The Role of Liquidity, Risk and Economic Activity in the Global Transmission of the Financial Crisis*

Alexander Chudik†
European Central Bank and CIMF

Marcel Fratzscher‡
European Central Bank

12 July 2010

Abstract

The paper analyses and compares the role that the tightening in liquidity conditions, the collapse in risk appetite and the severe contraction in economic activity played for the global transmission of the financial crisis. Dealing with identification and the large dimensionality of the empirical exercise with a Global VAR approach, the findings highlight the diversity of the transmission process. While liquidity shocks have had a more severe impact on advanced economies, it was mainly the decline in risk appetite and the collapse in economic activity that affected emerging market economies. The tightening of financial conditions was a key transmission channel for advanced economies, whereas for emerging markets it was mainly the real side of the economy that suffered. Moreover, there are some striking differences also within types of economies, with Europe being more adversely affected by the fall in risk appetite than other advanced economies. Finally, the findings of the paper suggest that what made countries more vulnerable to liquidity shocks and risk shocks was not only the external real or financial exposure, but rather the weakness of domestic macroeconomic fundamentals and institutions.

JEL Classification: E44, F3, C5.

Keywords: Liquidity, risk, economic activity, financial crisis, global transmission, global VAR (GVAR), shocks, modelling, US, advanced economies, emerging market economies.

---

*The views expressed in this paper are those of the authors and do not necessarily reflect those of the European Central Bank.

†Kaiserstrasse 29, 60311 Frankfurt am Main, Germany. Email: alexander.chudik@ecb.int.

‡Kaiserstrasse 29, 60311 Frankfurt am Main, Germany. Email: marcel.fratzscher@ecb.int.

1 Introduction

One remarkable feature of the current financial crisis has been the speed and apparent synchronicity with which it has spread around the globe. While it originated in the United States, it has affected not only economies that shared similar vulnerabilities, in particular the exposure of financial institutions to toxic assets, but it spread to virtually all economies, advanced and emerging alike. Moreover, the crisis has not been limited to the sphere of financial markets but has had a major impact on real economic activity, inducing the largest global recession since the Great Depression. Even after an initial de-coupling of emerging market economies (EMEs), global economic activity became temporarily highly synchronized in the second half of 2008 and the first half of 2009.

Different hypotheses have been put forward as to why the crisis has become truly global in reach. A first hypothesis is that of liquidity, and the fact that credit markets and in particular interbank markets became highly illiquid, leading to the collapse or near-collapse of numerous financial institutions and severely curtailing the capital available to the real side of the economy (e.g. Adrian and Brunnermeier (2009), Brunnermeier and Petersen (2010), Shin et al. (2010), Borio (2009)). A second hypothesis relates to the pricing of risk. While financial institutions in North America and Europe were highly leveraged and exposed, financial institutions in many EMEs, in particular in Asia and Latin America were not. Moreover, the financial crisis triggered a massive reversal of private capital flows globally - or what has been dubbed a "flight to safety" phenomenon - with capital exiting in particular EMEs and being shifted from relatively risky financial assets into safer assets such as US treasuries. Such a reallocation of global capital related to a re-pricing of risk may thus have spread the crisis, and even to countries and regions that had been less exposed through the liquidity channel.

A third hypothesis is linked to the collapse of global economic activity. The economic slowdown in the US and Europe of late 2007 and early 2008 quickly intensified and spread strongly to other parts of the world after the collapse of Lehman Brothers in September 2008. Declines in GDP growth rates in EMEs, even in many Asia and Latin American countries, in that period were as strong as those in advanced economies. This decline has been in large part been related to the severe recessions in advanced economies and the ensuing collapse in global trade, which had been significantly stronger even than that in GDP. This affected adversely in particular EMEs, which tend to be relatively more open and more dependent on trade than many advanced economies (e.g. IMF (2009)).

The paper sets out to explore the role of these three different mechanisms in spreading the crisis, both to advanced economies and to emerging markets. What complicates such an analysis using standard macro models is that the crisis comprises a relatively short period and that it is inherently difficult to identify meaningful measures of shocks to liquidity, to risk and to real economic activity at quarterly or monthly frequency. We tackle this issue by taking a financial market perspective, analyzing the response of short-term interest rates as a proxy for financial market conditions, and the response of equity markets as a proxy for the impact on the real economy. Using a Global VAR (GVAR) approach allows us to identify these three types of US-specific shocks: shocks to liquidity and to risk appetite (using the US TED spread between US short-term money market rates and US treasuries, and the US VIX index of implied volatility of the S&P500) and shocks to US economic activity - measured as surprises to high-frequency announcements of key US economic activity variables. Using weekly data, this enables us to trace the effect of these three types of shocks to a broad set of 26 economies worldwide.

The empirical approach we employ allows us to deal with the challenge of identification and in particular with the large dimensionality problem. We resort to a novel methodology introduced by Chudik and Pesaran (2010) and later extended by Pesaran and Chudik (2010) in the context of the analysis of VARs of growing dimensions (so-called infinite-dimensional VARs), a methodology which also establishes conditions under which the increasingly used Global VAR model developed by Pesaran et al. (2004) is applicable. In this set-up, *all* variables are treated as endogenous, which is arguably a very important advantage for our purpose. Restrictions to overcome the dimensionality problem are based on an intuitive concept, namely that of neighborhood effects. The restrictions employed in this paper allow for rich spatial and temporal interactions among variables. In particular, we allow for the US to potentially have a dominant influence on other countries, other sources of strong cross-section dependencies besides the dominant US variables (i.e. we allow for the presence of unobserved strong common factors), and an unspecified weak-form cross-section dependence of residuals (see Chudik, Pesaran, and Tosetti (2010)). The dominance of the US in financial markets also helps us distinguish US shocks from shocks to other economies. To distinguish between different types of US shocks and to separate them from other global shocks, we implement a standard sign restriction approach combined with a partial ordering of variables in the context of our high-dimensional VARs.

The paper highlights two key findings. The first set of empirical results focuses on the global transmission of shocks and the question what type of shock made the financial crisis truly global. The short answer is that all three types of shocks - liquidity shocks, risk shocks and real activity shocks - have mattered during the crisis. However, these shocks have had strikingly diverse effects on different sets of countries and on different market segments. First, advanced countries were more strongly affected by US liquidity shocks than EMEs. In fact, the decline in equity markets and the tightening in financial market conditions in response to a US liquidity shock in many advanced countries was even stronger than that in the US itself. Second, by contrast, EMEs have been vulnerable mainly to risk shocks and shocks to US economic activity, and comparably less so to US liquidity shocks. For instance, while negative news about US economic activity had little effect on EME equity markets before the crisis, they induced larger declines during the crisis than even for the US equity market itself. A third key finding is that in advanced economies it has been mainly the financing conditions that have been adversely affected by US-specific shocks, while in EMEs it is rather the real side of the economy that exhibited the greatest sensitivity to US shocks.

Fourth, there are some intriguing differences also among advanced economies and among EMEs in their response pattern. Among advanced economies, it has been in particular Europe that has seen the highest exposure to US shocks, and in particular to shocks to risk appetite. By contrast, most advanced economies seem to have been affected to a similar degree by US liquidity shocks. Among EMEs, shocks to US activity and to risk appetite have had larger negative effects on economies in Latin America and in particular in Central and Eastern Europe. By contrast, it has been in particular emerging economies in Asia that have been more severely affected by US liquidity shocks, compared to other EMEs.

These findings thus paint a striking picture of the global transmission of the crisis, and also highlight some crucial differences in the way the crisis spread. To some extent, the empirical results confirm some of our priors discussed above: EMEs were less affected by liquidity shocks, presumably as they had relatively more sound financial systems. Yet they were more strongly impacted by shocks to US economic activity, which may in part be due to the greater real exposure of EMEs. The fact that countries in Central and Eastern Europe were more exposed to deleveraging shocks in risk seems intuitive. Yet Asia appears to have been relatively more sensitive to US liquidity conditions than other EMEs, which may in part stem from the fact Asia has a greater financial dependence on the US, while Emerging Europe is more closely tied to developments in the euro area and in the UK.

In order to shed light on the factors accounting for this heterogeneity if the crisis transmission, the second part of the analysis investigates the channels of the transmission process of US-specific shocks. In particular, we analyze to what extent it was the external exposure - either through trade linkages or through financial linkages - and to what extent it was idiosyncratic, country-specific characteristics - such as related to countries' macroeconomic fundamentals and perceived riskiness - that made countries vulnerable to different types of external shocks. For this purpose, we employ a Bayesian Averaging of Classical Estimates (BACE) approach of Sala-i-Martin et al. (2004). It combines the averaging of estimates across models estimated by classical OLS, and is in particular useful for understanding which variables in a large set of potential determinants might have played a role.

We find that before the crisis, during more tranquil periods, the transmission of US-specific shocks to the rest of the world was strongly influenced by countries' financial exposure to the US and globally. This meant that countries which used to be more financially open and exposed to the US market, were affected more strongly by US shocks, in particular to shocks to investors' risk appetite. However, this appears to have changed during the crisis as the transmission of US shocks, in particular to liquidity, were substantially dependent on the strength of countries' own fundamentals. Those economies with a robust macroeconomy and with high reserves and a stronger current account were substantially less affected by US liquidity shocks. These findings have important implications, not just for our understanding of the global transmission of the crisis, but also what economic policy can do to shield the domestic economy from global shocks.

From the outset we stress a number of limitations and caveats of our approach. A key challenge we face is the identification of shocks and how to trace them in a very large system of 26 economies and different markets. We argue that the GVAR approach we use can deal well both with identification and with the dimensionality problem. Yet, our identification is limited to three sets of shocks - to liquidity, risk appetite, and the real economy - which are all US-specific in nature. However, the crisis dynamics was a lot more complex and many more types of shocks were involved. For instance, one type of shock we are not identifying is that to confidence, e.g. as triggered by the collapse of financial institutions such as Lehman Brothers or AIG, and which has been argued by many to have severely exacerbated the crisis. Moreover, while the US may have been the origin of the crisis, shocks subsequently originating in many other economies have also played a role in the crisis dynamics. Yet we do not and do not even attempt to identify such shocks. Our approach to analyzing the crisis dynamics and its drivers is necessarily simplified; however, we argue that it captures the central features of the crisis, and the analysis of these features - liquidity, risk and real economy shocks - is important for understanding the global transmission of the crisis.

The paper is related to three strands of the literature. A first strand has been focusing specifically on the origin and the transmission of the current financial crisis. Much of this work has concentrated on the domestic economy, specifically the US and its policy responses (e.g. Calomiris (2008), Taylor (2009)). On the international dimension of the crisis, Tong and Wei (2009) investigate whether the degree of financial constraints explains the effect of the crisis on foreign firms. The IMF (2009) analyses the transmission of financial stress from advanced to emerging economies, Fratzscher (2009) investigates the global transmission of US shocks to FX markets for a broad set of advanced and emerging market economies, while Bekaert et al. (2010) analyze and refute the presence of cross-border contagion in global equity markets during the crisis. By contrast, there is a large and prominent literature on the global transmission of past financial crises, with a strong interest in the role of contagion and related channels (e.g. Forbes and Rigobon (2002), Bekaert, Harvey, and Ng (2005); Bae et al. (2003), Karolyi (2003), De Gregorio and Valdes (2001), Dungey et al. (2004)).

The second strand of the literature is on the international financial market transmission of shocks. Much of this literature on international spillovers has focused on individual asset prices in isolation, for instance on equity markets. Early empirical work that has shaped this literature is Hamao, Masulis, and Ng (1990) and Engle, Ito, and Lin (1990) on the spillovers from the US to the Japanese and UK equity markets. More recent examples are Diebold and Yilmaz (2009), who develop a spillover index based on VAR models, and show that the evolution of return and volatility spillovers across 19 stock markets is strikingly different. Dungey and Martin (2007) study contagion across different countries and financial markets, analyzing mainly the transmission of volatility across markets, while the findings of Ehrmann, Fratzscher, and Rigobon (2010) highlight that the transmission of financial market shocks often occurs not only within asset classes but also across assets internationally.

Related work on international financial co-movements attempts to explain the evolution of financial spillovers through real and financial linkages of the underlying economies and on contagion in international markets. Focusing on mature economies, Forbes and Chinn (2004) find that the country-specific factors have become somewhat less important and bilateral trade and financial linkages are nowadays more important factors for explaining international spillovers across equity and bond markets. A related literature focuses on the effects of macroeconomic announcements on various asset prices. Andersen, Bollerslev, Diebold, and Vega (2007) and Ehrmann and Fratzscher (2005) look at the effect of macro announcements on high-frequency asset returns across several asset prices, such as exchange rates, interest rates and the yield curve, confirming the importance of news and in some cases finding a significant response of risk premia or an overshooting of asset prices.

As a third strand, the methodological approach of the paper links to a broad literature focusing on GVAR models. The framework for modelling international linkages known as GVAR was proposed by Pesaran et al. (2004). Since then, it has been developed further and used in various applications. For example, Pesaran et al. (2006) and Pesaran, Schuermann, and Treutler (2007) analyzed credit risk. An extended and updated version of the GVAR by Dées et al. (2007) treats the euro area as a single unit, and has been used by Pesaran, Smith, and Smith (2007) to evaluate a potential entry by the UK and Sweden into the euro. Chudik (2008) extends the GVAR approach by allowing for a global dominance of the US. Methodological foundations for the specification of auxiliary country models were developed recently by Chudik and Pesaran (2010) and later extended by Pesaran and Chudik (2010) to allow for dominant units. We follow the latter two papers to specify our country models, allowing for rich spatio-temporal linkages among economies.

The paper is structured as follows. Section 2 outlines the empirical methodology and identification of shocks to liquidity, risk and economic activity. It also briefly describes the underlying data and several measurement issues. The main empirical findings of the paper on the global transmission of the three types of shocks are presented in Section 3. Section 4 then analyses the determinants of the cross-sectional heterogeneity in the transmission of shocks across the 26 economies in our sample. Section 5 concludes.

2 Modelling of financial and economic variables with a global perspective

This section presents the empirical methodology through which we analyze the transmission of shocks in a large system with a large set of countries (section 2.1). Subsequently, the section explains several issues related to the identification of the underlying shocks to liquidity, risk and economic activity (section 2.2) and the data employed (section 2.3).

2.1 The model

Let $\mathbf{x}_{it}$ denote a vector of k_i domestic variables of country i in period t. We treat all (domestic and foreign) variables as jointly determined and we suppose that the vector of $k = \sum_{i=1}^{N} k_i$ variables, $\mathbf{x}_t = (\mathbf{x}'_{1t}, ..., \mathbf{x}'_{Nt})'$, is given by the following factor-augmented VAR model,

$$\mathbf{x}_t = \mathbf{\Phi}\mathbf{x}_{t-1} + \mathbf{\Gamma}\mathbf{f}_t + \mathbf{u}_t, \tag{1}$$

and

$$\mathbf{u}_t = \mathbf{R}\boldsymbol{\varepsilon}_t, \tag{2}$$

where $\mathbf{\Phi}$ is a large $k \times k$ matrix of coefficients, $\mathbf{u}_t = (\mathbf{u}'_{1t}, ..., \mathbf{u}'_{Nt})'$ is an $k \times 1$ vector of reduced form errors, $\mathbf{f}_t$ is $m \times 1$ vector of (strong) unobserved common factors, and $\mathbf{\Gamma}$ is the corresponding $k \times m$ matrix of factor loadings. We abstract here in the notation from higher-order lags or deterministic terms to keep the exposition simple. Without a loss of generality, we denote the US as country $i = 1$ throughout the paper. Our set of endogenous variables is:

$$\mathbf{x}_{1t} = (i_{1t}, r_{1t}, vix_t, ted_t, news_t)',$$

for the US economy, and

$$x_{it} = (i_{it}, r_{it})', \, i = 2, 3, ..., N,$$

for the remaining economies, where i_{it} denotes first difference in short term interest rates (in country i and period t), r_{it} denotes stock market returns, vix_t is the first difference in the log of the VIX index, ted_t is the first difference of the US TED spread between US short-term money market rates and US treasuries. Thus $k_1 = 5$ and $k_i = 2$ for $i > 1$. We define the vector of cross section averages as

$$\overline{\mathbf{x}}_t = \frac{1}{N-1}\sum_{i=2}^{N}\mathbf{x}_{it} = \begin{pmatrix} \bar{\imath}_t \\ \bar{r}_t \end{pmatrix},$$

where $\bar{\imath}_t$ and $\bar{r}_t$ are cross-section averages of the (non-US) first differences in interest rates and (non-US) stock market returns, respectively.

