
(coeff.x100)								
Constant term	-0.774**	-0.111	-0.348***	0.042	2.901	-0.313	-0.037	0.469***
Log(GARCH)	-0.096***	-0.018	-0.033***	-0.001	0.026	-0.041	-0.012	0.037***
<u>Cond. Variance Eq.</u>								
Constant term	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
ARCH(1)	0.118***	0.090***	1.002***	0.087***	0.109***	0.072***	0.148***	0.387***
GARCH(1)	0.867***	0.905***	0.444***	0.889***	0.879***	0.926***	0.845***	0.698***
GED parameter	1.380***	1.457***	1.239***	1.411***	1.251***	1.431***	1.395***	0.861***
<i>GED parameter crisis sub-period</i>	<i>1.405***</i>	<i>1.560***</i>	<i>0.301***</i>	<i>1.393***</i>	<i>1.178***</i>	<i>1.526***</i>	<i>1.885***</i>	<i>0.924***</i>
Log likelihood	7501	7446	12421	7176	8165	7149	8575	9355
Schwartz Info. Crit.	-5.911	-5.867	-9.800	-5.654	-6.436	-5.632	-6.760	-7.377

*Notes:* January 3, 2000- September 14, 2009 sample period (2540 observations); the financial crisis sub-period is August 17, 2007 – March 31, 2009 (423 observations); \*\*\* denotes significance at 1%, \*\* at 5%, and \* at 10%.

*Source:* Author’s own estimation based on Datastream data.

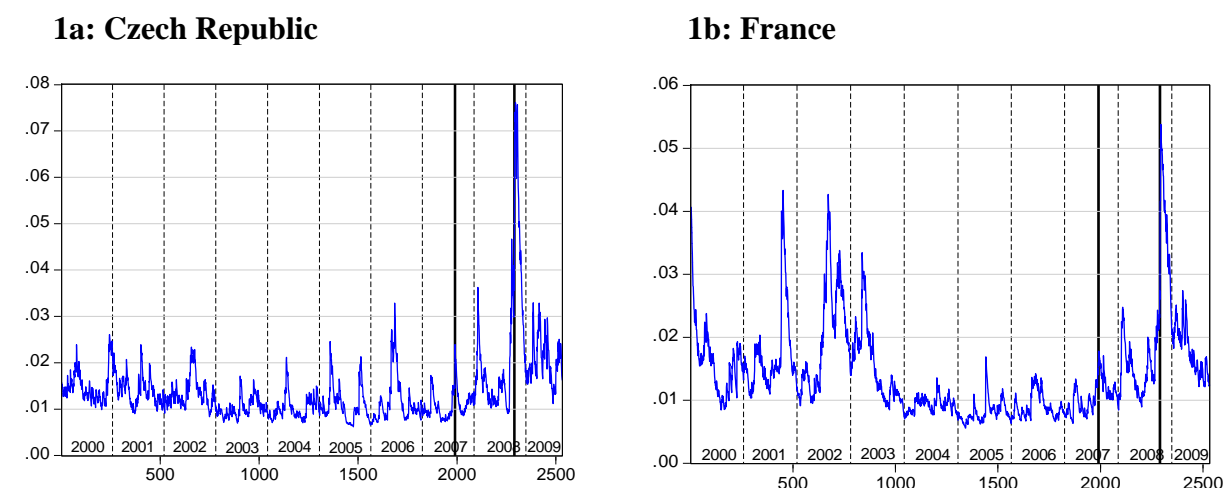
As implied by the signs of the estimated in-mean GARCH variance coefficients, the risk premium is positive and significant only for U.S. equity market index. It is significant and negative for the Czech and German market indexes. The result for the U.S. is in line with its fattest tail risk among all countries for the entire sample period (the lowest GED parameter). Risk convergence represented by the sum of ARCH and GARCH coefficients not exceeding unity is detected only in the Czech case. In line with the main argument of this study, leptokurtosis exhibited by stock market data is ubiquitous ( $GED \neq 2$ ). It is the most pronounced for the U.S., followed by the German, Polish, Czech, U.K. and Hungarian equity markets, and least pronounced for the Swedish and French markets.

To ascertain if the financial crisis has altered the degree of leptokurtosis of these equity market indexes, I repeat GARCH(1,1)-M-GED tests for the financial crisis sub-period starting from the outbreak of the crisis on August 17, 2007 and ending on March 31, 2009. During this sub-period, tail risks increased dramatically for the German market, less for the Polish and Hungarian markets, and actually decreased for the remaining markets. However, these results may be attributable to a smaller sample size and the variance resetting to a higher level associated with the crisis period.

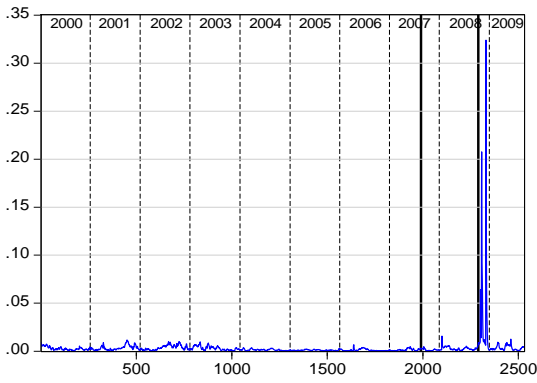
Further insights into the time distribution of the volatility series of stock market indexes are provided by the graphs showing GARCH conditional standard deviations (Figures 1a-h).

**Figures 1a-h:** GARCH one standard deviation residuals series for individual stock markets.

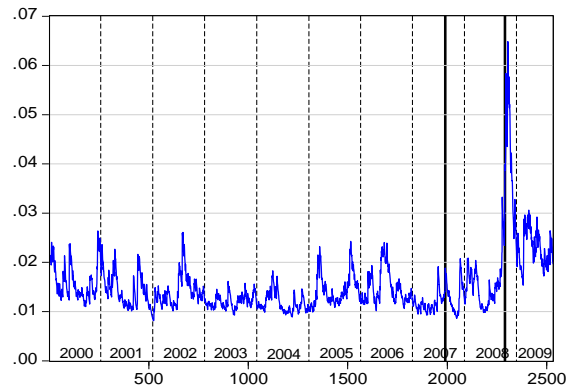
*Notes:* The left vertical line (observation #1989) coincides with the outbreak of the US subprime mortgage crisis on August 17, 2007 and the right line (observation # 2289) corresponds with the crisis peak on October 10, 2008.



