Vremenski promjenjiva integracija tržišta državnih obveznica europskih posttranzicijskih zemalja

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Abstract

The aim of this paper is to study time-varying integration between European post-transition government bond markets and eurozone bond market. We follow the empirical approach defined in Bekaert and Harvey's (1995) seminal paper, which enables direct estimation of the time-varying degree of financial markets integration. We thus investigate bond markets of eight new member states of EU and one non-EU member (Ukraine). The result of our empirical examination is a time-varying parameter of integration that is driven by a set of macroeconomic instruments defined in order to represent the intensity of real economic integration of analyzed countries into the eurozone, and their fiscal stances. Our results suggest integration varies with respect to economic development, as economically more advanced countries demonstrate a higher level of integration in the observed period. Moreover, we observe that integration decreased with the financial crisis, but it levelled off relatively swiftly afterwards. Depending on the country, joining the EU either exerted a positive boost on sovereign bond integration, or was neutral with regards to integration. We also show that macroeconomic performance relative to the eurozone benchmark and fiscal stance matter greatly for bond market integration in all countries under examination.

Keywords: European post-transition countries, sovereign securities markets, bond market integration

JEL classification: E44, F36, G15

Vremenski promjenjiva integracija tržišta državnih obveznica europskih posttranzicijskih zemalja

Sažetak

Cilj ovog rada je istražiti vremenski promjenjivu integraciju tržišta državnih obveznica između europskih posttranzicijskih zemalja i eurozone. Rad slijedi empirijski pristup koji su definirali Bekaert i Harvey (1995), koji omogućuje direktnu procjenu vremenski promjenjivog stupnja integracije financijskih tržišta. Mi stoga istražujemo tržišta obveznica osam novih zemalja članica Europske unije i jedne zemlje nečlanice Unije (Ukrajine). Rezultati naše empirijske procjene sugeriraju da je vremenska promjenjivost financijske integracije određena skupom makroekonomskih instrumenata definiranih tako da predstavljaju intenzitet realne ekonomske integracije analiziranih zemalja u gospodarstvo eurozone i stanje njihovih javnih financija. Naši rezultati sugeriraju da razina integracije varira u ovisnosti o stupnju ekonomskog razvoja jer ekonomski razvijenije zemlje iskazuju u promatranom razdoblju viši stupanj integracije. Nadalje, stupanj integracije se smanjio s početkom financijske krize 2008., no to smanjenje je bilo kratkog vijeka. U ovisnosti od zemlje do zemlje, pridruživanje Uniji je imalo ili pozitivan ili neutralan učinak na stupanj integracije. Također pokazujemo da makroekonomski rezultati analiziranih zemalja u odnosu na eurozonu te stanje javnih financija tih zemalja značajno utječu na stupanj integracije tržišta državnih obveznica u svim zemljama.

Ključne riječi: europske posttranzicijske zemlje, tržišta državnih obveznica, integracija tržišta obveznica

JEL klasifikacija: E44, F36, G15

1. Introduction[*]

A widely accepted concept in finance is that compensation for holding a risky asset is the key determinant of assets' returns. Besides this factor, international finance usually recognizes exchange rates as a source of variation in returns, but also an additional source that explains time variation of returns on assets. This additional source is not entirely country-specific, but a feature that links the local market with the world market – the so-called level of integration into world markets. In this paper we recognize the importance of integration in interpreting variation in European post-transition bond market returns by examining sovereign bond markets integration between post-transition countries and the eurozone. We measure integration by considering excess returns of sovereign bond yields, allowing country-specific information and obtaining a parameter of integration that varies over time. Although just 25 years ago these countries experienced a devastating breakdown of their socialist economies, today they have become more or less integrated with Western European economies. This integration process however was not smooth, but it rather varied with time, affected by different global and country-specific events. The variation in financial integration in particular is detrimental for these ex-communist countries and new EU member states as they cannot opt-out to remain outside the euro area. Therefore, they must keep their long-run sovereign bond yields in line with the yields of the European core. Our results suggest that sovereign bond market integration is one of the main factors in meeting the criteria for euro adoption.

We build on the seminal work on the time-varying world market integration of Bekaert and Harvey (1995), and on Abad et al. (2014) who study government bonds specifically. As we study the effect of different events on the level of integration, our sample covers the last three EU enlargements, the Lehman Brothers collapse, sovereign debt crisis in Europe, and the stabilization period that followed. The novelty in our approach is that we track and explain changes in the level of post-transition sovereign bond market integration country by country, and corroborate our findings using country-specific measures of risk and measures that represent the state of the economy, with the public finance stance included as explanatory variable.

Bekaert and Harvey (1995) argued that the fundamental question in the study of international finance lies in the source of differing expected returns. While a typical "finance-style" answer would be that the source is in differing risk exposure, research has demonstrated that international finance hides more such sources beside risk. The difficulty in recognizing and quantifying these sources

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increases as the level of world market integration decreases (Bekaert and Harvey, 1995). In other words, it is relatively easy to explain expected returns of assets in integrated markets, but it becomes challenging when markets are less integrated or segmented; in more formal language, when their covariance with the rest of the world (or with the common market under investigation) is not enough to explain expected returns.

As markets may become integrated, segmented or stand somewhere in between, the literature offers three classes of studies, as recognized by Bekaert and Harvey (1995). The first class is represented by Capital Asset Pricing Models (CAPM) such as Sharpe (1964), Lintner (1965), and Black (1972) who propose that markets are segmented. In light of the years in which those studies were made, and the level of international finance development before the onset of capital account liberalizations in the eighties, one can understand why the research focus at the time was on market segmentation. On the other hand, literature of the late eighties and of the nineties offers studies in which perfect world capital market integration is assumed. Harvey (1991) for example explores expected returns on a portfolio of different securities of 17 countries using risk exposure as a determinant of differing expected returns. In a more elaborate style, Dumas and Solnik (1995) argue that exchange rates can be a source of risk that adds to expected returns dynamics. Dumas (1994) on the other hand uses external variables such as leading indicators of the business cycle (as found in Stock and Watson, 1993) to explain the behavior of the international stock market. There is a variety of international CAPMs made in that period that assume integration, and either accept perfect integration or reject it based on modeling results.[1]

The third strand of literature based on the work of Errunza et al. (1992) presents the mild segmentation model or the case in which there is neither perfect integration nor perfect segmentation. Although the approach set out in Errunza et al. (1992) is more realistic than the previous two approaches, the problem is that the level of segmentation/integration in those models is fixed through time. Bekaert and Harvey (1995) solve this problem by allowing the degree of integration to change over time. Their model allows for any level of integration/segmentation that lies between two extreme cases of perfect segmentation and perfect integration. In this way, their model nests cases found in the first two strands of literature, thus generalizing previous modeling approaches. Beakert and Harvey's (1995) model is a flexible version of an international financial market; flexible in the sense that the level of integration can vary between extremes and change over time. The novelty introduced in their model is that conditionally expected returns are allowed to

[1] Some of these models are presented in Solnik (1983), Cho et al. (1986), Wheatley (1988), Bekaert and Hodrick (1992), Campbell and Hamao (1992), Ferson and Harvey (1993, 1994a, 1994b), and Harvey et al. (1994).

vary with respect to their covariance with some benchmark and with respect to the variance of country returns. When the market is perfectly integrated only the covariance enters the modeling specification; when it is perfectly segmented, only the variance counts. The variance in the model depends on country-specific variables, while the covariance depends on the benchmark information. The procedure results in an integration measure that varies over time and that spans from 0 to 1 where 0 stands for perfect segmentation and 1 for perfect integration.