The equation for country i in the VAR model (1) is

$$\mathbf{x}_{it} = \sum_{j=1}^{N}\mathbf{\Phi}_{ij}\mathbf{x}_{j,t-1} + \mathbf{\Gamma}_i'\mathbf{f}_t + \mathbf{u}_{it}, \tag{3}$$

where we have partitioned matrix $\mathbf{\Phi} = [\mathbf{\Phi}_{ij}]$ into $k_i \times k_j$ submatrices $\mathbf{\Phi}_{ij}$, and we have partitioned $\mathbf{\Gamma} = [\mathbf{\Gamma}_i]$ into $k_i \times m$ submatrices $\mathbf{\Gamma}_i$. Country equation (3) constitutes a rich specification, but it cannot be estimated due to the well-known curse of dimensionality. In our set-up, both N and T are relatively large, and the number of parameters in (1) grows at a quadratic rate with N. Some restrictions are therefore inevitable and we follow the approach developed by Chudik and Pesaran (2010), later extended by Pesaran and Chudik (2010), to deal with the dimensionality problem, while at the same time allowing for a rich set-up of the spatio-temporal linkages among variables. To this end, we impose the following assumptions. Let

$$\mathbf{\Phi}_i' = \mathbf{\Phi}_{ai}' + \mathbf{\Phi}_{bi}', \tag{4}$$

where

$$\mathbf{\Phi}_i = [\mathbf{\Phi}_{i1}, \mathbf{\Phi}_{i2}, ..., \mathbf{\Phi}_{iN}]',$$

$\mathbf{\Phi}_{ai} = [\mathbf{\Phi}_{ai1}, .., \mathbf{\Phi}_{aiN}]'$ captures the so-called neighborhood effects, and $\mathbf{\Phi}_{bi} = [\mathbf{\Phi}_{bi1}, .., \mathbf{\Phi}_{biN}]'$ captures the non-neighborhood effects.[1] The elements of $\mathbf{\Phi}_{bi}$ are assumed to be small, i.e. each of the non-neighbors only have a small *individual* impact, specifically

$$\|\mathbf{\Phi}_{bi}\|_\infty \leq \max_{j\in\{1,..,N\}}\|\mathbf{\Phi}_{bij}\|_\infty < \frac{K}{N}, \tag{5}$$

where $\|.\|_\infty$ denotes the maximum absolute row-sum matrix norm. But note that the aggregate impact of non-neighbors, namely $\mathbf{\Phi}_{bi}'\mathbf{x}_{t-1} = \sum_{j=1}^{N}\mathbf{\Phi}_{bij}\mathbf{x}_{j,t-1}$, is in general not negligible and as shown in Chudik and Pesaran (2010) it depends on the strengths of cross-section dependence

[1] $\mathbf{\Phi}_{bi}$ could arise for instance also from missspecifications of the spatial weights matrices.

among variables. Furthermore, we suppose that the matrix $\mathbf{\Phi}_{ai}$ can be written as

$$\mathbf{\Phi}_{ai} = \mathbf{S}_i \mathbf{D}_i, \tag{6}$$

where $\mathbf{D}_i$ is $d_i \times k_i$ matrix of unknown coefficients to be estimated for country i, and the $k \times d_i$ linkage matrix $\mathbf{S}_i$ compose of trade and financial weights, and it also allows for the dominance of the US variables,

$$\mathbf{S}_i = \left(\mathbf{E}_1, \mathbf{E}_i, \mathbf{W}_i^{Tr}, \mathbf{W}_i^{Fi}\right),$$

in which the $k \times k_i$ selection matrix $\mathbf{E}_i$ selects country i variables from the vector $\mathbf{x}_t$, i.e. $\mathbf{E}_i'\mathbf{x}_t = \mathbf{x}_{it}$ for all i, and $\mathbf{W}_i^a$ for $a \in \{Tr, Fi\}$ are $k \times 2$ spatial-weights matrices that define country-specific (local) spatial averages of foreign variables. Two weighting schemes are considered: trade weights (indexed by Tr) and financial weights (indexed by Fi). In this notation, we have $\mathbf{S}_i'\mathbf{x}_t = \left(\mathbf{x}_{1t}', \mathbf{x}_{it}', \bar{\mathbf{x}}_{wit}^{Tr\prime}, \bar{\mathbf{x}}_{wit}^{Fi\prime}\right)'$, i.e. the neighbors of country i are the US (dominant unit), its own past, country-specific trade-weighted spatial averages $\bar{\mathbf{x}}_{wit}^{Tr} = \mathbf{W}_i^{Tr\prime}\mathbf{x}_t$, and country-specific financial-weighted spatial averages $\bar{\mathbf{x}}_{wit}^{Fi} = \mathbf{W}_i^{Fi\prime}\mathbf{x}_t$. The dominance of the US is also reflected in the assumption about the matrix $\mathbf{R}$, which fully characterizes the contemporaneous correlations among the reduced-form errors $\mathbf{u}_t$. In contrast to what common in the factor-model literature, see for instance Forni and Lippi (2001), Forni et al. (2000) and Forni et al. (2004), we allow for strong cross-section dependence in $\mathbf{u}_t$ to reflect the potential dominance of the US. We partition $\mathbf{R} = [\mathbf{R}_1, \mathbf{R}_{-1}]$, where $\mathbf{R}_1$ denotes the first k_1 columns of $\mathbf{R}$, and we assume that

$$\begin{aligned} \|\mathbf{R}_1\|_1 &= O(N), \\ \|\mathbf{R}_{-1}\|_\infty &< K, \\ \|\mathbf{R}_{-1}\|_1 &< K, \end{aligned}$$

where $\|.\|_1$ denotes the maximum absolute sum column matrix norm. The unbounded column norm of $\mathbf{R}_1$ essentially allows for the dominance of the US, and it also implies strong cross-section dependence in $\mathbf{u}_t$. Bounded row and column norms of $\mathbf{R}_{-1}$, imply that once conditioned on the dominant US shocks (and the unobserved strong factors in $\mathbf{f}_t$), the innovations $\mathbf{R}_{-1}\boldsymbol{\varepsilon}_t$ are weakly cross sectionally dependent. We do not specify the exact form of $\mathbf{R}_{-1}$, but we note that this includes all commonly used spatial models in the literature, c.f. Pesaran and Tosetti (2010).

The analysis of infinite-dimensional VARs by Peseran and Chudik implies that under the limiting restrictions spelled out above, under $m \leq 2$ and under additional regularity requirements that ensure stability of the system as $N,T \xrightarrow{j} \infty$, infinite-dimensional model (1) can be arbitrarily well characterized (as $N \to \infty$) by the following country-specific finite dimensional models, which can be consistently estimated separately on country-by-country basis. Variables of dominant unit has to be jointly considered together with granular cross section averages $\overline{\mathbf{x}}_t$ in the marginal US model,

$$\mathbf{z}_t = \sum_{\ell=1}^{p_1} \mathbf{A}_\ell \mathbf{z}_{t-\ell} + \sum_{\alpha \in \{TR,Fi\}} \sum_{\ell=1}^{q_{\alpha 1}} \mathbf{B}_\ell \overline{\mathbf{x}}'_{w_\alpha 1t} + \boldsymbol{\xi}_t + O_p\left(N^{-1/2}\right), \tag{7}$$

where $\mathbf{z}_t = (\mathbf{x}'_{1t}, \overline{\mathbf{x}}'_t)'$, and the reduced-form errors are

$$\boldsymbol{\xi}_t = \mathbf{A}_{\boldsymbol{\xi}} \begin{pmatrix} \mathbf{u}_{1t} \\ \mathbf{f}_t \end{pmatrix}.$$

It should be noted that the dominant (US) variables become effectively dynamic common factors for the remaining variables (c.f. Pesaran and Chudik (2010)) and because of this $\mathbf{u}_{1t}$ and $\mathbf{f}_t$ are not identified, only reduced-form errors $\boldsymbol{\xi}_t$ are.

For countries $i = 2, 3, ..., N$, the following conditional models can be consistently estimated

$$\mathbf{x}_{it} = \mathbf{C}_{i0}\mathbf{z}_t + \sum_{\ell=1}^{s_i} \mathbf{C}_{i\ell}\mathbf{z}_{t-\ell} + \sum_{\ell=1}^{p_i} \mathbf{H}_{i\ell}\mathbf{x}_{i,t-\ell} + \sum_{\alpha \in \{TR,Fi\}} \sum_{\ell=1}^{q_{\alpha i}} \mathbf{B}_{i\ell} \overline{\mathbf{x}}'_{w_\alpha i,t-\ell} + \mathbf{e}_{it} + O_p\left(N^{-1/2}\right), \tag{8}$$

where $\mathbf{e}_{it} = \mathbf{E}'_i \mathbf{R}_{-1} \boldsymbol{\varepsilon}_t$. Note that although $\mathbf{e}_{it}$ are (weakly) cross sectionally dependent, they are serially uncorrelated and orthogonal (in a limit as $N \to \infty$) with contemporaneous variables in $\mathbf{z}_t$. We are a bit more general on the structure of the model, allowing for different types of inter-linkages, and as a result we restrict the number of lags in the empirical analysis below to one, and we estimate the coefficients of the marginal US model and the conditional non-US country models by using Ridge regression.

In order to analyze cross-country linkages, spillovers and to perform simulations, the estimated country models have to be solved in one system, as it is custom in the GVAR literature. We depart slightly from other GVAR papers by allowing for a factor structure in the solved global system, reflecting the presence of global shocks in $\boldsymbol{\xi}_t$. Substitute (7) into (8) to obtain

$$\mathbf{x}_{it} = \sum_{\ell=1}^{\max\{p_1,q_i\}} \mathbf{P}_{i\ell}\mathbf{x}_{t-\ell} + \mathbf{C}_i \boldsymbol{\xi}_t + \mathbf{e}_{it} + O_p\left(N^{-1/2}\right), \tag{9}$$

where

$$\mathbf{P}_{i\ell} = \mathbf{H}_{i\ell}\mathbf{E}_i + \sum_{\alpha \in \{Tr,Fi\}} \left(\mathbf{B}_{i\ell}\mathbf{W}_i^{a\prime} + \mathbf{C}_{i0}\mathbf{B}_{1\ell}\mathbf{W}_1^{a\prime}\right) + \left(\mathbf{C}_{i\ell} + \mathbf{C}_{i0}\mathbf{A}_\ell\right)\mathbf{W}'_z,$$

and $\mathbf{W}_z$ is implicitly defined by relation $\mathbf{z}_t = \mathbf{W}'_z \mathbf{x}_t$. Note that the US innovations $\mathbf{u}_{1t}$ and innovations in $\mathbf{f}_t$ effectively enter as a common factor in country models through $\boldsymbol{\xi}_t$. Finally, models (9) and equation for $\mathbf{x}_{1t}$ from marginal US model (7) can be stacked in one global VAR model that features a residual factor structure,

$$\mathbf{G}(L)\mathbf{x}_t = \mathbf{C}_i\boldsymbol{\xi}_t + \mathbf{e}_t + O_p\left(N^{-1/2}\right),$$

where $\mathbf{e}_t$ features weakly cross sectionally dependent innovations.

2.2 Identification of shocks and impulse-response analysis.

Global shocks in our set-up are given by factors $\mathbf{f}_t$ and the US innovations $\mathbf{u}_{1t}$. As mentioned earlier, these shocks enter residuals $\boldsymbol{\xi}_t$ in the US marginal model, but additional restrictions are needed if one wants to distinguish between US and foreign global shocks with non-US origin. To accomplish this, we suppose that the US shocks come first. Within the set of US shocks, we aim to distinguish between a US macro surprise shock, a stock market shock, an interest rate shock, a risk aversion shock and a liquidity shock. Macro news shocks are identified by coming first from the set of the US shocks. This is given by the measurement of these shocks, an issue to which we turn in the next sub-section.

We put TED and VIX second and third, before the money market and stock markets shocks. We postulate that an increase in the VIX lowers US stock markets and interest rates. By contrast, an increase in the TED spread is associated with a rise in short-term interest rates in the US and a decline in US stock markets. Importantly, no sign restrictions are imposed on the transmission of any of these shocks to foreign equity markets and stock markets.

Finally, we identify and distinguish US stock market shocks from US money market shocks by imposing the opposite sign on the response of equity markets across these two shocks. An increase in US short-term interest rates should lower US and foreign equity markets, while a rise in US equity markets should have a positive effect also on foreign equity valuations. These sign restrictions are standard in the literature on sign restrictions and has been strongly supported by empirical evidence (e.g. Rigobon and Sack 2004, 2005). Our identification scheme is summarized in Table 1.

Table 1: Summary of sign restrictions.

	i_{1t}	r_{1t}	vix_t	ted_t	$news_t$	$\bar{\imath}_t$	$\bar{r}_t$
VIX shock	$-$	$-$	$+$	.	.	.	.
TED shock	$+$	$-$	.	$+$	.	.	.
US interest rate shock	$+$	$-$	.	.	.	$+$	$-$
US stock market shock	$+$	$+$	.	.	.	$+$	$+$

2.3 Data

Finally, we turn to the description of the underlying data.

Our global coverage is restricted to a set of 26 advanced economies and EMEs. These cover 75% of world GDP and include relatively open and financially developed economies. In order to detect larger trends and results, we additionally distinguish between groups of countries, in particular between advanced economies (with excludes the US itself) and emerging markets. An alternative aggregation is across regions, distinguishing between Advanced Europe (euro area, Denmark, Norway, Sweden, Switzerland, UK) and Other Advanced economies (Japan, New Zealand, Australia), as well as across emerging market regions - Emerging Asia (Hong Kong, India, Indonesia, Philippines, Singapore, Taiwan, Thailand), Emerging Europe (Czech Republic, Hungary, Poland, Russia, and also including Turkey and South Africa), and Latin America (Argentina, Brazil, Mexico). Note that we treat the euro area as a single economy, rather than taking its member states individually. Other emerging economies have been excluded either because of data issues or because they tend to be relatively more closed financially.

All of the financial market variables we use stem from Bloomberg and have a standard definition. For money market rates, we use three-month rates. For stock markets, we use MSCI country indices in local currency. We use local currency returns in order to be consistent with the measurement of the money market rates, as well as to avoid that changes in the comovement across equity markets results from changes in exchange rate comovements. Figure 1 plots the stock market and interest rate data for three groups of countries: the US, advanced and EMEs; Figure 2 shows the data for the six regional groups.

Measuring risk and liquidity is more difficult. As is commonly done in the literature, we resort to using the VIX index, for the S&P500, as our proxy for financial market risk; and we use the TED spread as our proxy for US liquidity pressures. Figures 3 plot the evolution of the VIX and the TED spread over time. We note that these are obviously highly imperfect proxies for risk and liquidity; in particular as they focus on certain financial market segments (money markets for the TED spreads and equity markets for VIX). Yet we like the fact that both are US specific in nature, thus allowing us to compare their transmission with that of US-specific macro shocks and other US financial market shocks.