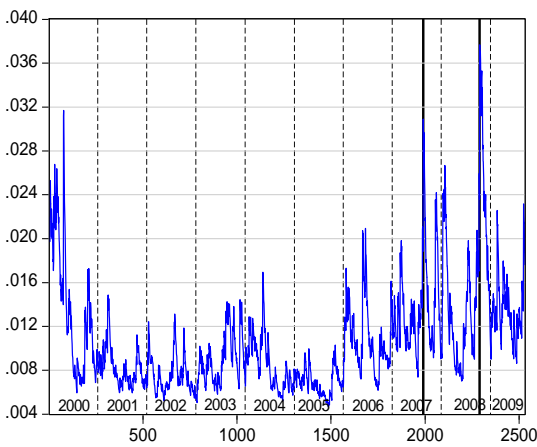
**1c: Germany**



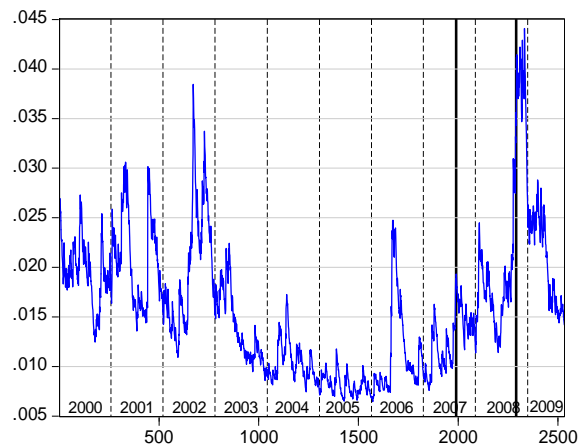
**1d: Hungary**



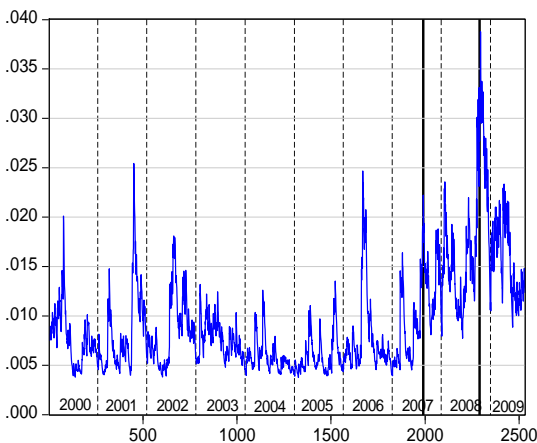
**1e: Poland**



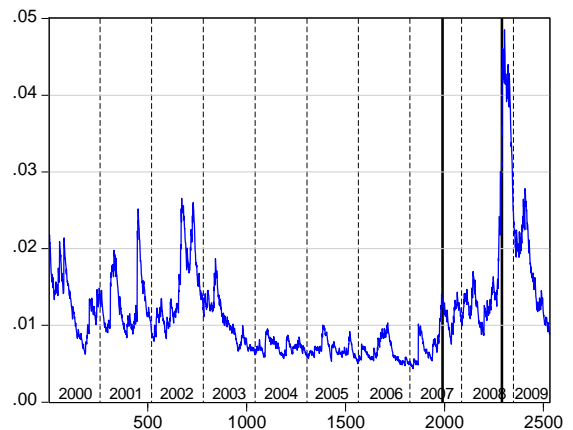
**1f: Sweden**



**1g: United Kingdom**



**1h: United States (S&P500)**



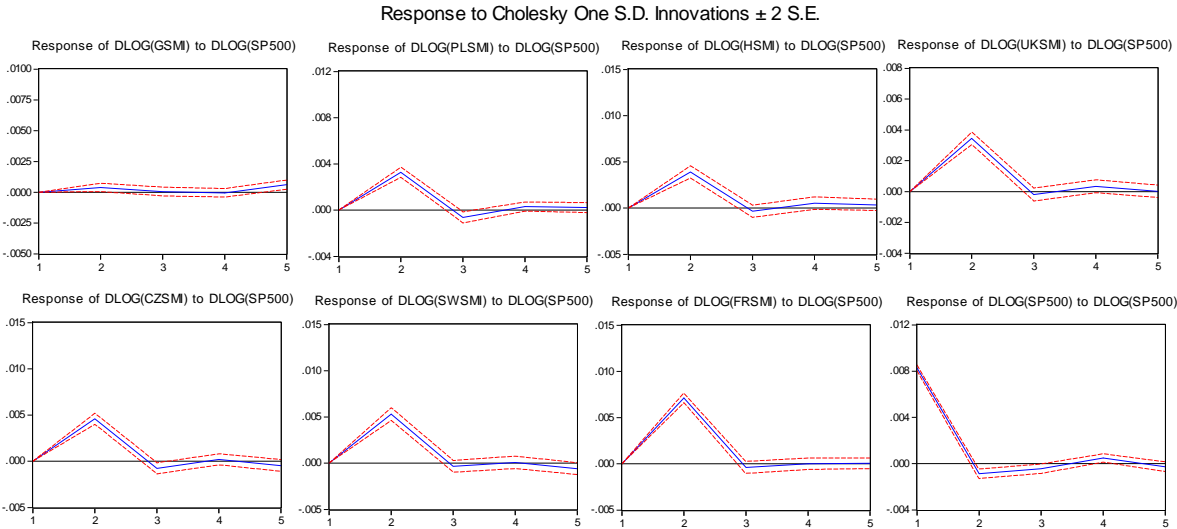
*Source:* Author's own estimation based on Datastream data.

The time patterns of GARCH standard deviations vary between the analyzed equity markets due to their institutional discrepancies that are systemic in nature, as well as to differences in macroeconomic fundamentals. Nevertheless, at least four common effects can be identified. First, GARCH volatility was considerably elevated by higher political risk

following the September 11, 2001 terrorist attack on the U.S. This result is more apparent for the U.S., U.K., French and Swedish equity markets and more subdued in the remaining cases. Second, the outbreak of the financial crisis in August 2007 did not have a significant impact on stock markets' volatility, as the crisis was originally believed to be confined to the subprime mortgage market in the U.S. only. Third, following the initial restraint at the onset of the crisis, stock markets' volatility became visibly elevated in December 2007 and early January 2008 when the crisis began spreading into global credit and derivative securities markets (Hellwig, 2008; Orłowski, 2008b). Fourth, the sudden occurrence of systemic risk in the early October of 2008 (in the aftermath of the Lehman Brothers collapse) induced an unprecedented shock to stock markets' volatility. The German market reaction is particularly interesting. While unperturbed during the benign instability periods in the past, the DAX volatility jumped by an unprecedented margin just four days after the global credit freeze on October 10, 2008, when it became apparent that the leading German banks had played a larger than previously assumed role in high-risk mortgage lending and asset securitization in the U.S. and elsewhere. This incident shows that the German equity market is susceptible to very pronounced tail risk, the scale of which could not be possibly estimated prior to the peak of this crisis.

The next step is to gain additional insights into equity market risk patterns by assessing global transmission of stock market volatility on the basis of impulse response functions. For this purpose, I analyze the vector autoregressive (VAR) setting with 5-day lagged periods for all stock markets. In particular, I focus on transmission of one-standard deviation shocks from the U.S. S&P500 index into the remaining equity market indexes, by using impulse response functions with the Bayesian (Monte Carlo) error distribution (Figure 2). By the nature of the Choleski decomposition, the impulse responses depend on the ordering of the variables, thus the responses are set to zero in the first period for all market indexes except for the S&P500.

**Figure 2:** Impulse responses of percentage changes ( $\Delta \log$ s) in individual stock market indexes to a one standard deviation of the percentage change in S&P500.



*Notes:* from upper left to lower right diagrams: German DAX40, Polish WIG40, Hungarian Budex, UK FTALL, Czech PrSMI, Swedish SWEDOMX, French CAC40, S&P500 itself. Data generating process (DGP) assumptions: 5 lags in VAR, Monte Carlo error distribution for 5 periods.

*Source:* Author's own estimation based on Datastream data.

The impulse response functions show pronounced two-day reactions of the examined stock market indexes to a one-standard-deviation shock in the U.S. S&P500. This shock transmission is uniform for all markets with the notable exception of the German DAX, which seems to be quite immune to the U.S.-generated shocks. However, the German effect is obtained from routine reactions over the entire sample period and it does not reflect the mid-October 2008 turbulence, thus it needs to be interpreted with caution.

To summarize, tail risks are prevalent in equity markets as implied by the GARCH testing of equity market indexes, particularly by the time distribution of GARCH standard deviations. The equity markets are subject to unparallel and rather unpredictable shocks during turbulent market periods. Shocks from the U.S. market seem to have triggered volatility outbursts in other markets. These prevalent tail risks along with their transmission channels should be taken into consideration in devising macroprudential policy responses aimed at mitigating market risk.