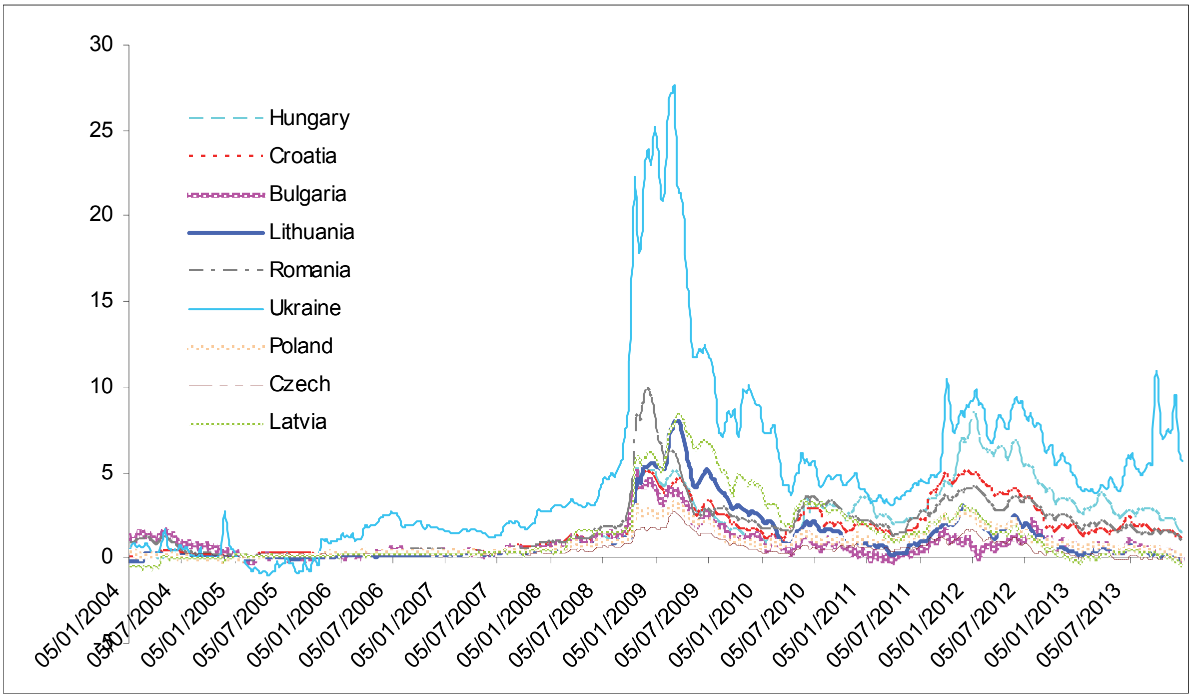
Building on the model developed by Bekaert and Harvey (1995), Barr and Priestley (2004) focus on the level of integration in world bond markets. Abad et al. (2010) follow this line of research and apply the CAP-based model on the European bond market investigating the effect of the euro introduction on the degree of integration in the EU. They then expand their work in the sense that they examine the time-varying integration of EU bond markets and compare it with the 2007 financial crisis (Abad et al., 2014). As in Bekaert and Harvey (1995) and Hardouvelis et al. (2006) they allow integration to vary with events and over time.

In this paper, we continue the work of Abad et al. (2014) by focusing on European post-transition market integration solely, and by extending our event examination research beyond the world financial crisis and the sovereign debt crisis in Europe, features unexplored in the literature. The above-mentioned paper does include three new EU member states (Poland, the Czech Republic and Hungary), but it leaves out a big number of other European post-transition countries and the specific characteristics of these markets.[2] As opposed to Abad et al. (2014), we consider eight new EU member states and one non-member – Ukraine. Moreover, as we examine the period between 2004 and 2013, we intentionally do not omit data that include the European sovereign debt crisis, and that is for three reasons. First, we believe that this event deserves a comment on the change in the level of integration. Second, our model allows for country-specific variables enabling us to study countries individually with respect to the sovereign debt crisis event. And finally, as we incorporate a measure of the state of public finance, we believe that we can detect risk that originates from the fiscal sphere. Figure 1 presents sovereign bond yield spreads over Germany for the countries explored, and from the graph we can detect major events that were reflected on the bond market. Up to the Lehman Brothers collapse in 2008, we observe relatively low spreads - a sign of convergence and stability. Tensions increased thereafter pushing up risk premia in 2008, 2010, and again in 2012. Later on we notice stabilization of yield spreads in all countries, except in war-involved Ukraine.

[2] The only other study that focuses on the three biggest European post-transition countries is Kim et al. (2006). Besides these three countries, we also explore Bulgaria, Croatia, Latvia, Lithuania, Romania, and Ukraine.

Our contribution is twofold. First, we examine changes in the level of European post-transition sovereign bond market integration country by country. And second, as we base our findings on country-specific measures of risk and measures that represent the relative state of the economy, we can discuss the dynamics of integration with respect to convergence of these countries to the benchmark. More specifically, we can for example comment the effect of the state of public finance on the level of integration and on integration dynamics.

Figure 1. Sovereign bond yield spreads over Germany (in percent; weekly data)



Source: Bank of America Merrill Lynch Bond Indices.

The aim of this paper is to study time-varying integration of European post-transition government bond markets with the German market used as benchmark, a proxy for the eurozone bond market. The result of our empirical examination is a time-varying parameter of integration that is driven by a set of "instruments" that are relative to the case of Germany. Our results suggest that integration varies with respect to economic development, as "richer" countries demonstrate a higher level of integration in the whole period. Moreover, we observe that integration decreased with the financial crisis, but it did return to previous levels relatively swiftly. For Bulgaria and Romania we can see a significant increase following their EU accession in 2007. However, data suggest the opposite for Croatia after July 2013. The latter might be either the result of economic crisis that hit Europe after 2008 or maybe we need more data to make conclusions about Croatia as we examine only a six-month period after Croatia joined the EU.

The remaining part of the paper is organized as follows. Section 2 presents how we measured integration. Section 3 describes the data and the "instruments" for the price of risk and the integration parameter. Section 4 presents the empirical results, while Section 5 concludes.