The measurement of US macroeconomic news shocks is based on the announcement of US macroeconomic series. There is by now a sizeable literature on the transmission of such macro news shocks to asset prices, both within the US and internationally - see e.g. Andersen, Bollerslev, Diebold, and Vega (2007) and Ehrmann and Fratzscher (2005) for two specific examples of this literature. Macroeconomic news in this literature are measured as the unexpected component of the announcement about a specific macroeconomic variable, such as GDP. Our expectations data stem from Bloomberg surveys of financial market participants that are conducted in the week prior to a particular announcement.

Based on the expectations and the actual announcements, we can then calculate the surprise or news component of each announcement. We include in our analysis 8 different US macro series: GDP, industrial production, retail sales, NAPM/ISM, non-farm payroll employment, unemployment, consumer confidence, workweek. We call our US macro shock variable a proxy for shocks to US real economic activity because these 8 components focus on the evolution and changes of the real side of the US economy. Moreover, rather than looking at these series individually, we create an unweighted aggregate US macro news series. The aggregation is done by normalizing each of the eight time series by their standard deviation over the sample period, and then by aggregating them by week. Note that by its very nature, macroeconomic news are exogenous as expectations should incorporate all available information before an announcement takes place. Figure 4 plots this weekly US macro news series. Efficient and unbiased expectations should imply that such macro surprises should not exhibit a trend over time. The figure indeed confirms this feature,[2] and also suggests that the magnitude of the macro surprises has not increased substantially during the financial crisis.

As to the data frequency, our analysis uses weekly data. Using weekly, rather than lower frequency data has the advantage that it should capture better the transmission of shocks in financial markets. Moving to higher than weekly frequency is complicated by the non-overlapping trading times across markets, a problem which is reduced by using weekly data.

Finally, we restrict the length of our data sample to start only in 2005, which allows us to distinguish between a pre-crisis period - 1 January 2005 - 6 August 2007, and a crisis period - 7 August 2007 - end July 2009. Table 2 presents some descriptive statistics for the different data series, distinguishing between the pre-crisis and the crisis periods.

3 Estimation results

We now turn to presenting the main estimation results from the global VAR approach. Our first focus is on the overall impulse responses across country groupings in order to identify general, overarching trends and differences, before we turn to individual countries. While the first subsection present the findings from the impulse response functions of the GVAR, the second subsection outlines the results of the forecast error variance decomposition

3.1 Impulse response functions

Figures 5-14 show the generalized impulse response functions (GIRFs) for advanced economies and emerging markets, where impulse responses are unweighted averages across all countries in a respective group. Further below, Figures 16-25 provide the GIRFs for the 26 individual countries rather than the country aggregates.

The first of the figures shows the GIRFs for the effect of liquidity shocks on foreign equity markets. What stands out is that the elasticity of stock markets to liquidity shocks has decreased somewhat during the crisis. This does not necessarily indicate that liquidity has become less important as the volatility and magnitude of liquidity shocks has increased substantially during the crisis - recall that Table 2 shows that the standard deviation of daily changes in TED spreads has increased fivefold during the crisis; we will return to this point further below when discussing the variance decomposition. Moreover, note that while stock markets in advanced economies were less sensitive to US liquidity shocks than EMEs before the crisis, the former responded as strongly or stronger during the crisis.

[2] A formal test for the unbiasedness and the efficiency of US macro news and their underlying expectations is provided in Ehrmann and Fratzscher (2005).

Figure 10 provides the corresponding impulse responses of money markets to liquidity shocks. While money markets neither in advanced economies nor in EMEs responded much to such shocks before the crisis, they did so during the crisis. And advanced economies' money markets were more sensitive to such shocks than EMEs during the crisis. Moreover, the effect of liquidity shocks on money markets appears to have some persistence as the contemporaneous responses of markets in advanced economies are as strong as those in the subsequent week.

Looking at the impact if liquidity shocks on individual countries (Figures 16 and 21) rather than country aggregates confirms this picture, yet also indicates that there is a fair bit of heterogeneity in the response patterns across countries. Another advantage of looking at the contemporaneous impulse responses for individual countries is that it allows us to also show the error bands - which underlines that our coefficients are much more tightly estimated for the crisis period than for the period before the crisis, in particular for advanced economies.

We next turn to the effect of risk shocks on global equity markets and money markets. Figure 6 shows the impulse response functions of stock markets to shocks to the VIX. Overall, there is strong increase in the sensitivity of stock markets to VIX shocks during the crisis - in fact the average contemporaneous effects double in magnitude during the crisis as compared to the pre-crisis period. Moreover, the increase is larger for EMEs than for advanced economies. Among EMEs, it has been in particular Latin American countries than have become highly sensitive to VIX shocks (whereas Asian are much less sensitive). Among advanced economies, it is in particular the European economies that have become significantly more sensitive to US VIX shocks during the crisis.

The impulse responses of individual countries to VIX shocks (Figures 17 and 22) provide a more detailed break-down by country, again underlining a significant cross-country heterogeneity. For instance, EME equity markets most affected by VIX shocks during the crisis are Russia, Mexico and Brazil, while EME money markets most responsive are those of Hong Kong and Singapore.

The third type of shock is that to US macroeconomic variables. Figures 7 and 12 show the impulse response functions of US macro news shocks for stock markets and money markets, respectively. What is striking from this set of figures is that it has been in particular global stocks markets that have become substantially more sensitive to US macro shocks during the crisis. While equity markets did not react much to such shocks before the crisis, equities in EMEs and advanced economies responded as strongly during the crisis as the US itself. Among advanced countries, it has been in particular the European economies that have become significantly more sensitive, exhibiting a contemporaneous response that is about twice as large as that of other advanced countries.

The picture for the impulse responses of money markets to US macro news shocks is more mixed. There is no homogenous increase in the sensitivity of money market rates globally during the crisis. However, exceptions are the European economies and the Latin American economies that have become substantially more responsive during the financial crisis.

Fourth, the effect of US stock market shocks yields a striking picture. What is striking is that the comovement of foreign stocks markets with the US market (Figure 8) has not increased but even mostly declined somewhat during the crisis. This implies that while equity markets may have become more sensitive to risk shocks and macro news shocks during the financial crisis, equity market comovements have not changed markedly as this increased sensitivity has been as strong in the US itself as in the rest of the world.

The picture is somewhat more nuanced when analyzing the impulse response functions of money markets globally to US stock market movements (Figure 24). Here it seems that in particular advanced economies' interest rates have become significantly more responsive to the US, while no such clear pattern emerges for EMEs.

Fifth, the last type of shock we analyze is that to US money market rates (Figures 9 and 14). It again seems that advanced economies have become more responsive to such shocks compared to EMEs, though the figures for the individual countries again underline the presence of a significant degree of heterogeneity across economies.

As a final note, Figure 15 plots impulse response functions of a shock to US macro news on VIX and the US TED spread. The IRFs are intuitive and suggest that better than expected US macroeconomic news reduce the VIX, and more strongly so during the crisis. By contrast, TED spreads do not appear to be particularly sensitive to US macro news shocks, neither before nor during the crisis.

In summary, the empirical findings thus reveal a striking picture of the global transmission of the crisis, and highlight some crucial differences in the way the crisis spread. First, advanced countries were more strongly affected by US liquidity. Second, by contrast, EMEs have been vulnerable mainly to risk shocks and shocks to US economic activity, and comparably less so to US liquidity shocks. For instance, while negative news about US economic activity had little effect on EME equity markets before the crisis, they induced larger declines during the crisis than even for the US equity market itself. A third key finding is that in advanced economies it has been mainly the financing conditions that have been adversely affected by US-specific shocks, while in EMEs it is rather the real side of the economy that exhibited the greatest sensitivity to US shocks.

To some extent, the empirical results confirm some of our priors discussed earlier on: EMEs were less affected by US liquidity shocks, possibly as they had financial systems less exposed to those assets that adversely affected many advanced economies. However, they were more strongly impacted by shocks to US economic activity, which may in part be due to the greater real exposure of EMEs. The fact that countries in Central and Eastern Europe were more exposed to deleveraging shocks in risk seems intuitive. Yet Asia appears to have been relatively more sensitive to US liquidity conditions than other EMEs, which may in part stem from the fact Asia has a greater financial dependence on the US, while Emerging Europe is more closely tied to developments in the euro area and in the UK.

3.2 Variance decomposition

After discussing the findings for the impulse response functions in the previous sub-section, we now turn to the results for the variance decomposition. As a general remark, an overall increase in the sensitivity of a particular market to a specific shock does not necessarily imply that this shock has become more important as an overall driver of that market. Similarly, the fact that the effect of a US liquidity shock of a given magnitude has increased on some but not all foreign equity markets does not necessarily imply that the overall importance of this type of shock has not increased.

Figure 3 plots the forecast error variance decomposition for US shocks on global (non-US) equity markets. It shows the average contributions to the total variance across all non-US economies in our sample, together with the average contributions to the variance of non-US shocks.

Overall, three findings stand out. First, US-specific shocks have increased in importance, roughly doubling the share of the variation of foreign equity markets they explain during the crisis as compared to the pre-crisis period. The same holds for foreign money markets, though the US-specific shocks we identify generally explain less of US and foreign money market movements. During the crisis, the five US-specific shocks we analyze account for about 50% of the stock market movements outside the US.

Second, US liquidity shocks have become highly important for global stock markets during the crisis. While they accounted for about 9% of the variation of non-US equity markets before, they explain up to a quarter of the equity market movements during the crisis. This is consistent with the findings for the impulse responses of the previous sub-section. Although the sensitivity to a given US liquidity shocks has not risen for all foreign equity markets, the magnitude of US TED movements has increased dramatically (see Table 2 above). By contrast, while risk shocks remain important, the variance of foreign stock or money markets they explain has not increased. US macro shocks explain little of the variances, yet they should not be expected to given their definition to capture only a small fraction, i.e. the announcement surprises of US activity variables.

And third, also the importance of movements in US stock markets and money markets has risen for foreign markets. However, the share they explain during the crisis is clearly dwarfed by liquidity and risk shocks.

4 Analysis of cross-country differences in the transmission of shocks

The previous section has highlighted that there is a substantial degree of heterogeneity across countries in the response patterns to US shocks to liquidity, risk and economic activity. This section analyses what factors may help explain this cross-sectional heterogeneity.

To shed light on the cross-section heterogeneity in the transmission of US shocks to the rest of the world, we estimate the following cross-section regression

$$y_i^{(s)} = c^{(s)} + \sum_{\ell=1}^{K} \beta_\ell^{(s)} x_{i\ell} + \zeta_i^{(s)}, \text{ for } i = 2, ..., N,$$

where $y_i^{(s)}$ is the contemporaneous impact of a US shock s (to US macro news, VIX, TED, US money market or US stock market) on the stock market or the money market of country i, and $x_{i\ell}$ for $i = 2, ..., N$ and $\ell = 1, 2, ..., K$ is the set of K fundamentals specific to country i.

We focus on two alternative explanations for why a country may respond more or less strongly to a given US-specific shock than other countries. A first potential explanation is the direct exposure to the US economy, either through trade or through financial linkages. One would expect that countries with more trade with the US (relative to domestic GDP, or to total trade) or with stronger financial linkages are affected more strongly, as the crisis in the US should set off a decline in US import demand and a repatriation of capital to the US. An alternative explanation is that the global shock transmission may depend on the strength of country-specific fundamentals. This implies that during a crisis, investors may not withdraw capital indiscriminately, but may focus on those with weaker fundamentals and less resilience to external shocks.

Hence, our set of regressors includes both the country-specific macro variables (such as the current account, reserves, trade openness, financial integration), country-specific institutional variables (the quality of the institutions) and also bilateral trade and financial debt and equity exposures to the United States. A full list is provided in Table 4.

We have in total 14 candidate explanatory variables and our country dimension is 26. Hence, instead of running OLS on the full set of regressors, or a general-to-specific selection procedures to select a parsimonious model, we adopt the Bayesian Averaging of Classical Estimates (BACE) approach, as outlined by Sala-i-Martin et al. (2004), to analyze factors behind the cross-country heterogeneity of the transmission of US shocks to the rest of the world. The BACE approach was originally developed to analyze determinants of growth. It combines the averaging of estimates across models estimated by classical ordinary least squares (OLS) and is particularly useful for understanding which of the large set of determinants (if any) might play a role empirically.

Following the exposition of Sala-i-Martin et al. (2004), the posterior probability of a model M_j given data y and a number of potential regressors K, can be expressed as

$$P(M_j/y) = \frac{l_y(M_j)P(M_j)}{\sum_{i=1}^{2^K} l_y(M_i)P(M_i)}, \tag{10}$$

where $P(M_j)$ is the prior probability that M_j is the true model and $l_y(M_j)$ is the likelihood of model M_j. The likelihood approach is based on the Schwarz model selection criterion and includes a degrees-of-freedom correction to take account of the fact that models with more variables have a lower sum of squared errors:

$$l_y(M_j) = T^{-k_j/2} SSE_j^{-T/2}, \tag{11}$$

where SSE_i is the OLS sum of squared errors under model i.

This posterior can be used to select the "best" model (usually the one with highest posterior probability). However, the strategy of using only the best model has been shown to predict worse than model averaging and there may be no unique model that characterizes the data satisfactorily. Therefore, using the posterior model probabilities as weights, Bayes' rule says that the posterior density of a parameter is the average of the posterior densities conditional on the models with weights given by the posterior model probabilities.

$$P(\beta/y) = \sum_{j=1}^{2^K} P(M_j/y)P(\beta/y, M_j), \tag{12}$$

where K is here equal to 14 in our case.

A posterior mean is defined to be the expectation of a posterior distribution. Therefore, taking expectations with respect to (12) the posterior mean and variance are then defined as follows:

$$E(\beta/y) = \sum_{j=1}^{2^K} P(M_j/y) E(\beta/y, M_j), \tag{13}$$

where $E(\beta/y, M_j)$ is the OLS estimate for β with the set of regressors used in model j, i.e. this gives us the posterior mean conditional on model j. One issue not addressed is the determination of the prior probabilities of the models, $P(M_j)$. We specify a flat model prior probabilities by considering each model equally likely.

We run two different BACE estimations, one for the period before the crisis, and one for crisis period. Tables 5 and 6 present the summary results for foreign stock markets, while Tables 7 and 8 show corresponding results for foreign money markets. The tables show posterior p-value of fundamentals and estimated posterior means.

Moreover, Figures 26 and 27 show the relevance of these different fundamentals in a graphical presentation. More precisely, the charts show the response of countries' stock and money markets conditional on the strength of their fundamentals or exposure to the US. The split is made for a. countries with high reserves vs. low reserves; b. those with a good sovereign rating versus a bad rating, c. ICRG political (high/good vs low/bad) institutions, and d. high vs low. trade openness and exposure to the US.

Overall, the results provide only limited evidence that real or financial exposure to the US has played a substantial role in explaining the global transmission of the crisis. By contrast, the quality of institutions and domestic fundamentals - such as the size of reserves and the sovereign rating - appear to have been relevant during the crisis.

We stress that this evidence is no more than illustrative as our analysis here is conducted purely in the cross-section, and the size of our cross-seciton is limited to the 26 economies in our sample. Nevertheless, these points help illustrate the heterogeneity and some of the cources of the heterogeneity in the global transmission process.