## VI. Interest Rate Risk

The second component of market risk examined in this study is interest rate risk, proxied by volatility of the three-month domestic interbank lending rates. Changes in these rates denoted as  $\Delta i_{t|rt}^{IB}$  enter the conditional mean equation as a regressant, thus for the purpose of this analysis  $Y_{t|rt} = \Delta i_{t|rt}^{IB}$  in Eq.(1).

The results of the GARCH(1,1)-M-GED estimations of daily changes in interbank rates are shown in Table 3. These results are highly significant statistically as the GED parameters are all very low, indicating high leptokurtosis. They are considerably below the levels estimated for the volatility of equity market indexes. Evidently, interbank rates tend to be very stable at benign market periods, but extremely explosive at turbulent market times. Moreover, risk premiums associated with interbank rate volatility (logGARCH-in-mean coefficients) vary significantly across the examined countries. In the Czech case, there is a high, positive risk premium, in line with the disproportionately stronger ARCH effect (shocks to volatility) in relation to the GARCH effect (persistence in volatility). In contrast, in the U.S., Sweden and the U.K., the risk premia are negative consistently with the stronger role of the GARCH relative to ARCH effects, although the interpretation of the U.K. Libor time series is less straightforward. The London interbank rate tests had to be augmented with higher-order ARCH and asymmetric threshold (TGARCH) effects due to high instability of the simple GARCH(1,1) specification.

In addition, Table 3 shows evidence of volatility or risk divergence observed in the Hungarian interbank rate and the Euribor as the sum of ARCH and GARCH coefficients is greater than unity for the entire sample period. This volatility divergence seems to be attributable to the financial crisis and can be also observed in Figures 3b and 3c. In contrast, the volatility patterns of the remaining interbank rates suggest risk convergence, since the estimated  $h_1 + \gamma_1 < 1$ . It can be further noted that leptokurtosis exhibited by the Czech, Polish, Swedish and U.K. interbank rate data increased, i.e. GED parameters declined during the financial crisis sub-period. During the same sub-period, tail risks for Hungarian, eurozone and U.S. rates decreased as their GED parameters increased and their mean volatility became reset at higher levels.



**Table 3:** GARCH(1,1)-M-GED estimation of changes in interbank rates

	<i>Czech R.</i>	<i>Eurozone</i>	<i>Hungary</i>	<i>Poland</i>	<i>Sweden</i>	<i>U.K. 1)</i>	<i>U.S.</i>
<u>Cond. Mean Eq.</u> (coeff.x100)							
Constant term	+1.615***	-0.030	-2.250	-109.63***	-116.55***	-24.05***	-8.39***
Log(GARCH)	+1.690***	-0.003	-0.003*	-0.017***	-13.46***	-343.1***	-10.31***
<u>Cond. Variance Eq.</u>							
Constant term	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
ARCH(1)	0.543***	0.737***	2.021***	0.149***	0.003***	0.122***	0.061***
GARCH(1)	0.153***	0.544***	0.133***	0.413***	0.650***	0.099***	0.399***
GED parameter	0.718***	0.712***	0.386***	0.402***	0.693***	0.636***	0.479***
<i>GED parameter crisis sub-period</i>	<i>0.517***</i>	<i>0.746***</i>	<i>0.687***</i>	<i>0.118***</i>	<i>0.431***</i>	<i>0.416***</i>	<i>0.646***</i>
Log likelihood	8083	8456	6340	5363	7694	6242	7818
Schwartz Info. Criterion	-6.371	-6.666	-4.993	-4.221	-6.063	-4.906	-6.161

*Notes:* Three-month interbank rates: Prague Pribor, Euribor, Budapest Bibor, Warsaw Wibor, Stockholm Stibor, London Libor, USD Libor. January 3, 2000-September 14, 2009 sample period (2540 observations); the financial crisis sub-period is August 17, 2007 – March 31, 2009 (423 observations); \*\*\* denotes significance at 1%, \*\* at 5%, and \* at 10%.

1) Due to significant second-order asymmetric effects, the U.K. Libor time series is specified with threshold terms as TGARCH(2,2,1)-M-GED; the ARCH(2) coefficient = -0.122\*\*\*, TARCH(1) coefficient = 0.069\*\*\*, TARCH(2) coefficient = -0.069\*\*\*.

*Source:* Author's own estimation based on Datastream data.

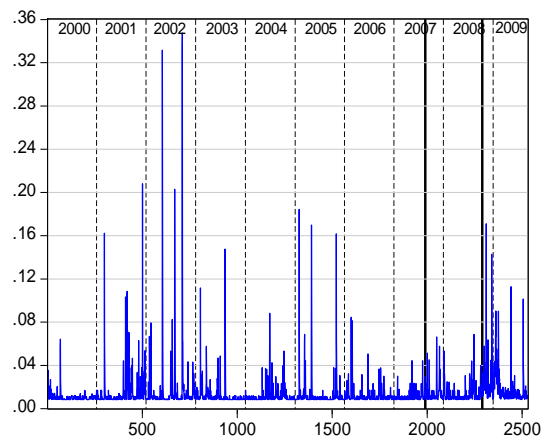
The time patterns of the interbank rate volatility series are shown in Figures 3a-h. During the early period of the present decade, the Czech and Polish interbank rates show very high volatility triggered by both domestic and external factors. The domestic factors include insufficiently developed bond markets and inflationary pressures. The term spreads on sovereign bonds were highly unstable and did not provide adequate benchmarks for other interest rates, including interbank rates, following the inception of the long-term government bond markets in these countries. In addition, they experienced elevated political risk in the aftermath of the September 11, 2001 attack on the United States that contributed to interest rates volatility in all emerging European markets<sup>5</sup>. Figures 3a and 3c indicate that volatility of interbank rates in Poland and the Czech Republic during the early period was much higher than in the course of the recent crisis. In a somewhat different vein, volatility of the Hungarian interbank rates reached very high levels in 2003 when the country's fiscal discipline changed its course resulting in higher government borrowings and ultimately higher volatility of interest rates. Volatility of the Euribor (Figure 3b) was also very high in the early years of the present decade, as credibility of the financial system in the new currency area needed to be established. Volatility of interbank rates in the United States was soaring as well due to elevated political risk following the September 2001 attack (Figure 3g).

<sup>5</sup> Further evidence on factors affecting risks faced by Eastern European banking sectors is provided by Männassoo and Mayes (2009) who demonstrate the adverse effects of inflationary pressures, exchange rate movements and bank-specific institutional deficiencies on these risks.

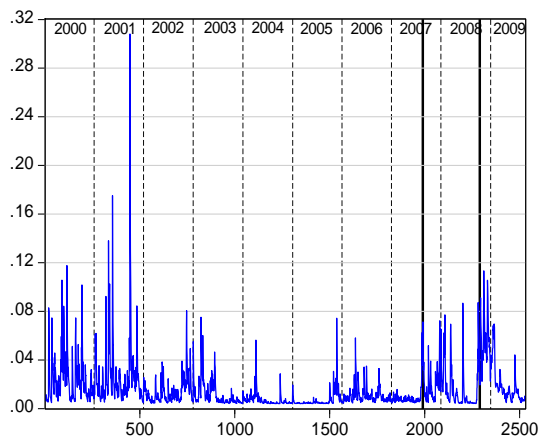
**Figures 3a-g:** GARCH one standard deviation residuals series for changes in interbank rates.

*Note:* The left vertical line (observation #1989) coincides with the outbreak of the US subprime mortgage crisis on August 17, 2007 and the right line (observation # 2289) corresponds with the crisis peak on October 10, 2008.