2. Measuring integration

2.1. Model

In the modeling procedure, we follow Abad et al. (2014) who analyze European government bond market integration and build their methodology on Bekaert and Harvey's (1995) CAP-based model. The model implies that expected excess returns on the local bond market depend on the covariance with the eurozone bond market and on its own variance. This idea about the nature of determinants affecting bonds' expected returns reaches back to Stehle (1977), who analyzes pricing of global versus individual stocks by modeling expected returns as a function of the covariance with the local market portfolio and of the covariance with the component of the world market portfolio which is orthogonal to the local market portfolio. Furthermore, Chan et al. (1992) in their analysis modeled conditional expected US market returns by the covariance with other countries and its own variance. In the presence of unequal integration level of local bond markets, the aim of this analysis is not to apply the proposed model for pricing individual local bonds, but to characterize the path of integration through time for each local bond market as a whole.[3]

We assume that with the information set $\Im_{t-1}$, conditional excess returns in each country *i* are generated by:

$$E_{t-1}\left(R_{i,t}\right)=\theta_{i,t}\lambda_{E,t}Cov_{t-1}\left(R_{E,t},R_{i,t}\right)+(1-\theta_{i,t})\lambda_{i,t}Var_{t-1}\left(R_{i,t}\right) \quad (1)$$

where $R_{i,t}$ is the excess return on the local sovereign bond market, $R_{E,t}$ is the excess return on the eurozone sovereign bond market, proxied by German bond market, Cov_{t-1} and Var_{t-1} are the conditional covariance and variance operators respectively, $\lambda_{E,t}$ is the eurozone price of risk and $\lambda_{i,t}$ is the price of risk for country *i*. The prices of risk, $\lambda_{E,t}$ and $\lambda_{i,t}$ will depend respectively on the exponentially weighted eurozone variables and on local macroeconomic variables of country *i.* The

[3] The model proposed by Bekaert and Harvey (1995) lacks an intercept, even though in their specification tests the intercept is incorporated.

parameter $\theta_{i,t}$ which falls in the interval [0,1] is time-varying and represents a measure of the conditional level of integration of market *i* with the eurozone bond market. The parameter $\theta_{i,t}$ takes the value 1 when markets are completely integrated, reducing equation (1) in pricing just to the covariance with the eurozone bond market. When the parameter $\theta_{i,t}$ takes the value 0, only the variance is priced.

To infer $\theta_{i,t}$ from the data, we adopt the guiding idea from Abad et al. (2014) and condition $\theta_{i,t}$ on a set of local macroeconomic variables that measure real economic integration and fiscal stance of examined countries. We assume that deviations of the information local variables from zero reduce the degree of integration, independent of their sign:

$$\theta_{i,t} = \exp\left(-\left|\alpha_{0,i} + \alpha_i' X_{i,t}\right|\right)$$

where α_i is a vector of country *i* -specific parameters and $X_{i,t}$ is a vector of country *i* -specific set of variables in $\Im_{t-1}$. The functional form $\exp\left(-\left|\cdot\right|\right)$ constrains the parameter $\theta_{i,t}$ between zero and one.

In order to infer the time-varying local price of risk $\lambda_{i,t}$ from data, we let the local price of risk to be a function of local financial variables:

$$\lambda_{i,t} = \exp\left(-\left|\beta_{0,i} + \beta_i' Z_{i,t}\right|\right),$$

where β_i is a vector of coefficients for each country *i*, and Z_i represents a set of local financial variables.

The estimation procedure is divided into several steps. First we model the conditional variance of the excess return on the eurozone bond market $R_{E,t}$ with a univariate GARCH(1,1) model (Bollerslev 1986; Taylor, 2008) with conditional mean zero:

$$\begin{aligned} R_{E,t} &= Y_t \cdot \sigma_t, \\ \sigma_t^2 &= \omega + \alpha \cdot R_{E,t-1}^2 + \beta \cdot \sigma_{t-1}^2, \end{aligned} \qquad (2)$$

where Y_t are independent and identically distributed standard normal random variables and provided that $\omega > 0$ and $\alpha + \beta < 1$ in order to assure stationarity of the unconditional variance process.

Second, we model the excess return of the eurozone government's bond portfolio by a nonlinear regression

$$E_{t-1}\left(R_{E,t}\right) = \lambda_{E,t} Var_{t-1}\left(R_{E,t}\right) \quad (3)$$

where the estimated conditional variance process σ_{t-1}^2 from the previous step is used for the conditional variance of the excess return $R_{E,t}$. Moreover, following Bekaert and Harvey (1995) and Abad et al. (2014) the eurozone price risk $\lambda_{E,t}$ is modeled as a function of a set of information variables:

$$\lambda_{E,t} = \exp\left(-\left|\beta_{0,E} + \beta_E' Z_{E,t}\right|\right),$$

where β_E is a vector of coefficients and Z_E represents eurozone information variables. From this estimation procedure, we obtain the estimated values for the eurozone government bond market price of risk.

Third, let $R_t^i = \left[R_{E,t}, \quad R_{i,t}\right]^T$ be the vector of excess returns $R_{E,t}$ and $R_{i,t}$, for each country *i*=1,…,9, and define e_t^i as the disturbance vector.

To infer the parameters $\theta_{i,t}$ and $\lambda_{i,t}$ for each country *i* from the nonlinear regression equation (1), we model the conditional covariance matrix with a bivariate diagonal BEKK (1,1) GARCH model proposed by Engle and Kroner (1995):

$$R_t^i = e_t^i = \Sigma_{i,t}^{1/2} z_t^i,$$

$$\sum_{i,t} = C_i' C_i + A_i' e_{t-1} e_{t-1}' A_i + G_i' \sum_{i,t-1} G_i \quad (4)$$

where for each country *i,* C_i is a (2x2) upper triangular matrix and A_i and G_i are (2x2) diagonal matrices and we assume that the two-dimensional random vector z_t^i has the following two moments: $E(z_t^i)=0$ and $Var(z_t^i)=I_2$, I_2 being the identity matrix of order two.

An advantage of this model of conditional variances is that it guarantees positive definite conditional variance matrices under weak conditions. Furthermore, the model imposes restrictions across equations consequently reducing the generality and number of parameters relative to other multivariate GARCH models. For the model parameters estimation, we use the Quasi-Maximum Likelihood method, since as shown by Bollerslev and Wooldridge (1992), the standard errors calculated using this method are robust even when the normality assumption is violated. For each country *i*, *i*=1,…,9, we estimate the relevant variance-covariance elements from equation (4).

Fourth, we impose the results on the individual countries from the third step and the estimated eurozone government bond market price of risk from the second step in *N*=9 bivariate nonlinear regressions given by (1). In that respect, we restrict the estimates of the eurozone government bond market price of risk $\lambda_{E,t}$ and of the coefficients in the conditional variance of the eurozone market $Var_{t-1}(R_{E,t})$ from equation (3) to be the same in all countries. Once these estimates are imposed in each of the *N*=9 nonlinear bivariate regressions, we infer the time-varying level of integration $\theta_{i,t}$ for each country *i*, and the vector of estimated coefficients for the local price of risk $\lambda_{i,t}$.[4]

3. Data

3.1. Excess returns – price of risk

In order to estimate equation (1) and obtain the time-varying degree of sovereign bond market integration we use Bank of America Merrill Lynch government bond yields collected from Bloomberg. Our sample includes nine post-transition European economies: Bulgaria, Croatia, Czech Republic, Hungary, Latvia, Lithuania, Poland, Romania, and Ukraine. Regrettably, weekly bond yield data for other post-transition European countries were not available, which limited our analysis to the aforementioned countries. Our model includes eight EU member states that joined EU in three enlargement rounds (Czech Republic, Hungary, Latvia, Lithuania, Poland joined in May 2004,

[4] A disadvantage of this procedure is that we ignore the sampling error from the parameter estimation from the second step.