5 Conclusions

The financial crisis of 2007-10 has been remarkable in its global reach, severely affecting financial markets and economic activity in virtually all advanced economies and also emerging markets. The objective of the paper has been to better understand the global transmission process through which the crisis has spread. We have focused on three distinct types of shocks, which have been emphasized widely as key culprits of the crisis: a tightening in liquidity conditions and credit markets; a severe re-pricing of risk and flight of investors into safe asset classes; and a strong and synchronous collapse of economic activity. Moreover, the objective of the paper has been not only to understand how this transmission process has taken place, but also to gauge what account for the cross-country differences in the way countries have responded to these shocks.

The empirical analysis is build on a Global VAR approach, which allows us to deal both with the identification of the shocks and their transmission, as well as with the large dimensionality of the analysis for 26 economies and 2 financial market segments.

The findings of the paper suggests that all three types of shocks have played a role in the global transmission process. However, the findings show marked cross-country differences in the global transmission. Shocks to liquidity conditions have been relatively more important for advanced economies than for EMEs. By contrast, EMEs have been more strongly affected by shocks to risk appetite and to US economic activity than this was the case for most advanced economies, with the exception of the euro area. A second striking difference is that the effect of US-specific shocks has been more important for interest rates and financing conditions in advanced economies, while in EMEs it has been in particular equity markets that have been affected the strongest.

Overall, a first point the results of the paper therefore highlights is that the global transmission of the crisis has been complex and cannot be reduced to a single dimension only. Of course, the most apparent feature of the crisis has possibly been the liquidity and credit crunch it induced. Yet, while this has had a major effect of advanced economies, for EMEs it was in particular the rise in risk aversion and a re-pricing of risk as well as the major impact on the real side of the global economy that affected their economies and markets. In turn, the fall of the global economy into a severe recession further exacerbated the liquidity conditions and the retrenchment of financial investors globally, hence inducing a vicious cycle of weakening financial conditions and deteriorating real economy developments.

A second key lesson we draw from the findings is that countries were by no means innocent bystanders, but the severity with which they were hit by the crisis, and the different shocks it entailed, was not only related to their real and financial openness and external exposure, but to a substantial extent also to the strength of their domestic macroeconomic fundamentals and institutions. Hence strengthening domestic fundamentals and institutions could be a key ingredient for helping economies insulate, or at least reduce the adverse impact of global shocks.

Table 2: Descriptive statistics.

	Pre-crisis				Crisis			
	avg	min	max	std dev	avg	min	max	std dev
US variables								
TED spread (first diff.)	0.002	-0.166	0.218	0.054	-0.002	-1.010	0.972	0.292
VIX (log and first diff.)	0.001	-0.278	0.565	0.118	0.005	-0.370	0.438	0.134
money market rates (first diff.)	0.021	-0.099	0.104	0.028	-0.046	-0.903	0.572	0.199
stock markets (log and first diff.)	0.002	-0.045	0.035	0.014	-0.005	-0.201	0.115	0.042
US macro shocks	0.004	-0.568	0.679	0.201	0.033	-0.676	0.835	0.254
Stock market indices (log and first diff.)								
Advanced	0.004	-0.108	0.062	0.018	-0.004	-0.248	0.153	0.041
of which:								
- Advanced Europe	0.004	-0.108	0.062	0.019	-0.004	-0.248	0.153	0.044
- Other Advanced	0.003	-0.068	0.054	0.017	-0.004	-0.223	0.097	0.034
Emerging markets	0.005	-0.166	0.120	0.030	-0.002	-0.350	0.428	0.054
of which:								
- EME Asia	0.004	-0.118	0.092	0.024	-0.001	-0.286	0.172	0.046
- EME Europe	0.005	-0.166	0.120	0.034	-0.004	-0.350	0.428	0.053
- EME Latin America	0.006	-0.103	0.074	0.030	-0.001	-0.312	0.186	0.052
Money market rates (first diff.)								
Advanced	0.013	-0.160	0.203	0.030	-0.020	-1.572	0.900	0.136
of which:								
- Advanced Europe	0.016	-0.150	0.174	0.027	-0.017	-1.572	0.520	0.141
- Other Advanced	0.008	-0.160	0.198	0.034	-0.019	-1.120	0.900	0.120
Emerging markets	0.003	-4.241	4.829	0.209	-0.014	-3.290	4.520	0.288
of which:								
- EME Asia	0.014	-1.250	2.965	0.181	-0.024	-1.500	0.980	0.213
- EME Europe	-0.005	-2.248	4.829	0.191	-0.005	-3.290	4.520	0.314
- EME Latin America	-0.008	-4.241	3.102	0.311	-0.007	-2.458	4.188	0.409

Source: Bloomberg for all variables; see text for details.

Table 3: Variance decomposition.

	US macro news	TED shock	VIX shock	US stock m.	US money m.	Rest
Stock Markets						
	Pre-crisis period					
Advanced (excl. US)	0.35	9.63	16.10	3.19	1.80	68.93
Emerging	0.44	8.23	9.24	3.47	3.13	75.50
	Crisis period					
US	7.26	33.57	14.48	21.32	15.59	7.77
Advanced (excl. US)	3.29	25.81	9.20	9.50	6.98	45.21
Emerging	3.99	19.81	9.76	9.44	4.66	52.33
Money Markets						
	Pre-crisis period					
Advanced (excl. US)	0.42	0.67	1.96	0.22	0.15	96.59
Emerging	0.64	0.59	0.67	1.26	5.17	91.68
	Crisis period					
Advanced (excl. US)	0.74	9.73	6.20	4.20	0.89	78.24
Emerging	1.13	4.59	3.21	3.21	2.78	85.07

Table 4: List of country fundamentals.

Macroeconomic
Openness, financial integration, rating notches, reserves as a share of GDP unemployment, growth, current account as a share of GDP
Quality of institutions
ICRG institutional measures: political category index, financial category index, economic category index
Bilateral exposure to US
trade exposure, financial debt exposure, financial equity exposure

Table 5: Cross section regression explaining transmission of US shocks on stock market prices during crisis.

	Crisis period, impact on stock prices				
US shock:	*i*	*r*	*vix*	*ted*	macro news
openness	20% (0.08)	19% (0.02)	19% (0.07)	22% (0.13)	21% (-0.08)
financial int.	21% (-0.03)	21% (0.02)	19% (-0.01)	20% (-0.01)	20% (-0.01)
trade exposure	**53% (-1.93)**	**60% (1.87)**	**57% (-2.32)**	44% (-1.98)	46% (1.45)
equity exposure	35% (-1.53)	**65% (2.61)**	29% (-1.44)	**51% (-2.38)**	25% (0.41)
financial debt exposure	25% (1.03)	**56% (-3.02)**	40% (2.59)	29% (1.60)	**81% (-2.61)**
rating notches	18% (0.01)	**57% (-0.05)**	**59% (0.11)**	23% (0.03)	27% (-0.03)
icrg- political	20% (-0.01)	25% (0.00)	**59% (-0.05)**	24% (0.01)	35% (0.02)
icrg- financial	18% (-0.01)	23% (0.02)	24% (0.02)	28% (-0.04)	20% (0.01)
icrg - economic	18% (0.01)	21% (-0.02)	39% (0.06)	26% (0.04)	**72% (-0.06)**
market cap	20% (-0.00)	22% (0.00)	22% (0.00)	31% (-0.00)	18% (0.00)
reserves	22% (0.00)	19% (0.00)	19% (-0.00)	20% (0.00)	21% (0.00)
unemployment	23% (0.02)	18% (-0.00)	18% (-0.01)	25% (0.03)	19% (-0.01)
growth	18% (0.02)	20% (0.01)	21% (0.04)	19% (0.02)	26% (0.04)
current account	20% (-0.01)	19% (0.00)	26% (0.01)	34% (-0.03)	29% (-0.01)

Notes: posterior probabilities of variable relevance are imported. Probabilities higher than 50% are highlighted with bold fonts. Posterior mean of the estimated coefficient conditional on variable being included in the model is reported in parentheses.

Table 6: Cross section regression explaining transmission of US shocks on stock market prices before crisis.

	Before crisis period, impact on stock prices				
US shock:	*i*	*r*	*vix*	*ted*	macro news
openness	26% (-0.06)	19% (-0.03)	28% (0.10)	19% (0.03)	25% (-0.02)
financial int.	19% (-0.00)	19% (-0.00)	20% (-0.01)	21% (-0.01)	**77% (0.02)**
trade exposure	38% (-0.67)	26% (0.39)	**52% (-1.10)**	33% (-0.89)	19% (-0.00)
equity exposure	25% (-0.39)	44% (0.74)	49% (-1.34)	49% (-1.64)	**65% (0.54)**
financial debt exposure	48% (0.98)	27% (-0.57)	40% (1.47)	48% (2.06)	45% (-0.52)
rating notches	**93% (0.05)**	**89% (-0.04)**	**78% (0.07)**	**65% (0.05)**	44% (0.01)
icrg- political	39% (-0.01)	39% (0.01)	**64% (-0.03)**	40% (-0.02)	48% (0.01)
icrg- financial	27% (0.01)	19% (0.00)	24% (-0.01)	22% (0.01)	22% (0.00)
icrg - economic	30% (0.02)	21% (-0.01)	23% (0.02)	27% (0.03)	22% (-0.00)
market cap	19% (0.00)	18% (0.00)	19% (0.00)	32% (-0.00)	25% (0.00)
reserves	24% (-0.00)	19% (0.00)	27% (0.00)	19% (-0.00)	30% (-0.00)
unemployment	19% (0.01)	18% (-0.00)	24% (-0.02)	22% (-0.01)	41% (0.01)
growth	**56% (0.05)**	30% (-0.03)	21% (0.01)	26% (0.04)	37% (0.02)
current account	22% (-0.00)	22% (0.01)	22% (-0.01)	21% (-0.01)	22% (-0.00)

See notes to Table 5.

Table 7: Cross section regression explaining transmission of US shocks on money markets during crisis.

	Crisis period, impact on money prices				
US shock:	*i*	*r*	*vix*	*ted*	macro news
openness	**85% (1.96)**	**56% (1.93)**	41% (-1.69)	21% (0.36)	26% (-0.62)
financial int.	39% (0.34)	38% (0.45)	23% (0.24)	38% (0.40)	22% (-0.09)
trade exposure	33% (5.48)	20% (-1.13)	29% (-9.20)	19% (-2.40)	45% (-7.04)
equity exposure	21% (-2.27)	32% (6.90)	30% (8.27)	24% (6.18)	45% (7.27)
financial debt exposure	26% (-5.13)	24% (4.51)	35% (12.08)	23% (-6.95)	24% (-3.74)
rating notches	43% (0.23)	37% (0.29)	**96% (-0.78)**	50% (0.42)	32% (-0.17)
icrg- political	28% (-0.06)	25% (-0.06)	23% (0.07)	23% (-0.06)	24% (0.05)
icrg- financial	33% (0.16)	25% (-0.18)	21% (0.13)	21% (-0.11)	27% (-0.15)
icrg - economic	**65% (-0.27)**	**68% (0.43)**	29% (0.27)	30% (-0.23)	23% (0.00)
market cap	**59% (0.00)**	40% (0.01)	29% (-0.00)	23% (0.00)	27% (-0.00)
reserves	27% (0.02)	23% (-0.01)	28% (-0.04)	21% (-0.01)	25% (0.02)
unemployment	18% (0.01)	18% (0.04)	17% (-0.02)	20% (-0.10)	18% (-0.03)
growth	35% (0.32)	19% (0.00)	20% (-0.18)	**78% (0.95)**	**58% (-0.43)**
current account	30% (-0.07)	27% (0.09)	22% (0.05)	23% (-0.07)	36% (0.12)

See notes to Table 5.

Table 8: Cross section regression explaining transmission of US shocks on money markets before crisis.

	Before crisis period, impact on money prices				
US shock:	*i*	*r*	*vix*	*ted*	macro news
openness	**58% (0.79)**	18% (-0.01)	35% (0.50)	29% (0.37)	**65% (-0.56)**
financial int.	24% (0.08)	18% (0.00)	26% (-0.08)	20% (0.02)	26% (0.04)
trade exposure	22% (1.61)	29% (-1.56)	26% (1.46)	19% (0.08)	38% (0.55)
equity exposure	23% (1.67)	50% (2.32)	23% (0.61)	26% (1.65)	**59% (2.40)**
financial debt exposure	24% (2.28)	23% (0.13)	32% (2.41)	36% (3.35)	**83% (-5.11)**
rating notches	27% (0.08)	21% (-0.03)	23% (0.03)	21% (-0.05)	52% (0.07)
icrg- political	29% (0.04)	23% (0.02)	20% (0.01)	19% (-0.01)	**100% (-0.08)**
icrg- financial	19% (-0.03)	25% (-0.04)	**78% (0.13)**	19% (0.02)	49% (-0.06)
icrg - economic	26% (-0.09)	18% (0.00)	20% (-0.01)	21% (0.04)	**75% (0.11)**
market cap	36% (0.00)	**99% (0.00)**	30% (-0.00)	25% (0.00)	**73% (0.00)**
reserves	29% (0.02)	19% (0.00)	**56% (-0.03)**	20% (0.00)	**56% (0.02)**
unemployment	18% (-0.02)	18% (-0.01)	18% (-0.01)	17% (0.01)	23% (-0.01)
growth	19% (0.01)	26% (0.08)	**55% (0.21)**	18% (-0.01)	19% (-0.01)
current account	20% (-0.00)	19% (0.01)	25% (-0.00)	21% (0.02)	30% (-0.02)

See notes to Table 5.

References

Adrian and Brunnermeier (2009).

Andersen, Bollerslev, Diebold, and Vega (2007).

Bae, K.-H., A. Karolyi, and R. Stulz (2003). A new approach to measuring financial contagion. *Review of Financial Studies 16*, 717–763.

Bekaert, G., M. Ehrmann, M. Fratzscher, and A. Mehl (2010). Contagion and the global equity market collapse of the 2007-09 financial crisis. mimeo, April 2010.

Bekaert, G., C. R. Harvey, and A. Ng (2005). Market integration and contagion. *Journal of Business*, 39–69.

Borio (2009).

Brunnermeier and Petersen (2010).

Calomiris, C. W. (2008). The subprime turmoil: What's old, what's new and what's next. mimeo, Columbia Business School.

Chudik, A. (2008). *Global Macroeconomic Modelling*. Ph. D. thesis, Trinity College, University of Cambridge.

Chudik, A. and M. H. Pesaran (2010). Infinite dimensional VARs and factor models. *forthcoming in Journal of Econometrics*.

Chudik, A., M. H. Pesaran, and E. Tosetti (2010). Weak and strong cross section dependence and estimation of large panels. ECB Working Paper No. 1100, October 2009, revised April 2010.

De Gregorio, J. and R. Valdes (2001). Crisis transmission: Evidence from the debt.

Dées, S., F. di Mauro, M. H. Pesaran, and L. V. Smith (2007). Exploring the international linkages of the euro area: a global var analysis. *Journal of Applied Econometrics 22*, 1–38.

Diebold, F. and K. Yilmaz (2009). Measuring financial asset return and volatility spillovers, with application to global equity markets. *Economic Journal 119*, 158–171.

Dungey, M., R. Fry, B. Gonzalez-Hermosillo, and V. L. Martin (2004). Empirical modeling of contagion: A review of methodologies. *Quantitative Finance 5*(1), 9–24.

Dungey, M. and V. L. Martin (2007). Unravelling financial market linkages during crises. *Journal of Applied Econometrics 22*(1), 89–119.

Ehrmann, M. and M. Fratzscher (2005). Equal size, equal role? interest rate interdependence between the euro area and the united states. *Economic Journal 115*, 930–50.

Ehrmann, M., M. Fratzscher, and R. Rigobon (2010). Stocks, bonds, money markets and exchange rates: Measuring international financial transmission. *forthcoming Journal of Applied Econometrics*.