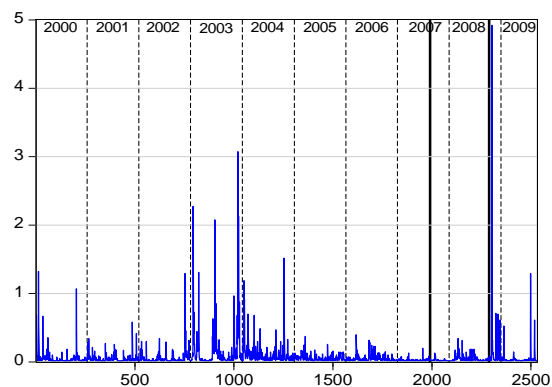
**3a: Czech Republic**



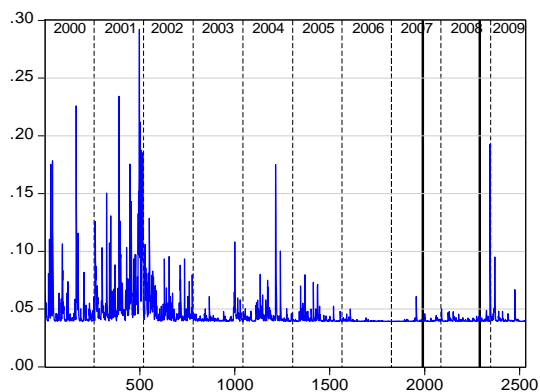
**3b: Eurozone**



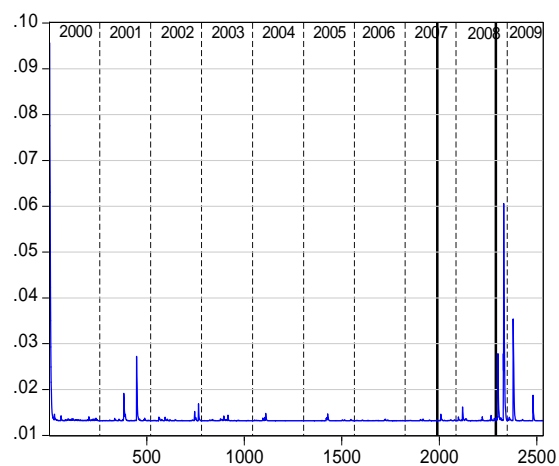
**3c: Hungary**



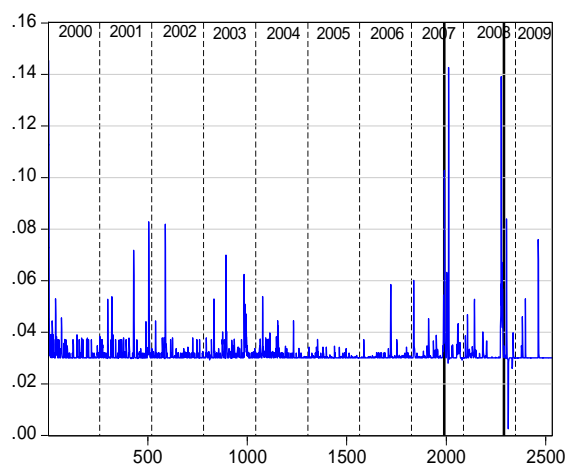
**3d: Poland**



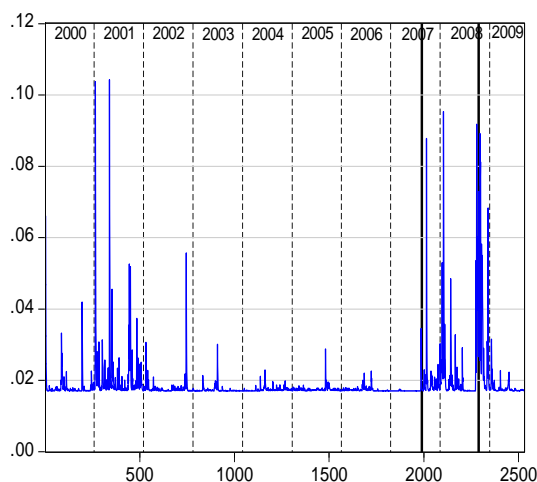
**3e: Sweden**



**3f: United Kingdom**



### 3g: United States

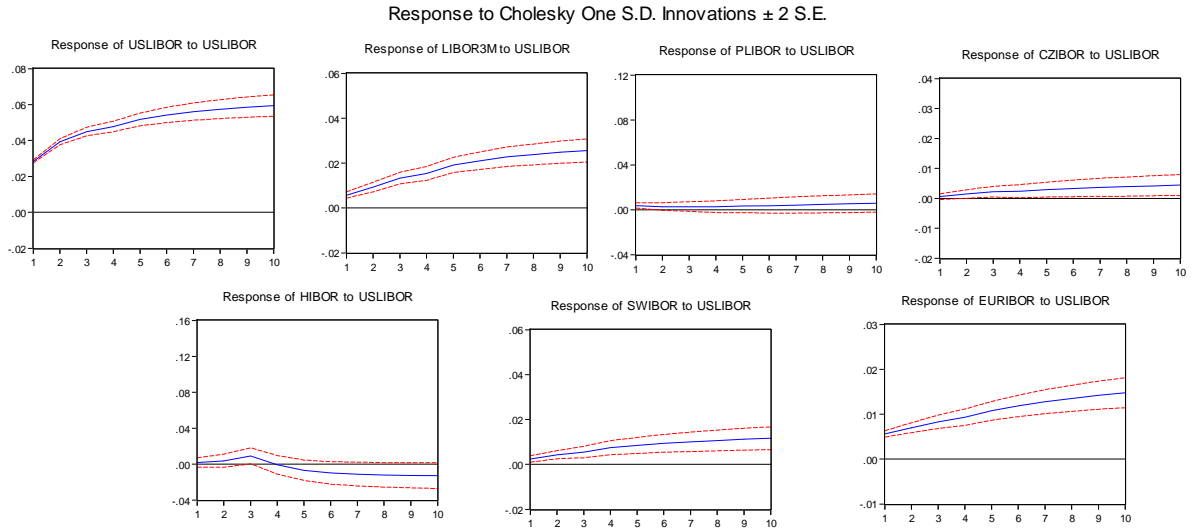


*Source:* Author's own estimation based on Datastream data.

In sum, the recent financial crisis has triggered large adverse effects on interest rate volatility in all examined countries. However, the degree of instability of interbank rates is not uniform. The most significant jump in interbank rates volatility can be observed in Hungary on October 12, 2008 (Figure 3c). This jump stemmed from spillover effects of the global credit market freeze in the aftermath of the Lehman Brothers collapse that, seemingly, had a strong effect on countries with less-disciplined macroeconomic policies, such as Hungary. Volatility of the U.S. (Figure 3g) and the U.K. (Figure 3f) interbank rates was in sync and certainly reached a zenith at that time, since both markets were at the source of the global credit malaise. It can be further noted that the transmission of global gyrations in interbank rates in October 2008 into the Swedish and Polish banking systems was considerably delayed. Interbank rates volatility in these countries peaked only at the end of 2008 and the beginning of 2009, because their banking systems were initially perceived as somewhat immune to the global credit freeze.