Romania and Bulgaria in January 2007, and Croatia in July 2013) and one non-EU member state (Ukraine). One country (Latvia) is also an EMU member state, while another (Lithuania) was in Exchange rate mechanism II in the period examined, and it adopted the common currency on January 1st, 2015. For all countries except the Czech Republic data cover the period from the first week of 2014 to the last week of 2013. In the case of the Czech Republic, the start date is the 29th week of 2004.

The excess bond return series (the dependent variable in equation (1)) is calculated relative to the 10-year German government bond. Thereby the excess return is defined as the difference of log-differences of government bond yields for the country examined and log-differences of bond yields for 10-year German government bonds. Excess returns for German government bonds were calculated in the same fashion, but using the overnight EURIBOR rate as benchmark. Weekly returns were calculated by taking averages of daily data. Using weekly instead of daily frequencies diminishes the problem of non-synchronous data, which is caused in instances when on certain days markets are closed in one country and open in another (Burns and Engle, 1998; Lo and MacKinlay, 1990).

3.2. Instruments for the price of risk

Following Abad et al. (2010; 2014) we use 1) lagged stock indexes returns and 2) the difference between lagged 10-year Government returns and lagged stock index returns in order to capture the differences in prices of risk on bond markets in individual countries. We must however note that Abad et al. (2010; 2014) use two additional variables as instruments for the price of risk of individual countries in their estimation: the slope of the yield curve, as measured by the difference between the 10-year and the 3-year government bond yield, and the difference between lagged corporate bond returns and 10-year government returns. Due to the fact that bond markets in emerging countries under examination are underdeveloped relative to core European countries, the data for the two latter instruments are not available, and thus could not be included into estimation.

The same indicators are used as instruments for European bond market risk. Since we proxy eurozone bond market with German indicators, we take lagged German stock indexes returns and the difference between lagged 10-year German government bond returns and lagged German stock index returns as “instruments” for regional price of risk. More detailed explanation of these variables and their sources can be found in Table A.1 of the Appendix.

3.3. Instruments for the time-varying integration parameter

The instruments by which we condition the degree of integration are either defined as relative to Germany or they represent deterioration or improvement of the fiscal position of the country. In the first group we use two variables: industrial production relative to Germany and export competitiveness relative to Germany. In the second group we experiment with the growth rate of the share of public debt in GDP.

The argumentation for using the first group of instruments, the ones relative to Germany, is straightforward as the negative values of instruments would suggest segmentation, while higher or positive values would suggest an increase in real economic integration which should be followed by increasing financial integration. Regarding fiscal position our intention was to capture the fiscal position of a country as it is one of the main determinants of perceived country risk that directly affects government bond returns. Due to that we use public debt/GDP growth rate as representation of country's improvement in fiscal position (when the instrument is low or negative suggesting slow relative public debt accumulation) or deterioration (when the instrument is high representing fast relative public debt accumulation). Although the literature often suggests using public debt/GDP differential relative to Germany (as is the case with the first two macroeconomic instruments), we find this line of thought misguided. The problem is that Germany has very high public debt to GDP ratio, in almost all cases high above the figure for specific countries explored here[5], so the difference in public debt to GDP ratios would not reflect true integration or segmentation but merely higher public indebtedness. We believe that true integration is not in catching up with German indebtedness, but on the contrary in reaching a sustainable share of public debt in GDP away from the one recorded for Germany and closer to the Maastricht criterion of 60% of GDP[6].

The first two instruments are fairly represented in literature (Abad et al., 2014; Mody, 2009), but we have noticed that despite the fact that a great number of countries is going through fiscal difficulties, the connection between fiscal position, excess returns and sovereign bond market integration is not explored[7]. There is research between the first two concepts (Mody, 2009), but the last link, the one with market integration is missing. Therefore we introduce a measure of potential fiscal deterioration and improvement in order to incorporate the fact that countries with higher debt levels

[5] The only exception is Hungary with its 79.3% of public debt in GDP recorded at the end of 2013.
[6] More detailed explanations for the instruments can be found in the Appendix A.2.
[7] Abad et al. (2014) do model public debt to GDP ratio but they construct it relative to Germany. This approach provides misleading results as all countries would indicate integration as all of them have lower relative debt levels when compared to Germany.

that further increase it are penalized on the international market. The other way to interpret this variable is in the context of economic growth prospects that decrease as this variable rises. In the light of equation (1) this would imply higher integration for rising public debt to GDP ratio so there are challenges in the exact interpretation of this variable where one must be cautious[8].

3.4. Descriptive statistics

Table 1 reports descriptive statistics on weekly government bond yields for nine post-transition countries and Germany. German government yield is characterized by the lowest mean and standard deviation, while the highest mean and standard deviation is recorded for Ukraine. Among new EU member states Czech Republic, Poland and Bulgaria have the lowest mean yield values, although Bulgarian yield changes are much more volatile when compared to the remaining two countries. On the other hand, Hungary, Romania, Croatia and Latvia have significantly larger mean yield values, especially when compared to the Czech Republic, with Latvian yield being considerably more volatile when compared to other EU member states. As expected, the Ljung-Box test indicates the presence of autocorrelation in yield series, while ARCH test suggests that the volatility in yields varies over time.

Table 1. Descriptive statistics on weekly government bond indices (in percent)

Country	**Mean**	**Standard deviation**	**Skewness**	**Excess kurtosis**	**Q(20)**	**ARCH(20)**
Germany	3.132	0.963	-0.527 [0.000]	-0.966 [0.000]	8940.0 [0.000]	3011.1 [0.000]
Bulgaria	3.980	1.322	0.594 [0.000]	0.245 [0.251]	8447.6 [0.000]	1719.6 [0.000]
Croatia	4.654	1.138	0.848 [0.000]	0.519 [0.015]	7287.3 [0.000]	1842.1 [0.000]
Czech Republic	3.601	1.045	-0.548 [0.000]	-0.410 [0.061]	8380.8 [0.000]	2629.5 [0.000]
Hungary	4.976	1.410	1.282 [0.000]	1.274 [0.000]	6961.4 [0.000]	1101.4 [0.000]
Latvia	4.502	2.076	1.177 [0.000]	1.543 [0.000]	8696.3 [0.000]	2746.4 [0.000]
Lithuania	4.256	1.699	1.510 [0.000]	3.133 [0.000]	8191.1 [0.000]	3045.5 [0.000]
Poland	3.976	0.992	-0.202 [0.059]	0.034 [0.873]	8357.7 [0.000]	2088.2 [0.000]
Romania	4.853	1.552	2.483 [0.000]	8.751 [0.000]	6389.8 [0.000]	1508.0 [0.000]
Ukraine	8.079	5.034	2.392 [0.000]	6.287 [0.000]	7193.1 [0.000]	1129.1 [0.000]

Note: Q(20) is the Ljung-Box test for twentieth order serial correlation. ARCH(20) is Engle's test for twentieth order ARCH, distributed as chi-square distribution with 20 degrees of freedom. *p*-values in brackets.