Engle, R. F., T. Ito, and W. L. Lin (1990). Meteor-showers or heat waves - heteroskedastic intradaily volatility in the foreign exchange market. *Econometrica 55*, 391–407.

Forbes, K. J. and M. Chinn (2004). A decomposition of global linkages in financial markets over time. *Review of Economics and Statistics 86*, 705–722.

Forbes, K. J. and R. Rigobon (2002). No contagion, only interdependence: Measuring stock market co-movements. *The Journal of Finance 57*(5), 2223–2261.

Forni, M., M. Hallin, M. Lippi, and L. Reichlin (2000). The generalized dynamic factor model: Identification and estimation. *Review of Economics and Statistic 82*, 540–554.

Forni, M., M. Hallin, M. Lippi, and L. Reichlin (2004). The generalized dynamic factor model: Consistency and rates. *Journal of Econometrics 119*, 231–235.

Forni, M. and M. Lippi (2001). The generalized factor model: Representation theory. *Econometric Theory 17*, 1113–1141.

Fratzscher, M. (2009). What explains global exchange rate movements during the financial crisis? *Journal of International Money and Finance 28*, 1390–1407.

Hamao, Y., R. W. Masulis, and V. Ng (1990). Correlations in price changes and volatility across international stock markets. *Review of Financial Studies 3*, 281–307.

IMF (2009). How linkages fuel the fire: The transmission of financial stress from advanced to emerging economies. World Economic Outlook, April 2009.

Karolyi, A. (2003). Does international finance contagion really exist? *International Finance 6*, 179–199.

Pesaran, M., L. Smith, and R. Smith (2007). What if the uk or sweden had joined the euro in 1999? an empirical evaluation using a global var. *International Journal of Finance and Economics 12*, 55–87.

Pesaran, M. H. and A. Chudik (2010). Econometric analysis of high dimensional VARs featuring a dominant unit. ECB working paper No. 1194, May 2010.

Pesaran, M. H., T. Schuermann, and B. J. Treutler (2007). Global business cycles and credit risk. In M. Carey and R. Stultz (Eds.), *The risks of financial institutions*, Chapter 9. University of Chicago Press.

Pesaran, M. H., T. Schuermann, B.-J. Treutler, and S. M. Weiner (2006). Macroeconomic dynamics and credit risk: A global perspective. *Journal of Money Credit and Banking 38*(5), 1211–1262.

Pesaran, M. H., T. Schuermann, and S. M. Weiner (2004). Modelling regional interdependencies using a global error-correcting macroeconometric model. *Journal of Business and Economics Statistics 22*, 129–162.

Pesaran, M. H. and E. Tosetti (2010). Large panels with common factors and spatial correlation. CESifo Working Paper No. 2103, September 2007, revised May 2010.

Sala-i-Martin, X., G. Doppelhofer, and R. I. Miller (2004). Determinants of long-term growth: A bayesian averaging of classical estimates (bace) approach. *The American Economic Review 94*(4), 813–835.

Shin, XX, and X. 2010 (2010).

Taylor, J. B. (2009). The financial crisis and the policy responses: An empirical analysis of what went wrong. NBER Working Paper No. 14631.

Tong, H. and S.-J. Wei (2009). Real effects of the subprime mortgage crisis: is it a demand or finance shock? *forthcoming in Review of Financial Studies*.

A Figures

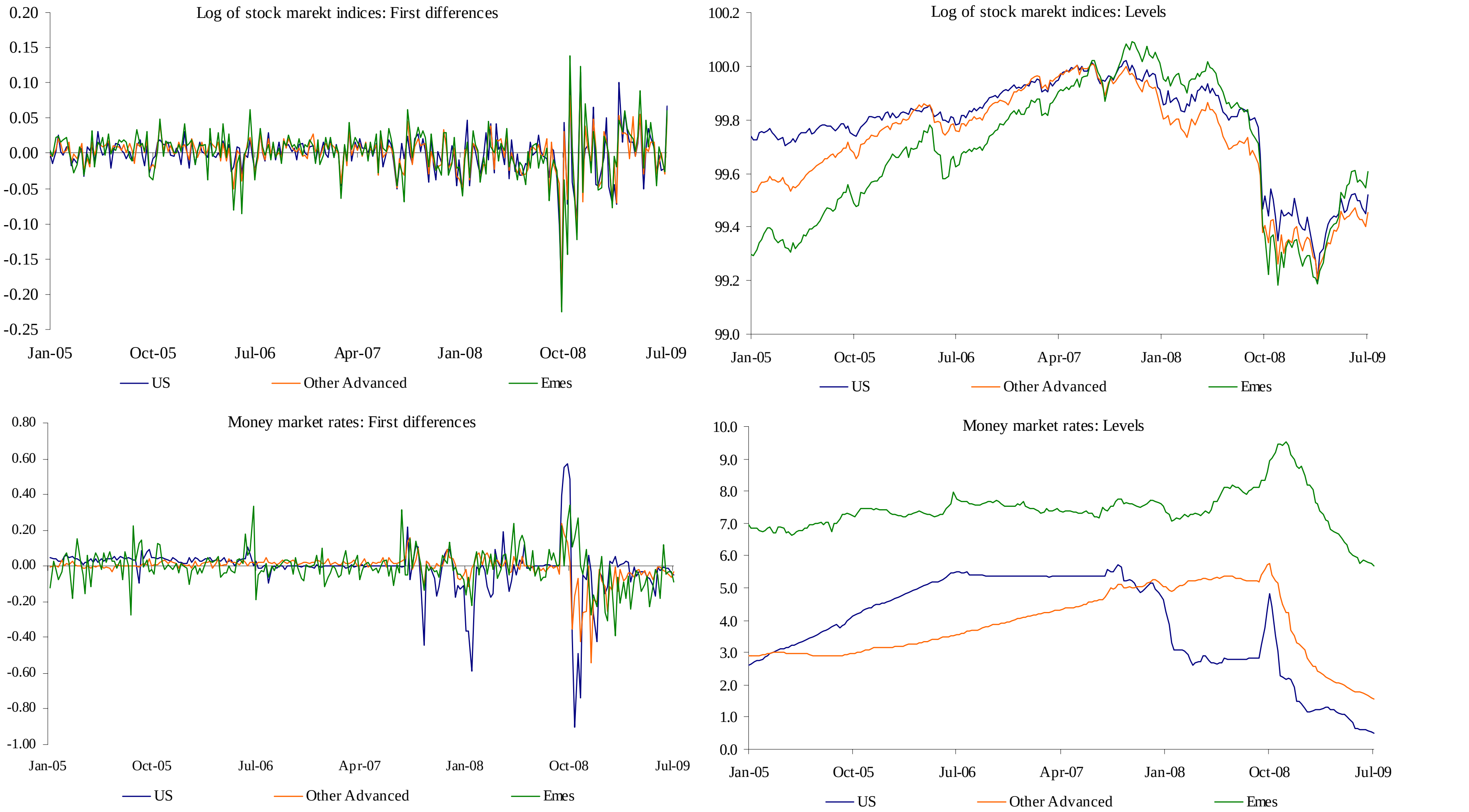


Figure 1: Stock market indices and money market rates - Unweighted averages of three groups: US, other advanced economies, and emerging markets

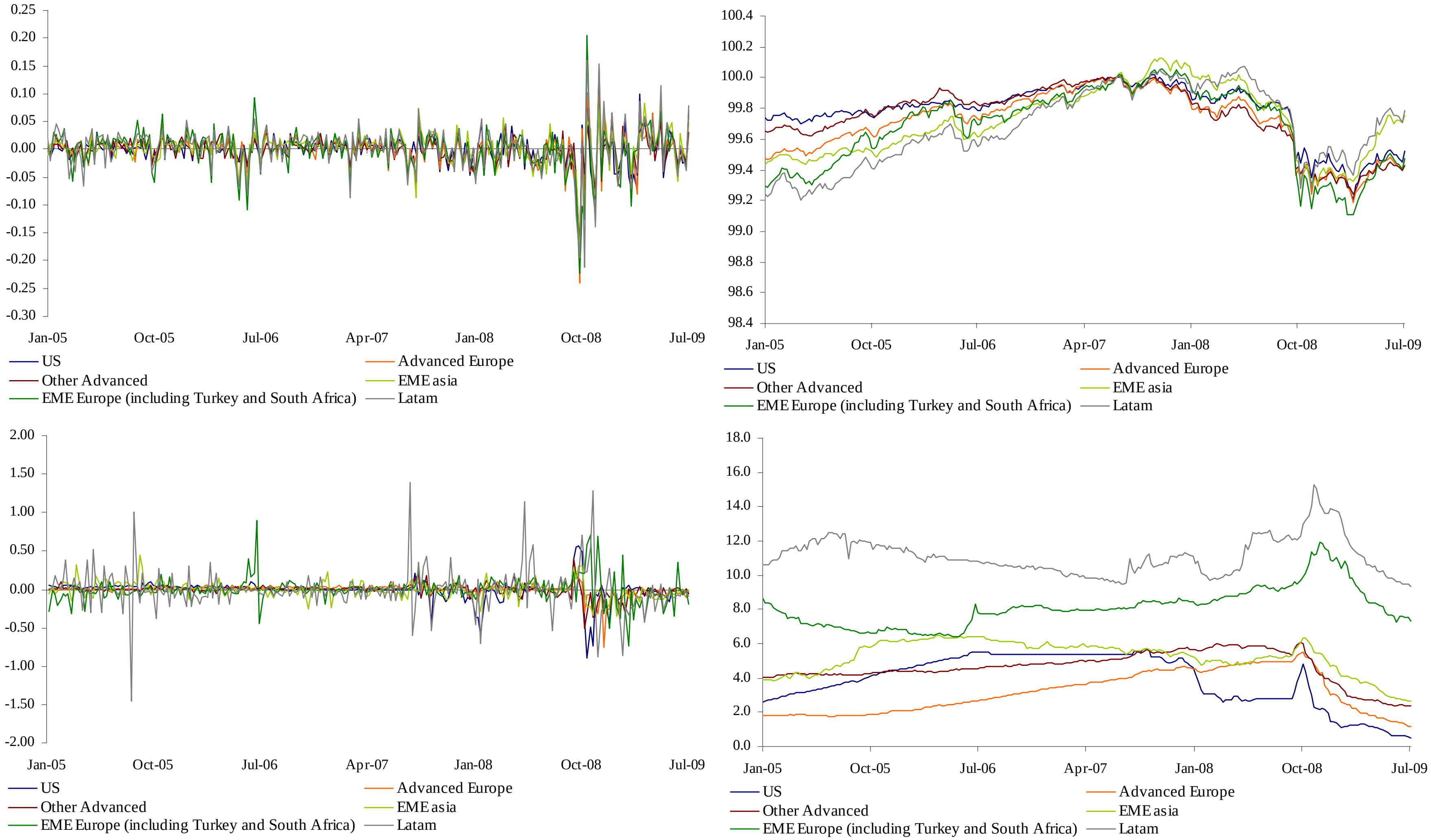


Figure 2: Stock market indices and money market rates - Unweighted averages of six groups: US, Advanced Europe, other Advanced, Emerging Asia, Emerging Europe (plus Turkey and South Africe), and Latin America

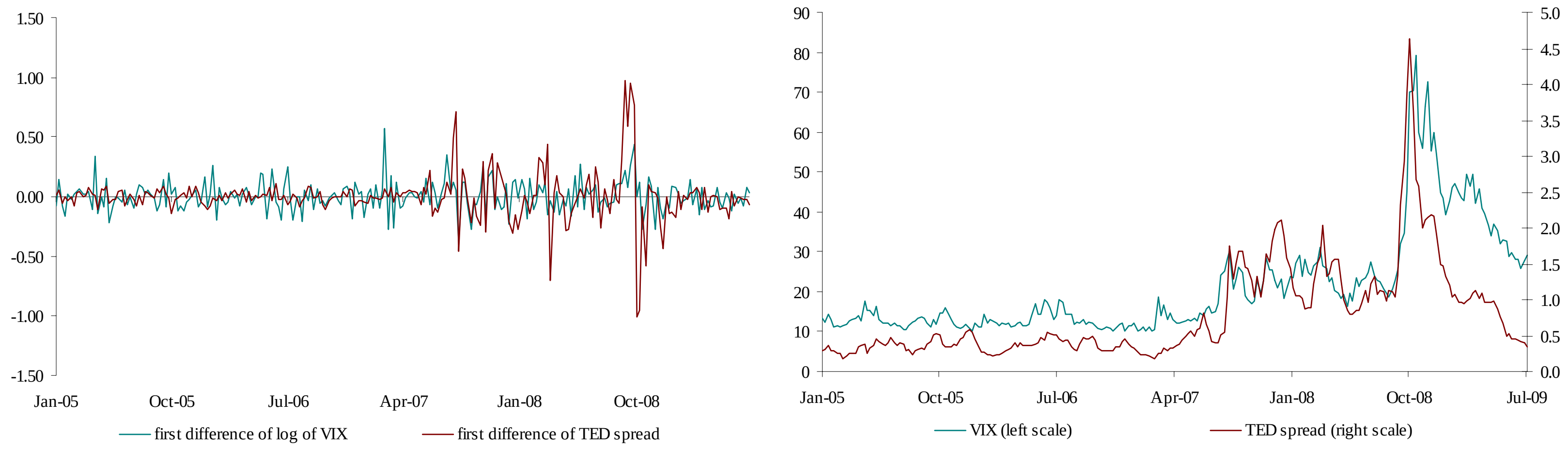


Figure 3: VIX and TED spread

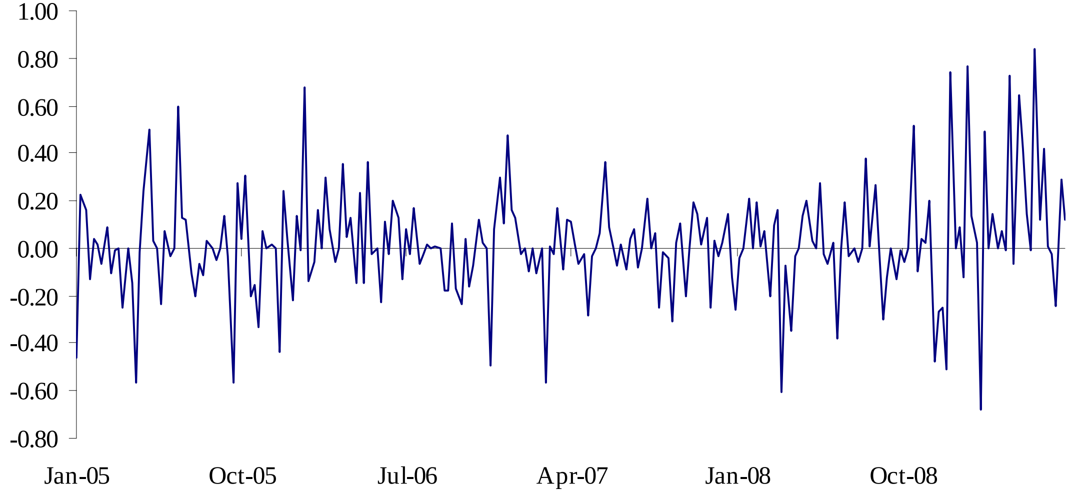


Figure 4: US macro surprise shocks

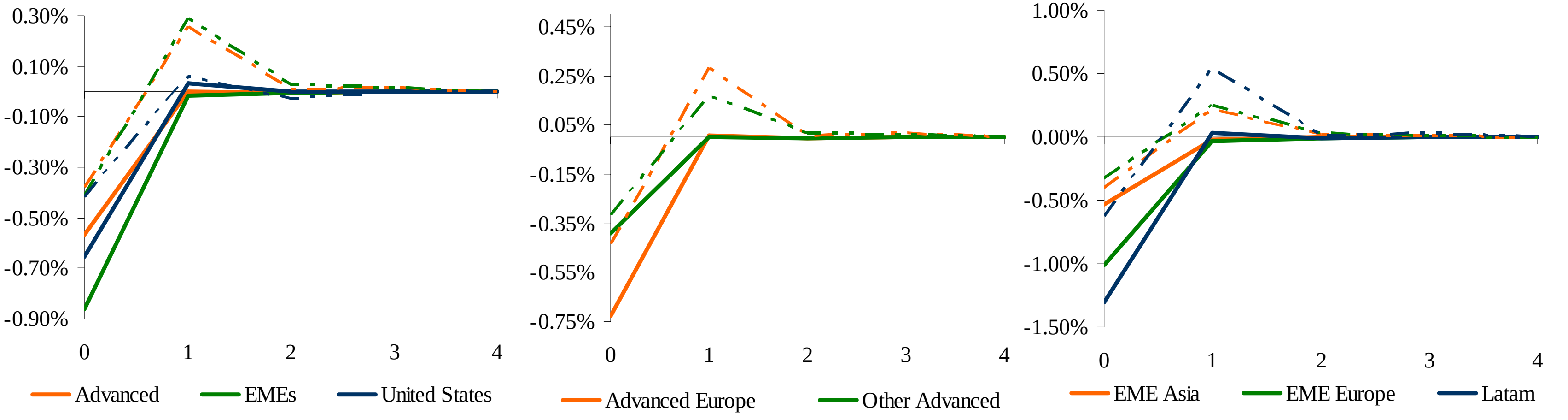


Figure 5: Impulse response function of a shock to US TED spread, impact on stock markets. Dashed lines correspond to crisis period.