The international transmission of shocks from the U.S. into other interbank credit markets can be observed from the VAR analysis and impulse response functions shown in Figure 4. The responses pertain to reactions of interbank rates at their levels and not at their first differences, as such treatment allows for a more straightforward interpretation of the obtained results. As it can be expected from the degree of integration and linkages between interbank lending markets, there is a strong transmission of a positive shock from the U.S. dollar (USD) 3M Libor to the U.K. Libor as well as to the Euribor. The transmission from the US to the Swedish interbank rate is moderate. In contrast, the impact of U.S. shocks on the emerging Europe is minimal. In the case of Hungary, some adverse effects can be observed for the duration exceeding four days. These results verify that the interbank lending markets in emerging Europe are less integrated with the U.S. market and, therefore, more immune to the absorption of U.S. shocks than their Western European counterparts.

**Figure 4:** Impulse responses of individual 3M inter-bank offer rates to a one-standard deviation change in the U.S. 3M LIBOR.



*Notes:* From upper left to lower right: US Libor, UK Libor, Polish Wibor, Czech Pribor, Hungarian Bibor, Swedish Swibor, Euribor. DGP assumptions: 5 lags in VAR, Monte Carlo error distribution for 10 periods.  
*Source:* Author's own estimation based on Datastream data.

Based on the examination of volatility dynamics and transmission effects of interbank rates during the recent financial crisis, an additional conclusion can be drawn that unexpectedly high interest rate volatility leads to deterioration in the capital position of financial institutions, particularly those with a significant foreign currency exposure. This was the case of banks in the larger new EU members, including Poland. These banks generated vast amounts of Swiss franc and euro denominated mortgage loans that subsequently increased in market value, as expressed in their domestic currencies, when these countries' currencies depreciated. This in turn, coupled with increasing interest rate volatility, widened the duration gap between banks' rate-sensitive assets and liabilities on the one hand, and deteriorated the market value of banks' equity on the other. In conclusion, rising volatility of interest rates contributes to widening of the leverage-adjusted duration gap and to decreasing of the equity capital of financial institutions. To lower their duration gap, protect solvency and avert possible bank runs in periods of crisis, financial institutions need to raise capital above the statutory required levels in tranquil market periods.

## VII. Exchange Rate Risk

Exchange rate volatility is tested by using the GARCH(1,1)-M-GED specification. The percentage changes in the exchange rate, denoted as  $(\Delta \log s_{t|rt})$ , enter the conditional mean equation as a regressant. Therefore,  $\Delta \log s_{t|rt} = Y_{t|rt}$  in Eq.(1). Euro (EUR) is chosen here as a benchmark in order to ascertain relative stability of the remaining European currencies, as well as the USD. The results are presented in Table 4.

These results show a significant negative risk premium on the EUR for the Hungarian forint (HUF) and USD (or positive risk premium on these two highly volatile currencies in EUR-terms) as implied by the negative signs of the logGARCH-in-mean coefficients.

Variability of the remaining currencies is in-sync with EUR, with no significant premiums or discounts detected. The HUF per EUR also shows the highest degree of leptokurtosis that was exhibited mainly during the two-year period following the country's abandonment of the crawling peg regime in October 2001 (see Figure 5b). It is, however, worth noting that for all examined currencies the tail risks associated with exchange rate volatility are less pronounced than the tail risks detected for interbank rates volatility.

**Table 4:** GARCH(1,1)-M-GED estimation of percentage changes ( $\Delta$ logs) in exchange rates (domestic currency values of 1EUR).

	<i>Czech R.</i> <i>CZK/EUR</i>	<i>Hungary</i> <i>HUF/EUR</i>	<i>Poland</i> <i>PLN/EUR</i>	<i>Sweden</i> <i>SEK/EUR</i>	<i>U.K.</i> <i>GBP/EUR</i>	<i>U.S.</i> <i>USD/EUR</i>
<u>Cond. Mean Eq.</u> (coeff.x1000)						
Constant term	-0.824	-0.556***	1.537	-3.360	1.710	4.651**
Log(GARCH)	0.024	-4.450***	0.169	-0.312	0.105	-0.470**
<u>Cond. Variance Eq.</u>						
Constant term	0.000***	0.000***	0.000***	0.000***	0.000***	0.000***
ARCH(1)	0.072***	0.173***	0.094***	0.067***	0.052***	0.032***
GARCH(1)	0.914***	0.879***	0.896***	0.926***	0.944***	0.964***
GED parameter	1.185***	0.818***	1.343***	1.570***	1.473***	1.477***
<i>GED parameter</i> <i>crisis sub-period</i>	<i>1.198***</i>	<i>1.243***</i>	<i>1.238***</i>	<i>1.747***</i>	<i>1.577***</i>	<i>1.298***</i>
Log likelihood	10854	10604	9514	10815	10209	9287
Schwartz Info. Crit.	-8.562	-8.362	-7.502	-8.531	-8.052	-7.323

Notes: January 3, 2000-September 14, 2009 sample period; crisis sub-period is August 17, 2007-March 31, 2009. \*\*\* denotes significance at 1%, \*\* at 5%, and \* at 10%.

Source: Author's own estimation based on Datastream data.

In addition, the HUF per EUR time series show strong risk propagation during the entire sample period, as the sum of ARCH and GARCH coefficients exceeds unity. The HUF's conditional volatility has been amplified by the recent financial crisis (Figure 5b)<sup>6</sup>. Again, volatility of the remaining currencies is broadly synchronized with EUR, the Czech koruna (CZK) and the Swedish krona (SEK) exchange rates showing even a mild volatility compression.

Figures 5a-f show a strong evidence that the recent financial crisis has contributed to a pronounced propagation of exchange rate risk for all examined currencies. These results are based on the distributions of the GARCH conditional standard deviation residuals over the sample period. It is worth noting that this propagation of exchange rate volatility did not

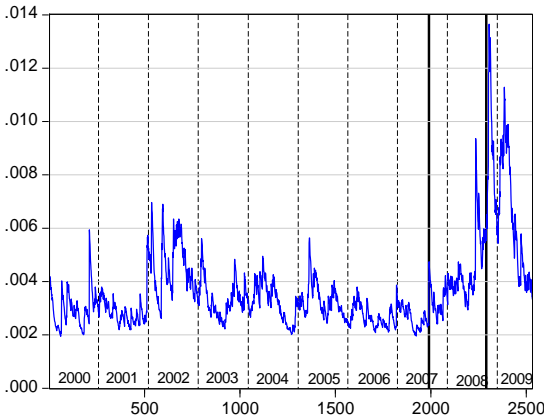
<sup>6</sup> There is strong evidence that the highest exchange rate risk in the case of Hungary stems from its high fiscal deficit and public debt, as well as pro-cyclicality of its real economy (Kočenda/Poghosyan, 2009). In light of this elevated exchange rate risk, the focus of the National Bank of Hungary on the exchange rate stability target comes into question. As shown by Orłowski (2008a and 2010), in spite of the official declaration of inflation targeting, monetary policy implementation in Hungary was focused on exchange rate stability. In hindsight, Hungarian monetary authorities are pursuing a very flexible approach to inflation targeting with two seemingly conflicting goals, i.e. low inflation and exchange rate stability. This dual-target approach unfortunately tends to exacerbate financial risk.

emerge instantly with the crisis' outbreak in August 2007. It evolved rather slowly during its early period between August 2007 and October 2008. Prior to this crisis, exchange rate volatility was generally quite subdued although rather uneven across the examined currencies and over the sample period. Initially, there was an increase in volatility for USD, the British pound (GBP), CZK and HUF, but a decrease for SEK. After the peak of the crisis in mid-October 2008, exchange rate risk escalated. This escalation persisted until February 2009 and was more severe than the one exhibited during the previous market turbulence of 2001-2002. Since then, it has been receding, however at a staggered pace through 2009. Nonetheless, the proliferation of exchange rate risk lagged behind that of equity market and interest rate risks. Plausible reasons for this lag can be derived from the examination of transmission channels of exchange rate volatility between international currency markets.