[8] Pagano and von Thadden (2004) emphasize this dilemma. We comment this difficulty with respect to the model we use in the Appendix A.2.

4. Results

As a first step in our modeling exercise, we need to estimate the univariate GARCH (1,1) model of excess returns on German government bonds (equation 2) in order to obtain the conditional variance of those returns. Table 2 presents model estimates and diagnostics, while Figure 2 displays the obtained conditional variance of German excess returns. This variance is subsequently used as an explanatory variable in the second step of our exercise.

Results for the GARCH (1,1) variance equation reported in Table 2 suggest that the first three coefficients ω (constant), ARCH term (α) and GARCH term (β) are statistically significant and exhibit the expected sign. The significance of α and β indicates that lagged conditional variance and lagged squared disturbance have an impact on the conditional variance, which in turn suggests that volatility in excess returns on German government bonds from the previous period explains current volatility. As the sum of GARCH and ARCH terms in the variance equation is lower than unity (0.9945), the conditional variance process is stable, although we can note that volatility shocks do seem quite persistent.

Conditional variance of German government bond excess return displayed in Figure 2 behaves in the expected way. It spiked in four distinctive time periods: the first one immediately after the collapse of Lehman Brothers in September 2008, and then again in late 2010 and 2011, and once again in the summer months of 2012 due to the European debt crisis. One can also observe that the conditional variance of the German government bond excess return at the end of our sample (the end of 2013) is still considerably large when compared to the pre-crisis period.

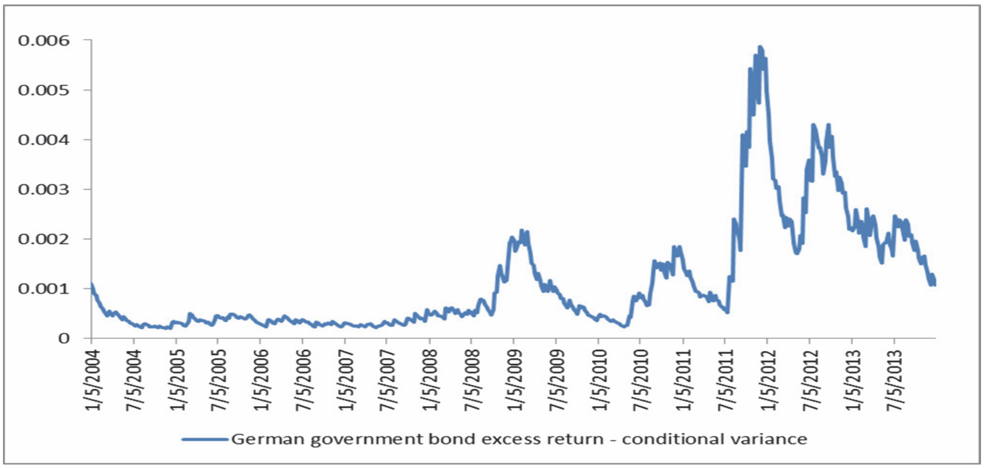
Table 2. GARCH (1,1) model of the German government bond excess return

	GARCH (1,1) coefficients
Mean equation	
μ	-0.0005
Variance equation	
ω	0.0965*
α	0.1114 ***
β	0.8831***
Log likelihood	1148.14
ARCH test	0.8754 [0.4173]
Jarque-Bera test	8.4943 [0.0143]

Note: *p*-values in parentheses, ***denotes significance at the 1% level, ** at 5% level, * at 10% level.

Source: calculation of the authors.

Figure 2. Conditional variance of the excess return of German government bond



Source: calculation of the authors.

We proceed by estimating excess returns on eurozone government's bond portfolio ($R_{E,t}$) described by equation (3). Thereby, the conditional variance of excess returns on German government bonds obtained in the previous step is used as a proxy for eurozone conditional variance, while $\lambda_{E,t}$ (representing the eurozone price of risk proxied by two instruments for the German price of risk) is plugged into equation (3) and estimated therein. This in turn means that we only need to estimate the two instruments from the $\lambda_{E,t}$ term, as all other model variables in equation (3) are known. The model is estimated using Quasi-Maximum Likelihood method.

Estimation results are presented in the first two rows of Table 3. As one can observe from the table, the constant ($\beta_{0,E}$) and two proxies for the eurozone price of risk – lagged German stock market returns ($\beta_{1,E}$) and lagged difference between German stock market and bond market returns ($\beta_{2,E}$) – are all statistically significant. Since they serve as a proxy for eurozone government bond market price of risk, they will be imposed on equation (1) in the final stage of the estimation, when the excess return on post-transition government bonds ($R_{i,t}$) is estimated.

In addition, before estimating equation (1), we also need to obtain the conditional variances of excess returns on post-transition government bonds, as well as conditional covariances between excess returns on German and post-transition government bonds. As already stated in the Methodology section, for that purpose we use a bivariate diagonal BEKK (1,1) GARCH model, whose estimation results are presented in the last five columns of Table 3. As one can verify from the table, diagonal elements in A and B matrices are significant for all countries, as is the C_{11} element of the upper triangular C matrix.

After deriving all necessary components for equation (1) and imposing a restriction regarding eurozone price of risk, we proceed by estimating equation (1) using Quasi-Maximum Likelihood method for government bond markets of each of the post-transition countries. The first four columns of Table 3 represent coefficient estimates of constant and instruments for the degree of bond market integration from term $\theta_{i,t}$, while the subsequent three columns represent the coefficient estimates of country-specific instruments for the price of risk from the term $\lambda_{i,t}$. As one can note from the table, variables capturing country-specific price of risk are significant in all countries except for Ukraine, where stock returns do not seem to influence local price of risk. At the same time, the export competitiveness of post-transition economies relative to Germany is relevant for explaining the time-varying degree of government bond market integration in all countries. Moreover, changes in the pace of industrial production relative to Germany influence the degree of integration in all countries except in Bulgaria and Hungary, while the share of public debt in GDP drives the integration process in all countries except in Latvia.