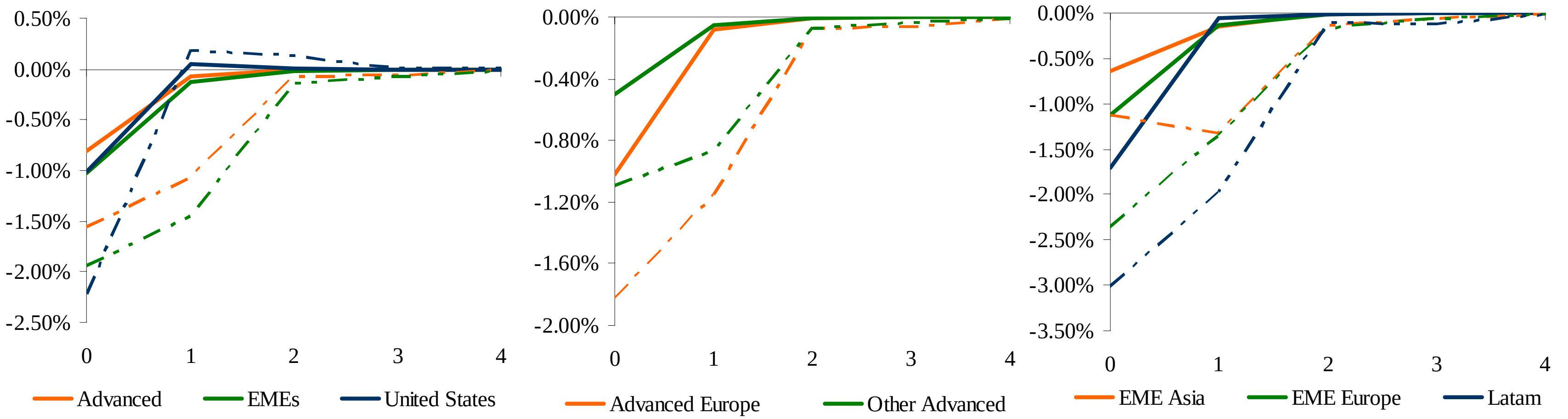


Figure 6: Impulse response function of a shock to VIX, impact on stock markets. Dashed lines correspond to crisis period.

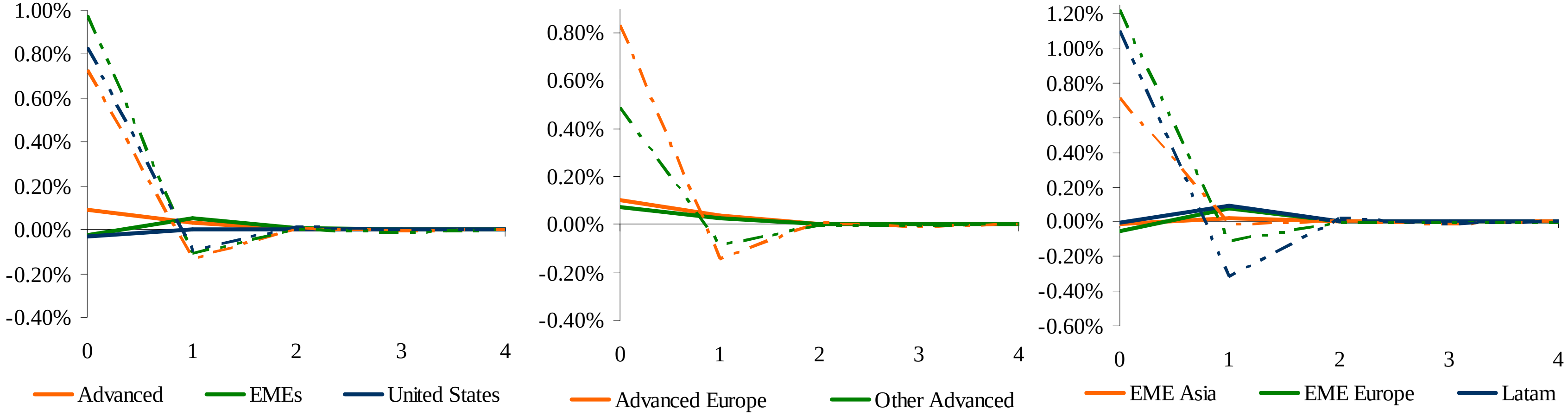


Figure 7: Impulse response function of US macro news shock, impact on stock markets. Dashed lines correspond to crisis period.

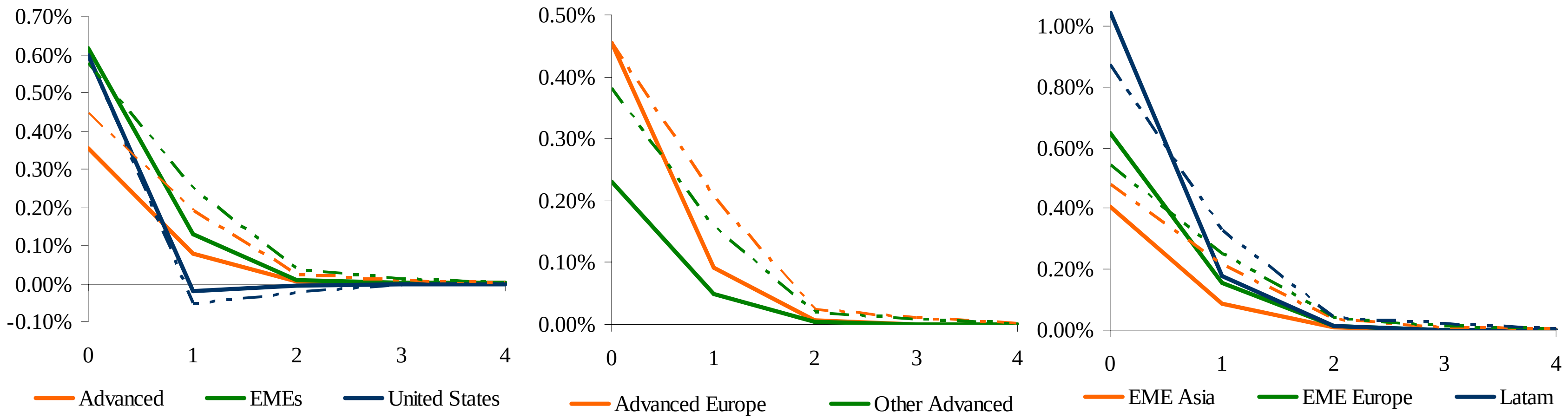


Figure 8: Impulse response function of US stock market shock, impact on stock markets. Dashed lines correspond to crisis period.

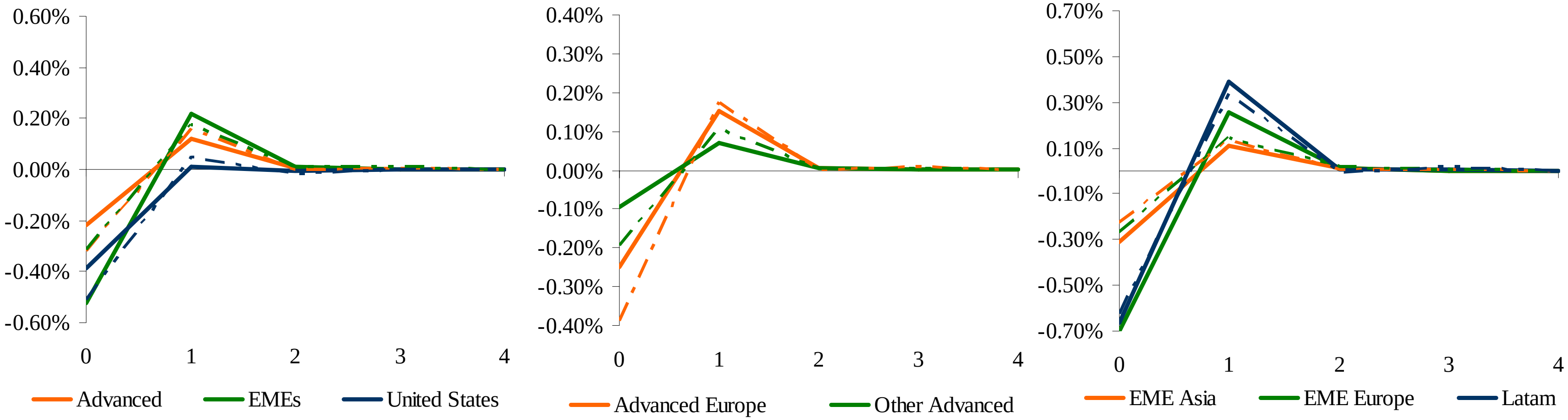


Figure 9: Impulse response function of US money market shock, impact on stock markets. Dashed lines correspond to crisis period.

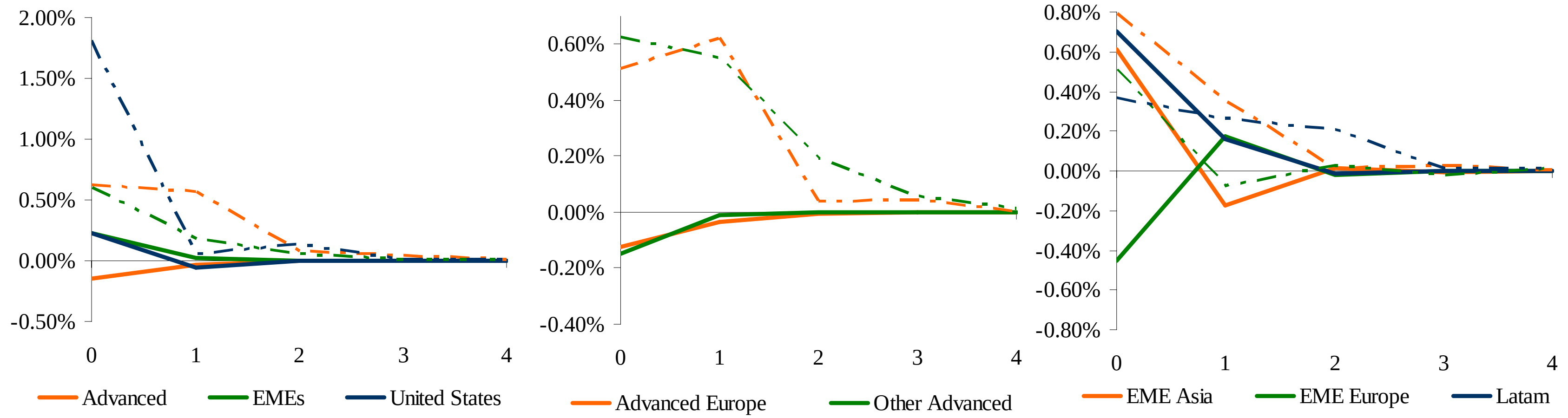


Figure 10: Impulse response function of US TED spread shock, impact on money markets. Dashed lines correspond to crisis period.

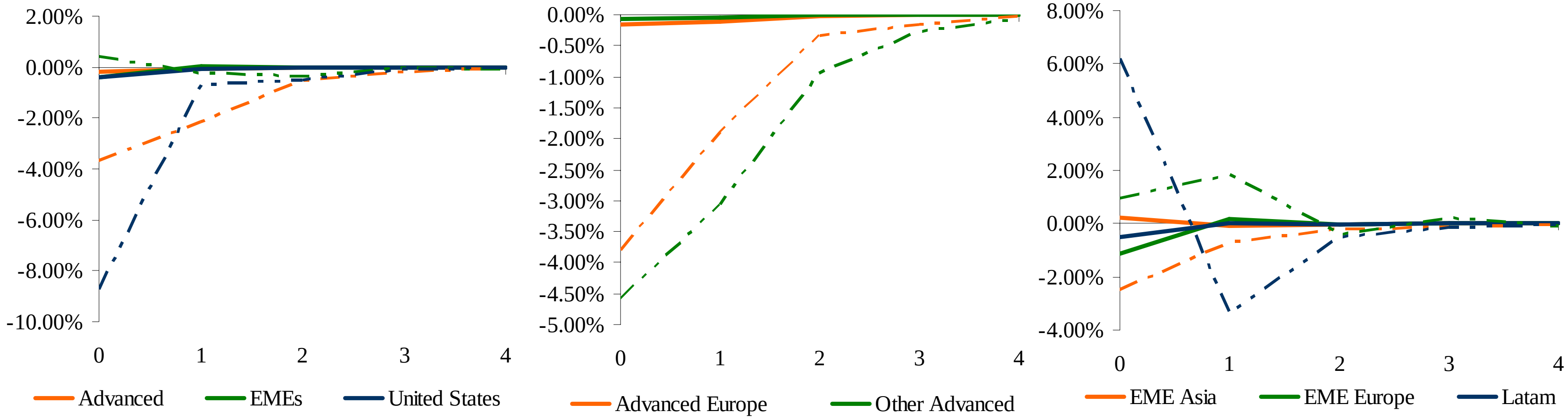


Figure 11: Impulse response function of a shock to VIX, impact on money markets. Dashed lines correspond to crisis period.