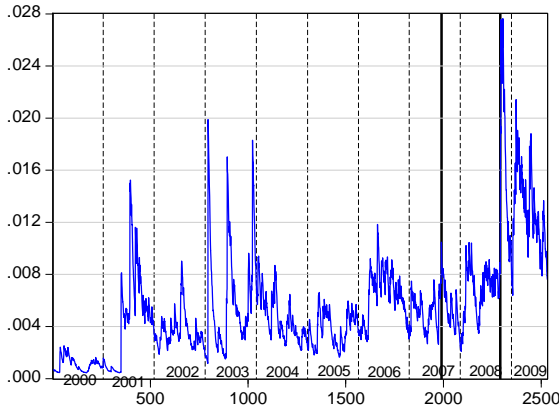
**Figures 5a-f:** GARCH one standard deviation residuals series for exchange rates (domestic currency values of one EUR).

*Notes:* The left solid vertical line (observation #1989) coincides with the outbreak of the US subprime mortgage crisis on August 17, 2007 and the right solid line (observation # 2289) corresponds with the crisis peak on October 10, 2008.

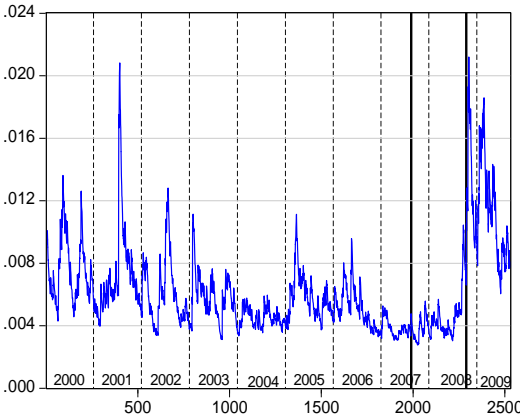
**5a: Czech Koruna (CZK) time series**



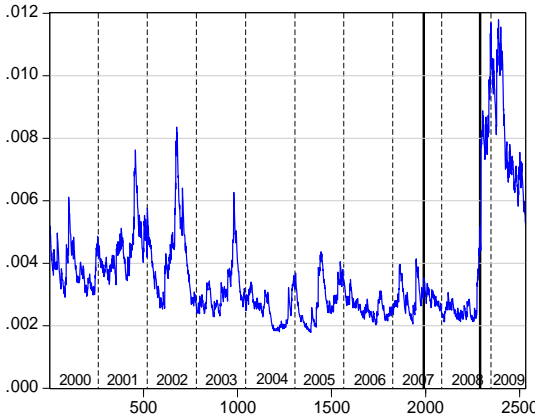
**5b: Hungarian Forint (HUF) time series**



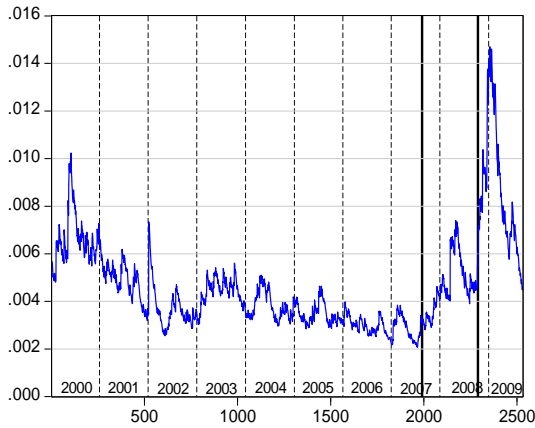
**5c: Polish Zloty (PLN) time series**



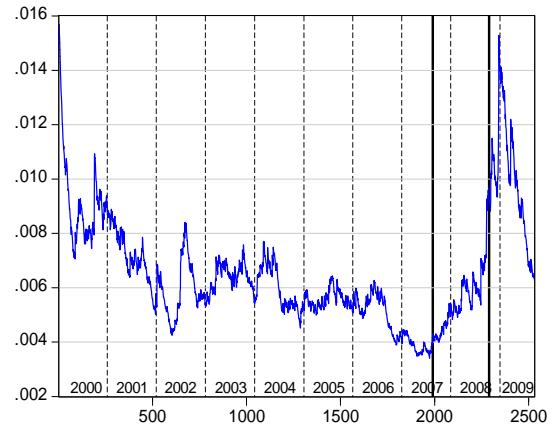
**5d: Swedish Krona (SEK) time series**



**5e: British Pound (GBP) time series**



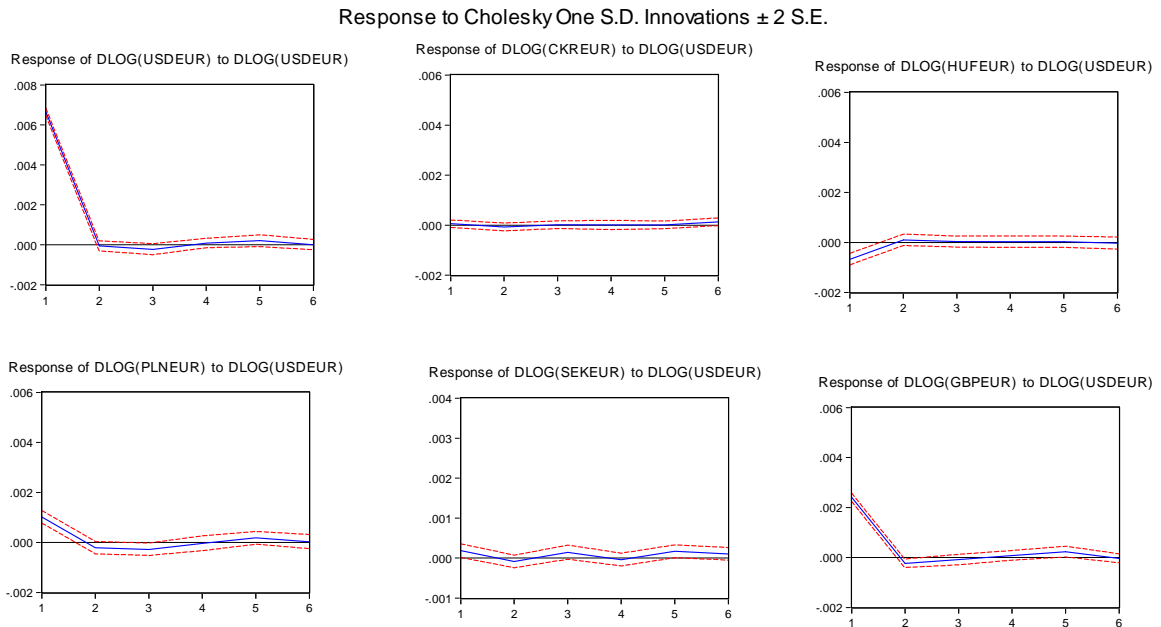
**5f: US Dollar (USD) time series**



Source: Author's own estimation based on Datastream data.

I conduct this examination on the basis of impulse response functions and present the results in Figure 6. The multiple graphs show responses of percentage changes in individual exchange rates ( $\Delta \log s_{t|rt}$ ) to a one-standard-deviation shock to the EUR value in USD. In essence, this cross-elasticity treatment shows time distribution of responsiveness (elasticity) of individual currencies to USD via their respective values in EUR.

**Figure 6:** Impulse responses of daily percentage changes in exchange rates to a one-standard deviation percentage change in the USD value of EUR.



Notes: From upper left to lower right EUR values in: USD itself, CZK, HUF, PLN, SEK and GBP. DGP assumptions: 5 lags in VAR, Monte Carlo error distribution for 6 periods.