Mean values of the integration parameter for the entire analyzed period vary considerably across countries. Czech Republic and Poland, as the two most developed post-transition countries with strong trade ties with core European countries, achieve the highest level of sovereign bond market integration relative to the eurozone. Their mean average integration parameter in the 2004-2013 period reached 0.73 and 0.72 respectively. Two Baltic countries (Latvia and Lithuania), Romania and Hungary exhibited lower mean level of sovereign bond market integration when compared to the Czech Republic and Poland and revolved around 0.5 (0.54 for Lithuania, 0.53 for Latvia and Romania, and 0.51 for Hungary). Even more segmented are Croatian and Bulgarian government bond markets, whose average integration parameter stood at 0.32 and 0.22 respectively. As expected, the Ukrainian market is the most segmented among analyzed government bond markets (its integration parameter is equal to 0.13).

Table 3. Model estimates

$$E_{t-1}(R_{i,t}) = \theta_{i,t}\lambda_{E,t}Cov_{t-1}(R_{E,t}, R_{i,t}) + (1-\theta_{i,t})\lambda_{i,t}Var_{t-1}(R_{i,t})$$
$$\theta_{i,t} = \exp\left(-\left|\alpha_{0,i} + \alpha_i' X_{i,t}\right|\right)$$
$$\lambda_{i,t} = \exp\left(-\left|\beta_{0,i} + \beta_i' Z_{i,t}\right|\right)$$
$$E_{t-1}(R_{E,t}) = \lambda_{E,t}Var_{t-1}(R_{E,t})$$
$$\lambda_{E,t} = \exp\left(-\left|\beta_{0,E} + \beta_E' Z_{E,t}\right|\right)$$
$$R_t^i = e_t^i = \Sigma_{i,t}^{1/2} z_t^i;\ \sum\nolimits_{i,t} = C_i' C_i + A_i' e_{t-1} e_{t-1}' A_i + G_i' \sum\nolimits_{i,t-1} G_i$$

	$\beta_{0,E}$	$\beta_{1,E}$	$\beta_{2,E}$									
Eurozone	1.208***	20.582**	44.595***									
	$\alpha_{0,i}$	$\alpha_{1,i}$	$\alpha_{2,i}$	$\alpha_{3,i}$	$\beta_{0,i}$	$\beta_{1,i}$	$\beta_{2,i}$	C11	C12	C22	A22	G22
Bulgaria	-2.6567	2.0185	-6.6485*	3.0224*	0.9911***	37.20***	51.754***	0.0033***	-0.00167	0.00008	-0.936***	0.3533*
Croatia	-4.98012	10.074***	-14.849**	-4.510***	1.6596***	46.7296***	57.223***	0.0062***	-0.0009	0.0022	0.9173***	0.3983**
Czech Rep.	-0.790	-14.781***	0.3959***	2.0240***	2.6865***	-15.946**	40.088***	0.00478*	-0.00008	0.00082	0.9363***	0.3513***
Hungary	-4.1646**	-7.0281	4.2186**	5.2966***	1.2303***	12.477*	28.347***	0.0041***	-0.00044	0.00251*	0.8494***	0.5278***
Lithuania	-1.000	-4.8505***	1.7808***	-2.946***	-4.6439	143.346***	184.513***	0.0060***	-0.0003	0.00097**	0.9271***	0.3750**
Latvia	0.2378*	-10.429*	4.5021*	0.4961	1.3561***	36.238***	43.517***	0.00397***	0.00025	0.01268	0.7764**	0.6302**
Poland	0.54004*	-5.0713**	7.8970**	2.1681**	2.4867***	-31.874***	25.278***	0.00882***	-0.0009*	0.0020*	0.8733***	0.4872***
Romania	1.6455**	-6.2661**	7.6169**	1.4191**	2.3207***	-22.651**	8.041**	0.00519***	-0.001**	0.00152**	0.9329***	0.360***
Ukraine	8.4497**	-81.850**	-12.835*	-6.2629**	0.5094**	0.1305	23.816***	0.0029***	-0.00954	0.0001	-0.946***	-0.3234***

Note: ***denotes significance at the 1% level, ** at 5% level, * at 10% level.
Source: calculation of the authors.

The analytical breakdown of the relationship between macroeconomic variables and the value of the integration parameter is presented in the Appendix A.2, where we present 3D plots which enable us to discern the value of the integration parameter for various scenarios related to three macroeconomic instruments of integration. However, exact values of integration parameter for different subperiods are obtained when data for macroeconomic instruments are multiplied by appropriate $\alpha_{1,i}$, $\alpha_{2,i}$, and $\alpha_{3,i}$ estimates and added to the constant $\alpha_{0,i}$. Average integration parameters for the entire period and relevant subperiods are presented in Table 4.

Table 4. Estimated values of time-varying integration parameter $\theta_{i,t}$

	Bulgaria	Croatia	Czech* Republic	Hungary	Latvia	Lithuania	Poland	Romania	Ukraine
Total period	**0.22**	**0.32**	**0.73**	**0.51**	**0.53**	**0.54**	**0.72**	**0.53**	**0.13**
2004-2005	0.00	0.27	0.82	0.47	0.51	0.65	0.52	0.45	0.09
2006-2007	0.02	0.06	0.64	0.37	0.27	0.56	0.71	0.39	0.32
2008-2009	0.16	0.10	0.65	0.37	0.57	0.35	0.75	0.54	0.12
2010-2011	0.35	0.50	0.80	0.63	0.52	0.46	0.78	0.51	0.12
2012-2013	0.56	0.66	0.75	0.72	0.79	0.68	0.81	0.75	0.00
Before joining EU	0.04	0.74	0.41	0.33	0.44	0.51	0.34	0.36	-
After joining EU	0.00	0.42	0.40	0.57	0.60	0.63	0.33	0.31	-
Before joining EMRII	-	-	-	-	0.58	0.43	-	-	-
After joining EMRII	-	-	-	-	0.41	0.67	-	-	-

*As data for the Czech Republic are not available before the 29th week of 2004, the time-varying integration parameter for the period prior to the start of the data range was calculated using estimates from macroeconomic instruments from $\theta_{i,t}$ term available after the 29th week of 2004.

Source: calculation of the authors.

When compared to Abad et al. (2014), our integration parameter estimates for the Czech Republic, Poland and Hungary are higher, but due to the fact that our data sample covers four additional years and due to the usage of different macroeconomic instruments for time-varying sovereign bond market integration, the two sets of results are not completely comparable.

The evolution of the sovereign bond market integration process over time also reveals interesting findings. The level of integration of all new member states increased during the observed period, although often not in a straightforward way. The only exception is the Czech bond market that was equally integrated around the time of EU accession and in the last observed subperiod (2012-2013). On the other hand, Ukraine is exhibiting the opposite trend. Until the end of 2007 its segmentation was somewhat reduced, but from 2008 onwards that trend reversed and its sovereign bond market has become increasingly segmented. Not surprisingly, in the last observed subperiod the Ukrainian market was completely segmented from the eurozone market.

Variations in the value of the integration parameter across subperiods suggest that the integration of sovereign bond markets in new member states gained strong momentum after 2010, even though that time period partially coincides with the European debt crisis. We feel that increased integration in the last four years is a combined outcome of strong economic performance of new member states and very loose monetary policies employed by several large economies around the globe.