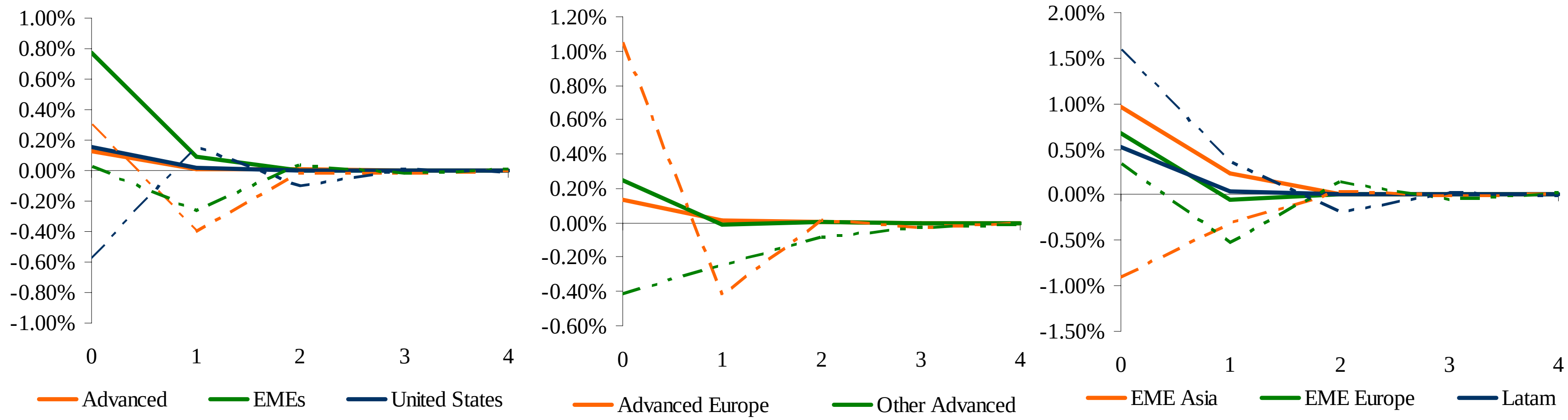


Figure 12: Impulse response function of US macro news shock, impact on money markets. Dashed lines correspond to crisis period.

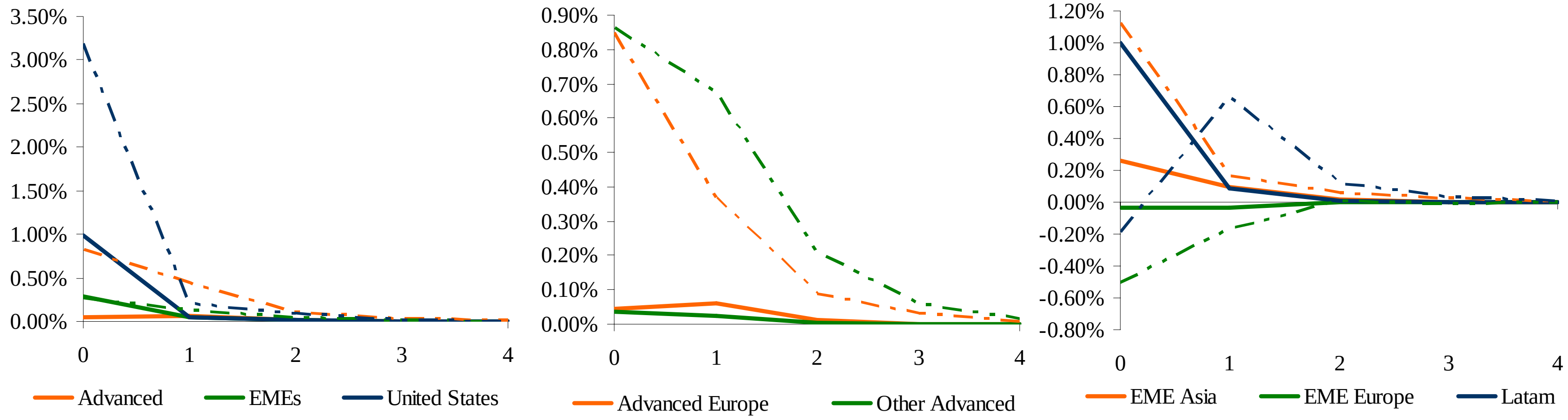


Figure 13: Impulse response function of US stock market shock, impact on money markets. Dashed lines correspond to crisis period.

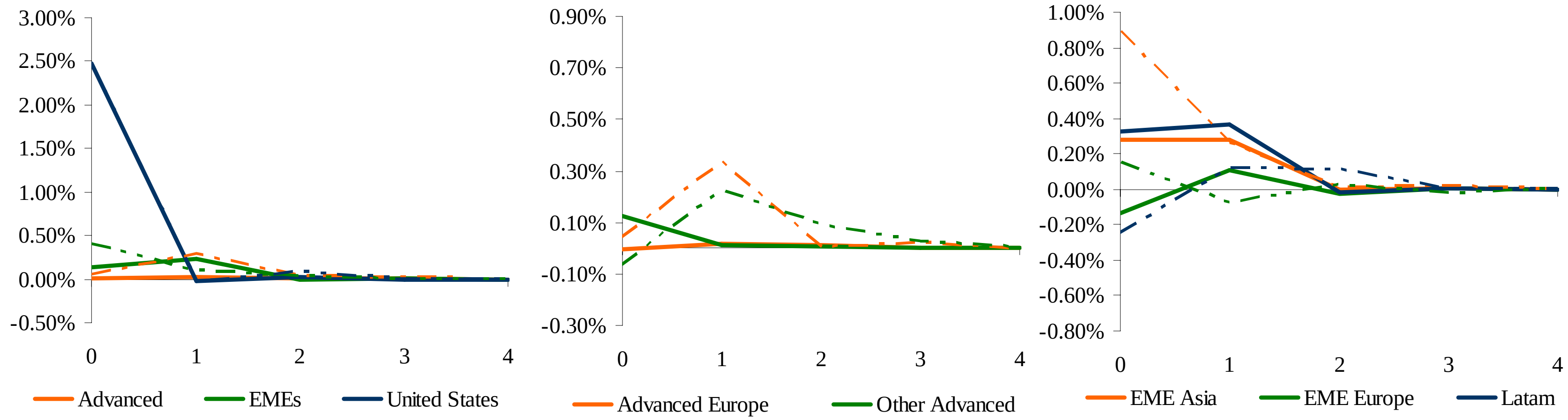


Figure 14: Impulse response function of US money market shock, impact on money markets. Dashed lines correspond to crisis period.

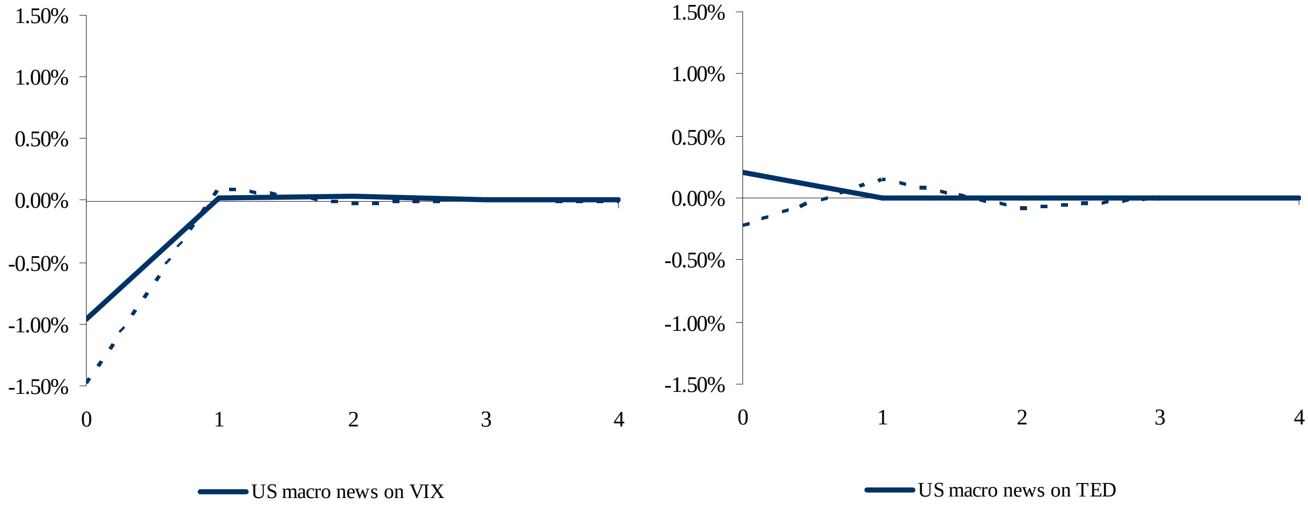


Figure 15: Impulse response function of a shock to US macro news, impact on VIX and TED. Dashed lines correspond to crisis period.

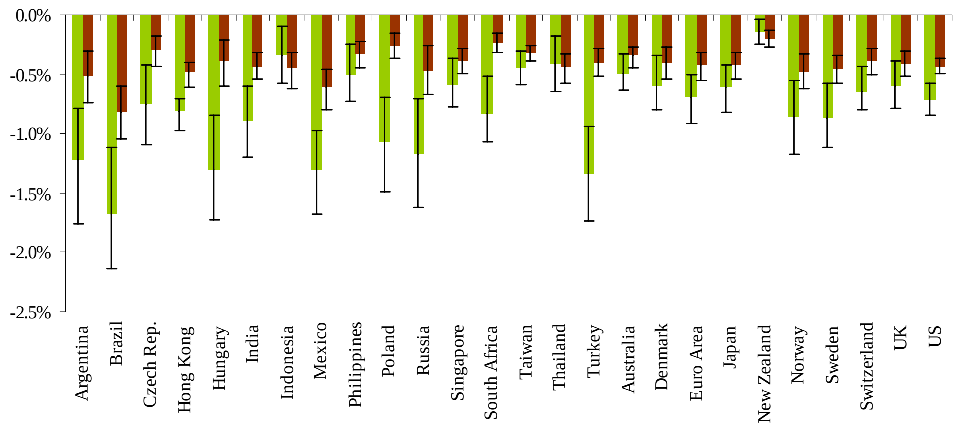


Figure 16: Contemporaneous impact of a shock to US TED spread on stock markets and 25-75% bootstrap error bands. Dark/brown bars correspond to crisis period; light/green bars to pre-crisis period.

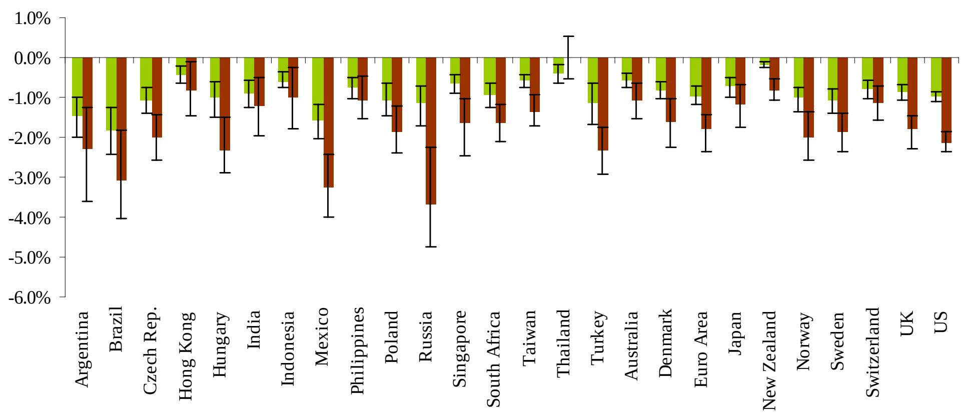


Figure 17: Contemporaneous impact of a shock to VIX on stock markets and 25-75% bootstrap error bands. Dark/brown bars correspond to crisis period; light/green bars to pre-crisis period.

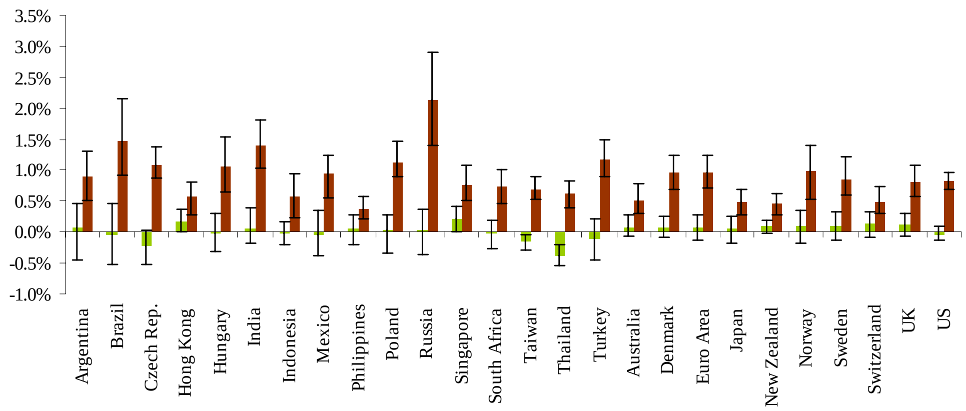


Figure 18: Contemporaneous impact of US macro news shock on stock markets and 25-75% bootstrap error bands. Dark/brown bars correspond to crisis period; light/green bars to pre-crisis period.

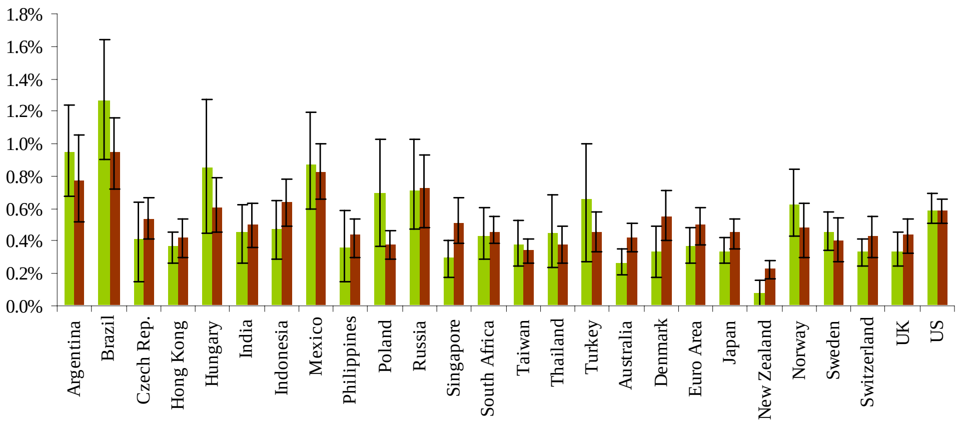


Figure 19: Contemporaneous impact of US stock market shock on stock markets and 25-75% bootstrap error bands. Dark/brown bars correspond to crisis period; light/green bars to pre-crisis period.

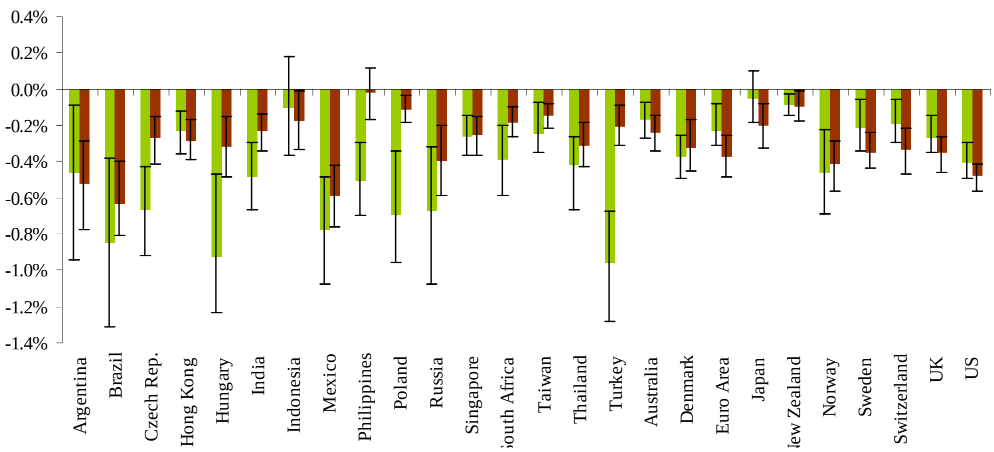


Figure 20: Contemporaneous impact of US money market shock on stock markets and 25-75% bootstrap error bands. Dark/brown bars correspond to crisis period; light/green bars to pre-crisis period.