Source: Author's own estimation based on Datastream data.

There is a strong, instantaneous transmission of depreciation of the GBP and the Polish zloty (PLN) in response to a one-standard-deviation shock depreciating USD in EUR terms (appreciating EUR). The reactions of the CZK and SEK rates are almost non-existent, while there is an adverse response of the HUF – the USD depreciation is causing the HUF appreciation. The HUF effect stems likely from the Hungary’s ERM2-shadowing exchange rate mechanism that was in place for most of the sample period. The PLN and GBP reactions imply effective pursuit of full-fledged floating exchange rate regimes. However, these regimes make their currencies more susceptible to the USD-generated shocks.

In sum, the scale of propagation of the exchange rate risk depends on susceptibility of local currency markets to the developments in global markets. It also depends on the state of macroeconomic fundamentals, with some resilience in countries with disciplined fiscal and monetary policies (for instance Sweden).

### **VIII. Policies Aimed at Mitigating Tail Risks and Reducing Pro-Cyclicality**

The widely unanticipated scope of the recent crisis has underscored the need for appropriate policies that would mitigate potential future volatility outbursts in financial markets and avert systemic risk. These policies need to account for tail risks associated with excessive volatility of key financial market variables that were examined in the previous sections.

Policies aimed at abating tail risks should have two distinctive characteristics: counter-cyclicality and flexibility. Pro-cyclicality stems from the interactions between financial and real economy variables. Therefore the nexus between tail risks and pro-cyclicality seems rather apparent. During times of volatility outbursts the rising risk premia on interest rates ultimately hinder investment and consumption, triggering recessionary effects. More pronounced tail risks pose a threat to financial stability and engender systemic risk. For this reason, *counter-cyclical policies* are likely to mitigate tail risks. This characteristic relates to both, monetary and macroprudential policies.

Because of the ubiquitous character of extreme tail risks across financial markets, a macroprudential policy approach seems to be well suited for mitigating these risks, as it relates to the financial system as a whole and considers aggregate risk as endogenous, stemming from the collective behaviour of market participants.<sup>7</sup> Before discussing specific macroprudential policies, I emphasize the desirable features of monetary policies that seem to be conducive to financial stability.

In principle, I subscribe to the dichotomy between the concerns of monetary policies and the concerns of financial stability policies as pointed out, among others, by Borio/White (2004), White (2009) and Svensson (2010). Monetary policy in its traditional sense aims at achieving price stability in the long-run, which is a necessary but not a sufficient condition for financial stability. Therefore, it is imperative to acknowledge that the task of containing tail risks cannot be accomplished by monetary policy alone. The perception of the monetary policy role in containing financial crises has evolved in light of the recent crisis. According to standard Keynesian prescription rooted in the experience of the Great Depression of the 1930s, monetary policy cannot effectively contain the crisis because it is unable to lower the cost of credit in the presence of severe shocks. This approach has been challenged by

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<sup>7</sup> For a comprehensive survey of macroprudential policy responses to systemic risk see Bullard, et.al (2009).



advocates of monetary expansion within the context of the recent crisis (Mishkin, 2009; Jobst, 2009; Curdia/Woodford, 2010). According to Mishkin (2009), the aggressive monetary policy easing in response to the recent crisis has been justified on the basis of very high perceived opportunity costs of refraining from it. An absence of monetary expansion would lead to exorbitant cost of credit and a further precipitation of systemic risk with even wider credit spreads. It's been known that the quantitative easing with zero-bound interest rates and massive liquidity injections of 2009 has helped reduce interest-rate spreads over risk-free government securities (such as the Treasury Bill-to-Eurodollar or TED spread). Several sudden jumps in those spreads have epitomized the main stages of the recent financial crisis (Orlowski, 2008b)<sup>8</sup>.

It seems that a forward-looking flexible inflation targeting policy based on a dual mandate of price stability and financial stability is likely to engender economic stability in the long-run.<sup>9</sup> Such policy is based on “constrained discretion” (Bernanke et al 1999), which allows for at times unexpected policy adjustments responding to transitory shocks of key financial variables. More specifically, a forward-looking flexible inflation targeting policy framework allows the central bank to focus on the inflation target and also on the additional policy objective which may (and should) include mitigating potential risks associated with credit bubbles. In essence, such forward-looking approach means that monetary policy should ‘lean’ against credit bubbles, rather than ‘clean up’ the bubble effects afterwards (White, 2009). In order to fulfil such dual mandate, monetary authorities should develop fairly accurate models that could project potential credit bubbles. Such models ought to take into consideration prevalent tail risks embedded in the behaviour of underlying financial variables. In contrast to a flexible policy with a dual mandate of price stability and financial stability, a fully discretionary policy without a specific objective of leaning against projected credit bubbles would hinder financial stability and undermine monetary policy predictability and credibility in the long-run. It is because unpredictability intensifies tail risks under stressful market conditions, as market participants demand substantial risk premiums on interest rates.

Within the framework of macroprudential policy approach, a *flexible treatment of capital adequacy requirements* deserves consideration (IMF GFSR, September 2009). At present, capital adequacy requirements are based on the Basel regime that assumes a constant capital ratio for the purpose of ensuring stability of the banking sector. However, these fixed requirements proved to be insufficient during the recent crisis when elevated interest rate volatility adversely affected banks capital and solvency. As demonstrated in this paper, various types of risk, particularly interest rate risk, are subject to sudden changes in response to shifts in market expectations and due to prevalence of tail risks stemming from excessive volatility. An adverse effect of elevated volatility takes place when assets and liabilities of a financial institution are mismatched in terms of maturities. Specifically, when a financial institution faces a large leverage-adjusted duration gap (the duration of assets exceeding the leverage-adjusted duration of liabilities), an increase in interest rates ultimately reduces the institution’s capital position, adversely affecting its solvency. For these reasons, capital

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<sup>8</sup> In the aftermath the Lehman Brothers collapse, the TED spread jumped to an unprecedented level of 464 basis points on October 10, 2008, reflecting a freeze of global credit markets. The massive liquidity injections by the Federal Reserve and other central banks have helped reduce the TED spread gradually to a more normal level oscillating around 20 bps since the beginning of September 2009, see Bloomberg interactive chart .TEDSP:IND.

<sup>9</sup> For the economies converging to the euro, I advocate the policy framework of *relative inflation forecast targeting* that aims at lowering differentials between the domestic and the euro area inflation forecasts (Orlowski, 2008a).

adequacy ratios should be specified as a range, rather than a fixed level, in order to secure their sufficiently flexible functioning. In good times, a regulatory authority may increase capital requirements allowing a financial institution to build a buffer against adverse events. Both mandatory core and total capital to risk-weighted asset ratios could be raised to higher levels or to an upper boundary of a predetermined range when volatility is out of sight. During times of financial distress these ratios could be reduced to a lower boundary in order to sustain bank lending.

The aspect of risk-based capital requirements within the framework of capital adequacy deserves a special emphasis. The risk-based weights that are assigned to the individual asset classes need to be better aligned with the actual risk exposure from these assets. Most importantly, modelling related to capturing risk needs to be adjusted to account for tail risks that are inherent in the behaviour of financial variables.

The implementation of a discretionary management of capital adequacy may pose difficulties to financial regulators due to imperfect forecasting of market behaviour, which is customarily affected by unpredictable random factors (Borio/Drehmann, 2009a and 2009b). In addition, a flexible treatment of capital adequacy could engender some uncertainty about the regulators' actions forcing financial institutions to impose higher interest rate risk premia or to contract lending at all times.