Our results also enable us to observe the short-run effects that joining the EU and the EMRII had exhibited on the integration of sovereign bond market. As evident from Table 4, in some member states like Hungary, Latvia and Lithuania, joining the EU boosted sovereign bond market integration, as the average degree of integration after joining increased when compared to four months prior to joining. EU accession in the Czech Republic, Bulgaria and Romania did not have an impact on the bond market integration, while in the case of Croatia EU accession decreased the level of integration.[9] During the observed period only two countries entered the EMRII: Latvia and Lithuania. Lithuania joined in June 2004, while Latvia followed suit in May 2005, although with different outcomes with regards to sovereign bond market integration. During four months after entering EMRII, sovereign bond market integration in Lithuania increased relative to four months prior to the entry. On the other hand, EMRII entry had the opposite short-run impact on the integration level in Latvia, although over the longer horizon the integration level in Latvia did rise and it peaked just before that country adopted the common currency in January 2014.

5. Concluding remarks

A quarter of a century has passed since the fall of the Berlin Wall and the collapse of the communist regimes in Central and South-eastern Europe countries. Looking from today´s perspective at that pivotal moment in European history which permanently changed the political and economic make-up of Europe, it is safe to conclude that countries of the ex-Eastern bloc have indeed come a long way. Just 25 years ago they were completely economically isolated from Western European countries.

[9] One must note that Croatia joined EU in dramatically changed economic conditions when compared to other new member states. At the time of accession the Croatian economy was already five years in recession, growth prospects of several large core European economies were bleak, and enlargement fatigue was already very much present in the narrative of the European Commission and the richest EU member states, which might have dampened bond market sentiment and expectations.

Moreover, they were facing devastating consequences of the meltdown of their socialist economies. Yet today they are witnessing rapid economic development and increasing economic and financial integration with Western European economies. However, the integration path of ex-communist countries can hardly be characterized as smooth. Transforming the economy from one economic system to another in such a short time period is bound to have its share of challenges and pitfalls. But when we compare these economies today and 25 years ago, it is clear that the effort invested in transformation and creation of a single and integrated European economic space benefited all stakeholders.

This paper examines one aspect of economic integration of ex-communist and post-transition countries. More specifically, it investigates a facet of financial integration - sovereign bond markets integration between post-transition countries and the eurozone. It concludes that these markets are still quite segmented, but their segmentation is diminishing over time. Sovereign bond markets of post-transition countries such as Poland and the Czech Republic, which achieved greater economic development and deeper real economic integration with the EU, exhibit the highest integration with the eurozone. Countries that lag behind Poland and the Czech Republic in economic terms, exhibit lower sovereign bond market integration. In the paper we also show that macroeconomic performance relative to the eurozone benchmark and fiscal stance also matter greatly for bond market integration. It thus turns out that post-transition sovereign bond markets become more segmented and their bonds become less substitutable for eurozone bonds if post-transition governments are on the borrowing spree. In line with what one would expect, investors can recognize a deteriorating fiscal stance of an economy and will price its sovereign bonds accordingly. A balanced path to real economic integration with the eurozone also seems to matter for sovereign bond market integration. If a country is able to improve its economic structure (in terms of expanding the manufacturing sector relative to Germany) and competitiveness (in terms of strengthening export performance relative to Germany) in a balanced way, domestic risk factors become less important for explaining excess bond returns relative to eurozone factors, and as a result post-transition sovereign bond markets become more integrated.

The importance of political commitment towards the process of European economic integration is clearly visible when one compares the time-varying level of integration for Ukraine and new EU member states. Although the estimated level of Ukrainian sovereign bond market integration was meager throughout most of the observed period, it is worth emphasizing that it had a completely diverging trend when compared to other post-transition countries that were fully committed to EU integration. Whereas all new member states have increased their sovereign bond market integration over time, the integration of the Ukrainian market steadily diminished and by the 2012-2013 period it was completely dissolved.

The results of this study have several important implications. First, despite the intensive integration process, the study clearly shows that post-transition sovereign bonds can still be considered as imperfect substitutes due to differences in their domestic risk factors (either market liquidity or default risk). Investors can therefore use these bonds for diversification purposes. Second, our results suggest that real and financial integration are inseparable, which in turn suggests that financial integration is a likely outcome if all necessary market reforms are undertaken. Third, as all new EU member states cannot opt-out to remain outside the euro area, they must closely watch their sovereign bond market developments. As low long-run sovereign bond yields[10] are one of five Maastricht criteria a member state must satisfy in order to adopt the euro, the time-varying nature of sovereign bond market integration can present a challenge when attempting to meet the criteria. The lower the integration level, the more likely is the chance that the country will fail to fulfil the sovereign yield target that also changes over time. Moreover, by the time the country adopts the euro, its sovereign bond market should achieve high degree of integration with the eurozone. The Latvian case shows that this is indeed possible. However, this does not suggest that after the adoption, the integration level will remain high. The results of this paper and factual evidence observed during the European debt crisis clearly show that real economic developments influence and condition sovereign bond market developments and integration.

[10] Sovereign bond yield should be no more than 2.0 percent points higher than the unweighted arithmetic average of the similar 10-year sovereign bond yields in the three EU member states with the lowest HICP inflation.

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APPENDIX

A.1. Data and variable information

Variable	*Description*	*Source*
Yield	Government bond yields. Data are generic and on a daily basis but have been transformed into weekly frequency using simple averages.	Bank of America Merrill Lynch Bond Indices and author's calculation
Return	Returns are modeled as excess returns where excess return is defined as the difference of log differences of government bond yields for the country examined and log differences of bond yields for 10-year German government bonds. Returns are calculated on a weekly frequency.	Author's calculation
Stock	Stock index return	Bloomberg database and author´s calculation
Difference	Difference between lagged government bond returns and lagged stock index returns	Bloomberg database and author´s calculation
Industrial production	Industrial production is compiled on a monthly basis and has been seasonally adjusted using ARIMAX12 and EViews. In order to obtain weekly data, industrial production has been linearly interpolated.	Eurostat and IMF International Financial Statistics for Ukraine
Industry	Industrial production relative to Germany is defined as industrial production for the country examined divided by industrial production for Germany minus 1.	Author's calculation
Competitiveness	Competitiveness is defined as share of exports in GDP. Data for exports are compiled on a monthly basis and for GDP on a quarterly basis. Due to that, both time series have been seasonally adjusted using ARIMAX12 and EViews. In order to obtain weekly data, both exports and GDP have been linearly interpolated.	Exports for all countries except for Germany have been obtained from WIIW database. Exports for Germany have been obtained from national statistics. GDP has been obtained from Eurostat, except for IMF International Financial Statistics for Ukraine.

Compete	Competitiveness relative to Germany is defined as competitiveness for the country examined divided by competitiveness for Germany minus 1.	Author's calculation
Fiscal	Fiscal position is defined as the week-on-week growth rate of the share of general government consolidated gross debt in GDP. Data are provided on a quarterly frequency so they have been linearly interpolated to obtain weekly frequency.	Public debt has been obtained from Eurostat and IMF World Economic Outlook Database for Ukraine. GDP has been obtained from Eurostat, except for IMF International Financial Statistics for Ukraine.