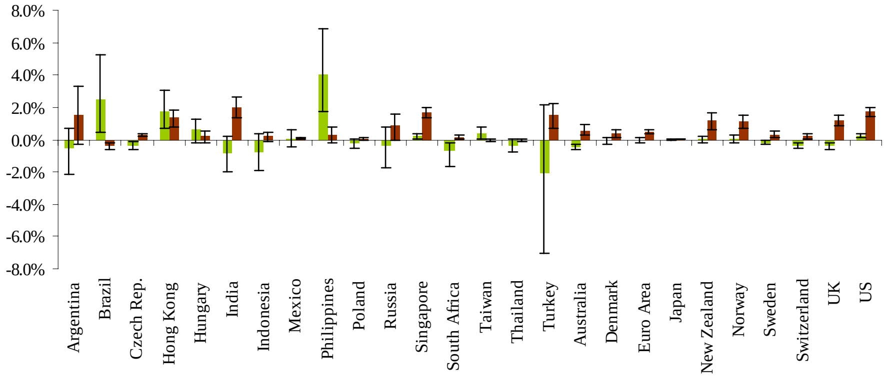


Figure 21: Contemporaneous impact of a shock to US TED spread on money markets and 25-75% bootstrap error bands. Dark/brown bars correspond to crisis period; light/green bars to pre-crisis period.

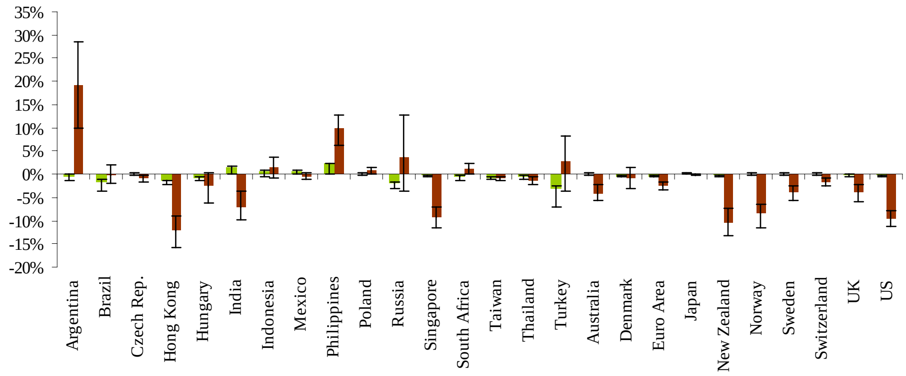


Figure 22: Contemporaneous impact of a shock to VIX on money markets and 25-75% bootstrap error bands. Dark/brown bars correspond to crisis period; light/green bars to pre-crisis period.

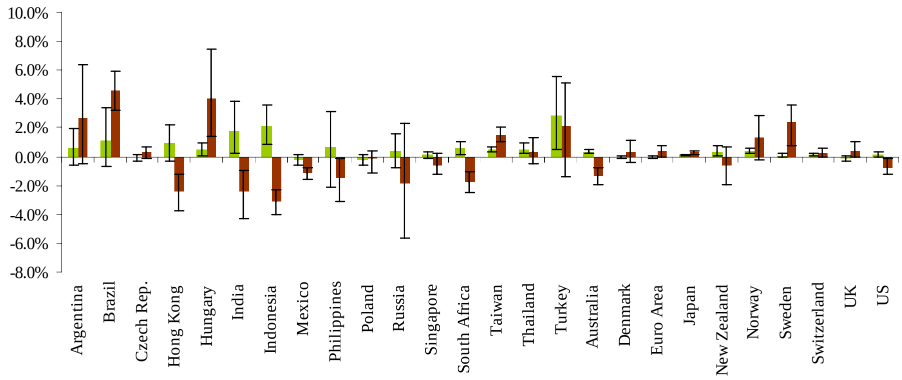


Figure 23: Contemporaneous impact of US macro news shock on money markets and 25-75% bootstrap error bands. Dark/brown bars correspond to crisis period; light/green bars to pre-crisis period.

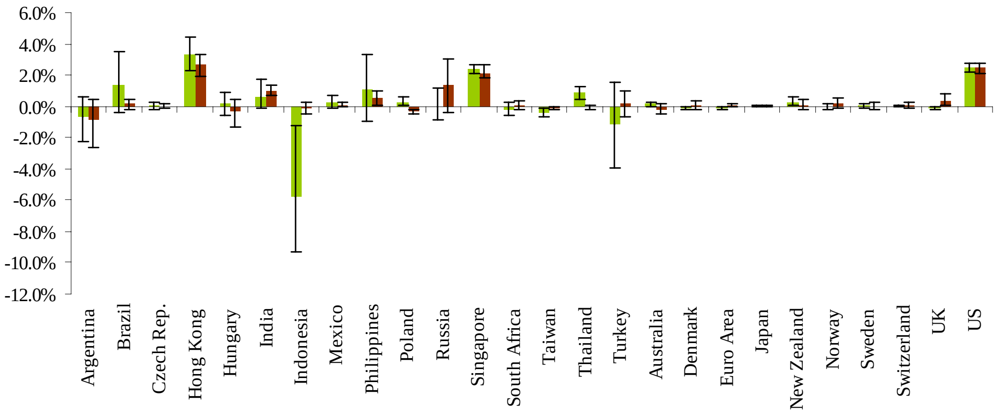


Figure 24: Contemporaneous impact of US stock market shock on money markets and 25-75% bootstrap error bands. Dark/brown bars correspond to crisis period; light/green bars to pre-crisis period.

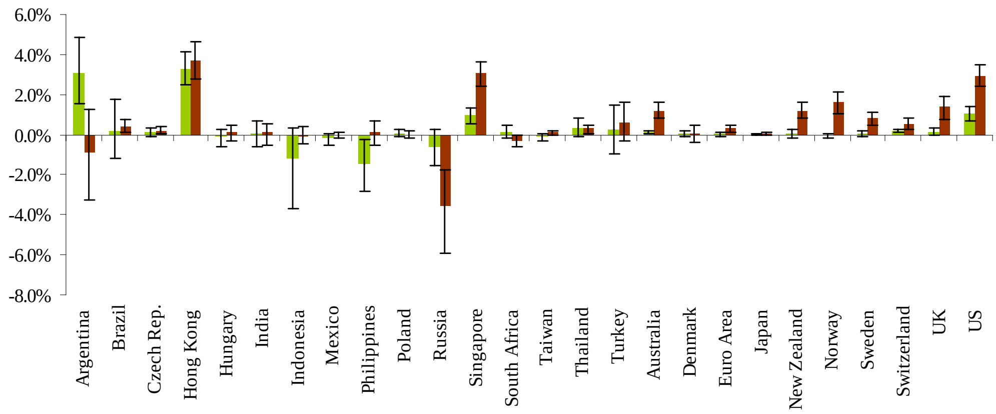
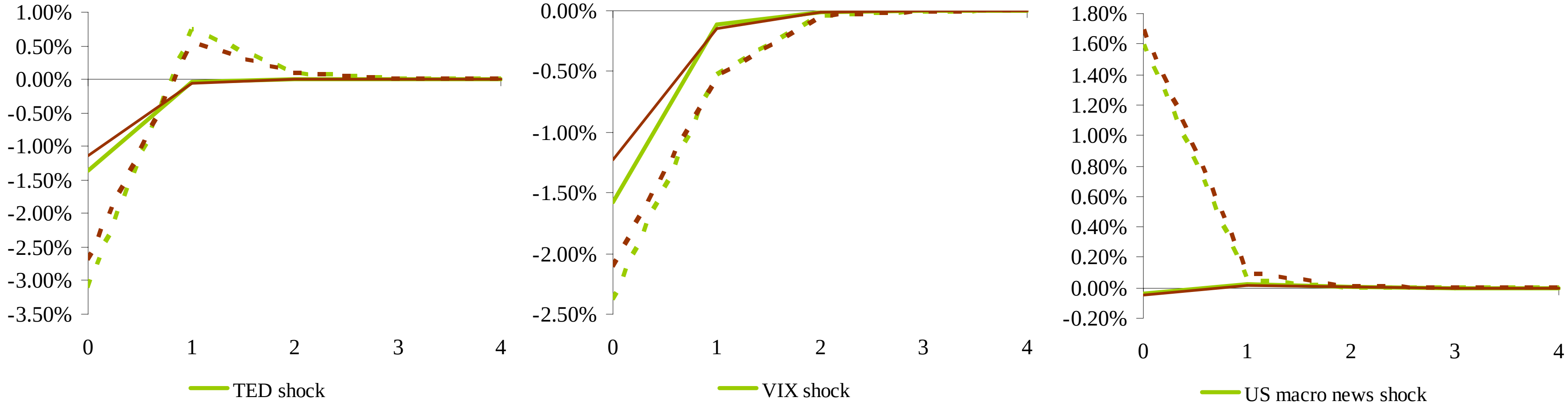


Figure 25: Contemporaneous impact of US money market shock on money markets and 25-75% bootstrap error bands. Dark/brown bars correspond to crisis period; light/green bars to pre-crisis period.

I. Trade openness (Dark/brown lines correspond to the group above median; light/green bars to the group below median.)



II. Rating notches (Dark/brown lines correspond to the group above median; light/green bars to the group below median.)

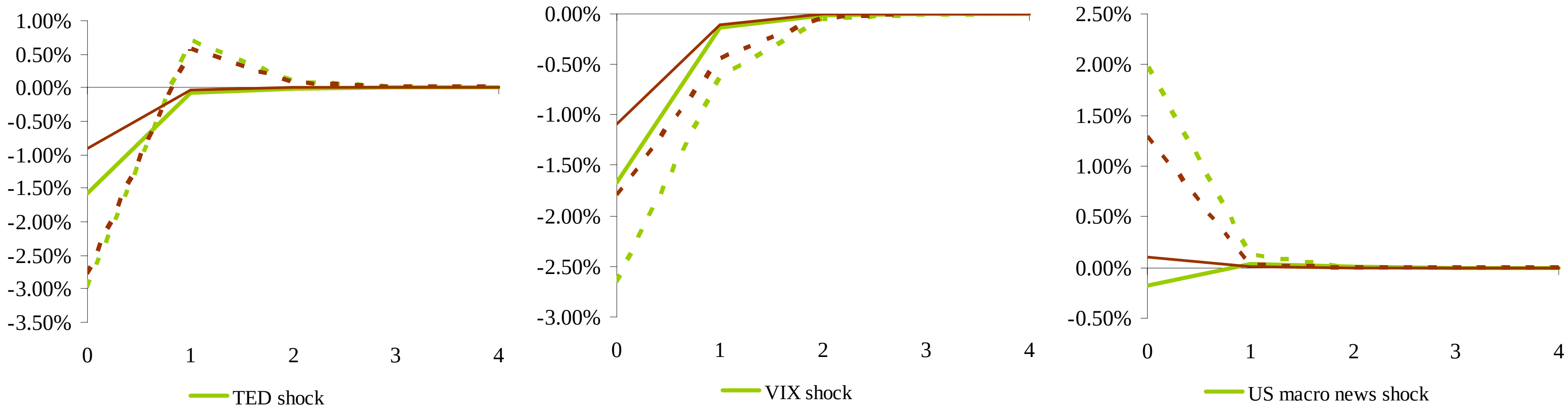
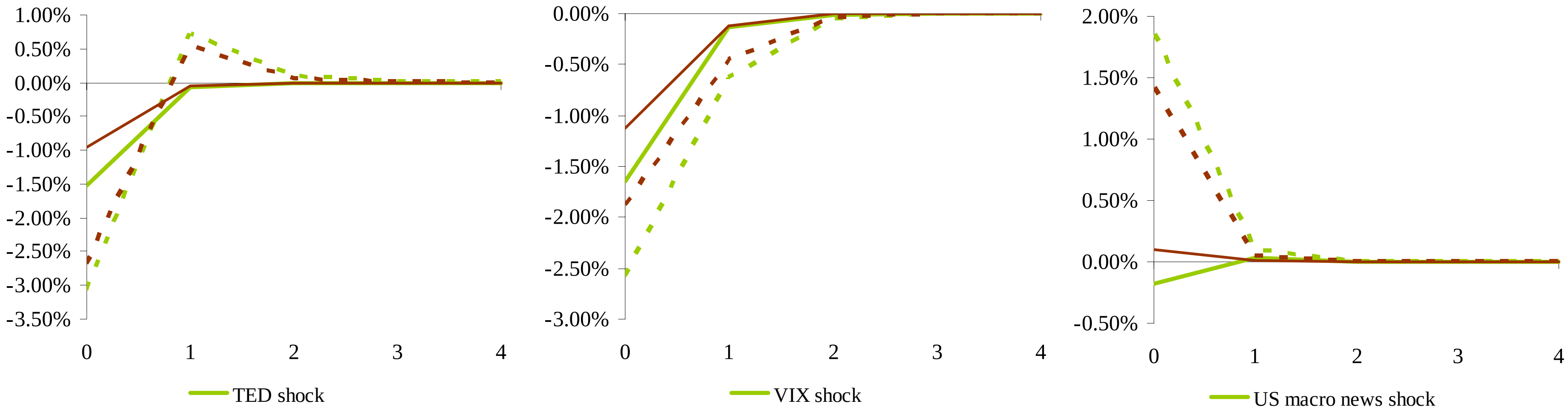


Figure 26: Impact of TED, VIX and US macro news shocks on stock markets. (Dotted lines correspond to the crisis period).

I. Political institutions (Dark/brown lines correspond to the group above median; light/green bars to the group below median.)



II. Reserves (Dark/brown lines correspond to the group above median; light/green bars to the group below median.)

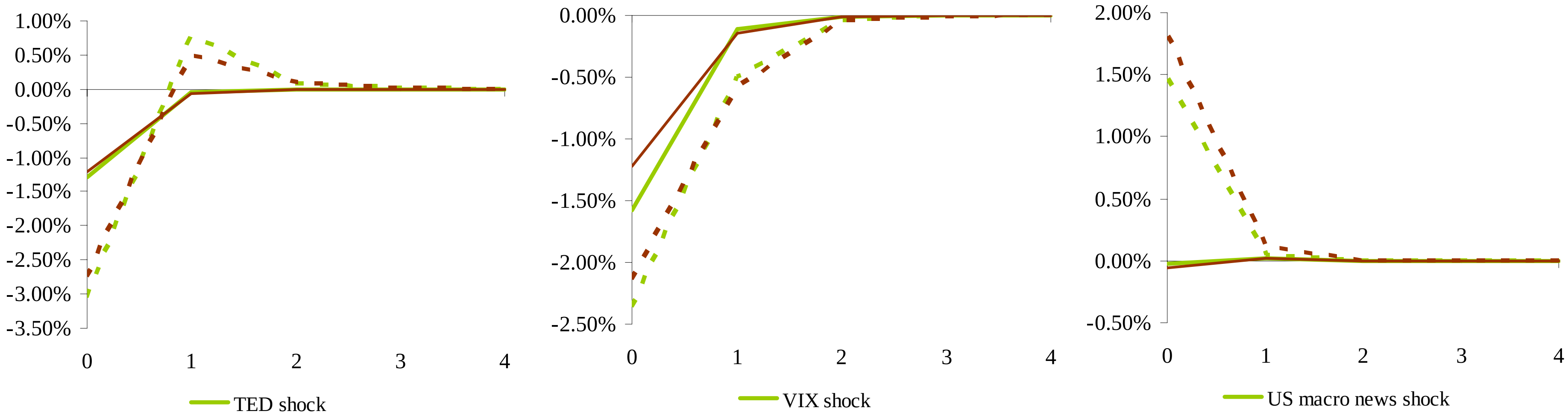


Figure 27: Impact of TED, VIX and US macro news shocks on stock markets. (Dotted lines correspond to the crisis period).