In addition to the range-specified capital adequacy ratios, flexible treatment of capital adequacy requirements can be accomplished by allowing financial institutions to issue *contingent capital*, as originally proposed by Flannery (2005). Contingent capital consists of debt instruments that can be converted into equity when sudden pressure on bank's balance sheet occurs and capital becomes insufficient.<sup>10</sup> Such conversion would strengthen the institution's capital position when it could otherwise face a credit freeze. Convertible capital entails a number of benefits for financial institutions. First, since it allows for replenishing of equity when it becomes depleted, contingent capital lowers the bank's point of default, thus it lessens the need for governments bailouts. Second, it provides banks with a readily available source of capital when it becomes more difficult to obtain. Third, it helps banks broaden the available tools of risk management using the same source of capital for both normal and stressful market conditions. In sum, convertible capital can provide leverage in good times and a buffer at bad times.

There are some potential drawbacks related to the use of contingent capital. First, investors may be reluctant to purchase such convertible debt instrument unless they have confidence that the issuing financial institution can survive a crisis. Second, if the financial institution encounters funding difficulties that would trigger a conversion, the value of a common equity would be adversely affected due to its dilution. On a positive side, such possibility should create additional incentive for a financial institution to manage against a possible downside. There is also (a less valid) concern that the convertible capital may take a dominant position over core capital in the capital structure of financial institutions. A challenging task for policy makers would be to determine a conversion trigger. An accurate timing of the actual conversion and a precise assessment of the required amount of contingent

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<sup>10</sup> A noteworthy version of contingent capital has been recently proposed by Kashyap, et. al (2008) who suggest to create a "capital insurance" for systemically important leveraged financial institutions. These institutions would be able to buy fully collateralized insurance policies from unleveraged institutions or government. In practical terms, such insurance could be provided by institutional investors (mainly pension funds or sovereign wealth funds) willing to assume greater risk for an additional premium.

capital may pose additional technical difficulties. However, none of these concerns have been adequately tested and they may be assuaged with an appropriate, specific regulation<sup>11</sup>.

In sum, contingent capital could serve as an effective tool for abating tail risks and improving the policy responses to future financial crises. It would allow policy makers to avoid the cyclicity of capital adequacy requirements. The anticipated timing of financial distress along with an expected magnitude of tail risks associated with the behaviour of financial market variables can be monitored and assessed for the EU markets by the newly-formed European Systemic Risk Board, which can also issue specific guidelines and directives for using these measures.

Within the framework of micro-prudential supervision a worth noting is a proposal to regulate trading in derivative financial securities, and in particular to subject these instruments to clearinghouse operations. Such treatment of derivative securities is essential for mitigating default and counter-party risks exposure of individual members of a clearinghouse by requiring them to meet capital and disclosure requirements. A clearinghouse operating as a central counter-party for trades executed on an exchange reduces the risk that a trader defaults on his obligation. Since it is capitalized by its members, a clearinghouse also allows regulators to assess market positions and prices. By spreading risks across its members, clearinghouse contributes to smoothing risks associated with individual securities, thus also to lowering tail risks. Considering these effects, this initiative is likely to reduce tail risks associated with market gyrations.

In addition to modifications in macro- and micro-prudential policies, the prevalence of tail risks should be considered in devising appropriate exit strategies from the recent expansionary policies aimed at stimulating economic growth and restoring financial stability<sup>12</sup>. Specific exit strategies should be based on gradual departure from quantitative easing and should take into consideration projections and responses to tail risks. Thus they should gradually switch their focus from ‘cleaning’ to ‘leaning’ against possible future credit bubbles.

## **IX. A Summary**

This study draws attention to the prevalence of tail risks of key financial variables in order to reflect upon the degree of their instability at times of financial distress. Tail risks have played a major role in proliferation of the recent global financial crisis that began in August 2007. The prevalence of tail risks was largely neglected prior to this financial meltdown. However, these risks had a profound impact on the propagation and escalation of the recent crisis.

The focus of the empirical analysis is on the detection of tail risks in selected financial variables that encompass market risk, i.e. equity market indexes, interbank rates and exchange rates. These variables are analyzed for a diverse group of EU member countries, including

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<sup>11</sup> Contingent capital requirements have been endorsed by policy-makers, including the Bank of England Governor Mervyn King (2009) and the Federal Reserve Chairman Ben Bernanke (2008).

<sup>12</sup> A compelling set of suggestions for proper sequencing of fiscal and monetary policy exit strategies is proposed by von Hagen, et.al (2009). The authors propose to begin from fiscal consolidation, followed by monetary tightening only when inflation expectations arise and pose a danger to growth and financial stability. In spite of the validity of this sequence, one may observe that there are wide-spread preferences for a reverse sequencing of monetary tightening followed by fiscal consolidation, due to prolonged unemployment effects in crisis-affected countries and the continuous needs for fiscal stimuli.

the three largest new EU members – Poland, Czech Republic and Hungary; the two largest eurozone members – Germany and France; and two incumbent members who pursue autonomous monetary policies – U.K. and Sweden. These countries' scores are compared with those of the United States, which is used as a benchmark. To capture the volatility time pattern and prevalence of tail risks, the GARCH-M-GED volatility dynamics analysis is employed. The inclusion of GED parameterization allows for estimating the degree of leptokurtosis.

Financial market variables in the selected countries exhibit large volatility outbursts, particularly at times of financial distress. The empirical tests reveal this endemic leptokurtosis in the conditional volatility patterns of all variables. Volatility outbursts of exchange rates seem to lag behind the respective volatility shocks for equity market indexes and interbank rates. The main finding of this study is that tail risks of interbank rates in the financial crisis were more pronounced than the tail risks of exchange rates and equity market indexes. The extreme risks of interbank rates are the most significant for Hungary, Poland as well as the United States, which may be attributable to their weaker macroeconomic policy discipline. This effect also implies that resiliency of the banking sectors in these countries against episodes of global credit crunch needs to be reinforced. The financial crisis exacerbated tail risks of interbank rates for all banking systems with the exception of the eurozone, Hungary and the U.S.

Leptokurtosis in the conditional volatility of equity market indexes is most pronounced for the Czech Republic, Poland and the United Kingdom – all of which follow highly autonomous monetary policies based on inflation targeting with flexible exchange rates. A significant increase in tail risks of equity markets during the financial crisis sub-period is detected for Germany, Hungary and Poland, but not for the remaining markets. In a similar vein, tail risks of domestic currency values of the euro are the most significant for the new EU member countries. In hindsight, financial markets of the new EU members remain to be highly vulnerable to large, unpredictable shocks stemming from global financial crises, implying that their sufficient institutional resiliency is yet to be developed. The findings of the prevalence of tail risks of financial market variables would be useful for developing monetary and macroprudential policies aimed at mitigating these risks.

Proper policies for abating tail risks still remain in a developmental stage. However, some useful policy actions can already be identified. Policies aimed at abating tail risks should have two distinctive characteristics: counter-cyclicality and flexibility. In my opinion, flexible monetary policy based on a dual mandate of price stability and financial stability, coupled with macroprudential regulations can be effective for mitigating these risks. For this purpose, I advocate a monetary policy regime based on flexible, forward looking inflation targeting that entails 'leaning' against anticipated credit bubbles. In terms of counter-cyclical macroprudential policies that are plausible for mitigating tail risks, I endorse flexible treatment of capital adequacy ratios for financial institutions as well as adopting contingent capital requirements. On the micro-level, I support regulating derivative instruments, specifically, subjecting trades in complex derivatives to central clearing. Such policy actions could be effective for both alleviating tail risks and abating systemic risk. For this reason, they deserve further consideration and development.

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