A.2. Instruments for the time-varying integration parameter in detail

We claim that there are domestic factors which, when compared to the benchmark, can add to the construction and explanation of the integration parameter level and dynamics. Specifically, industrial production relative to Germany reflects the business cycle and the growth potential. It is evident that the higher this indicator, the higher the integration parameter. Moreover, one would expect lower excess returns for countries that have a strong growth potential, suggesting higher market integration of these countries. Similar goes for our competitiveness measure as presented by the export share relative to Germany. Competitiveness is a synonym for financial stability of a country and it would imply its greater integration.

Since our fiscal position variable is constructed as a growth rate and not as difference, there exist four different interpretations of the fiscal position variable and the accompanying integration parameter. In the first case, a situation in which a country with a high public debt to GDP ratio depicts an increase in the share of public debt to GDP is interpreted as fiscal deterioration, and in line with that also as market segmentation. However, due to the construction of the integration parameter, an increase in the variable leads to a higher integration parameter so one must be careful when making conclusions. The other case is the one in which a country with a low public debt to GDP ratio depicts an increase in the share of public debt to GDP. This is interpreted as fiscally neutral, so there should be no consequences or only positive consequences for integration. The case in which public debt to GDP decreases in a country with high relative level of public debt is interpreted as fiscal improvement so the integration parameter should suggest an increase in integration although the parameter itself could suggest segmentation due to its construction. And finally, the case of low relative public debt and its further decrease would be correctly interpreted as segmentation as the lack of securities isolates the country from the international market. To sum up, the integration parameter suggests logical conclusions for countries that have low relative public debt but is counterintuitive for countries with high relative public debt such as Croatia and Hungary.

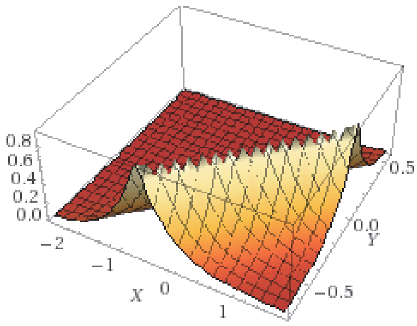
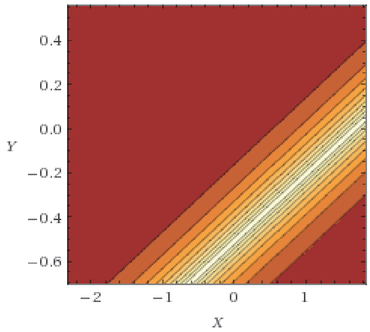
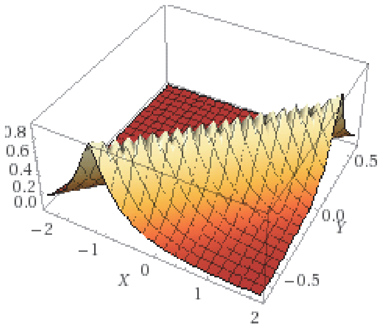
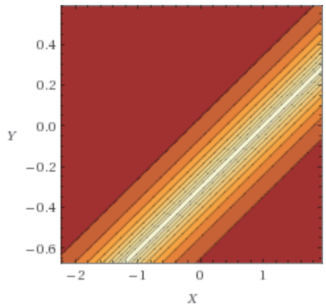
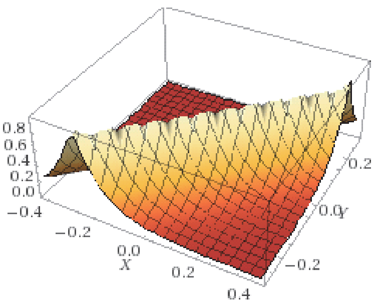
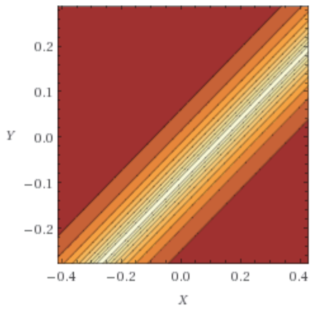
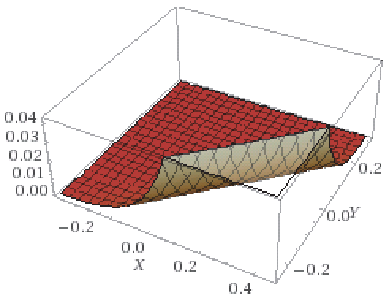
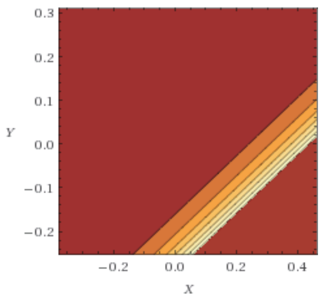
In order to simplify the interpretation of the integration parameter, we have constructed 3D and contour plots. Plots and derivations were made using WolframAlpha computational knowledge engine. The plots are presented below and they suggest how the integration parameter changes when each of the three instruments change. As it is only possible to construct a 3D plot, we have decided to use minimal and maximal values of the growth rate of debt to GDP ratio in order to mimic the movements in the three-instrument case.[11] Therefore, the obtained plots depict the evolution of the integration parameter $\theta_{i,t}$ for changes in competitiveness position and industrial position relative to Germany in two distinct fiscal situations. Although the plots differ from one country to the other, some commonalities do emerge. According to the color patterns depicted by the contour plots of all EU member states except Hungary, the integration parameter $\theta_{i,t}$ increases as both industrial production and export performance relative to Germany increase. Moreover, the integration parameter remains high as long as the economy is on the balanced path. By "balanced path" we understand a situation in which stronger industrial growth relative to Germany is accompanied by a proportional increase in export performance relative to Germany.[12] One must note that contour plots for Ukraine are characterized by completely different patterns, suggesting that the integration of the Ukrainian sovereign bond market behaves differently in response to changes in industrial and export performance. This finding should not come as a surprise taking into consideration the level of economic development of Ukraine, the absence of stronger economic cooperation with the EU, and frequent periods of political instability.

From the 3D plots one can also notice that the highest possible value of integration parameter is different for two distinct fiscal situations. If we derive equation (1) using the highest sample value of public debt change for individual countries, integration parameters are generally lower when compared to the situation in which the lowest sample values of public debt change for the same purpose. The only exceptions among the analyzed countries are: Bulgaria, where we see no discernible difference between the maximal attainable values of integration parameter in two fiscal states, and the Czech Republic for which integration parameters can achieve higher values if public debt changes are maximal. This finding clearly indicates that sovereign bond market segmentation in the majority of post-transition European countries gains strength as governments of these countries step up the intensity of public borrowing.

[11] We thank Ivan Zilic for drawing attention to the complexness of the theta interpretation and for suggesting deriving the expression using the above-mentioned engine.

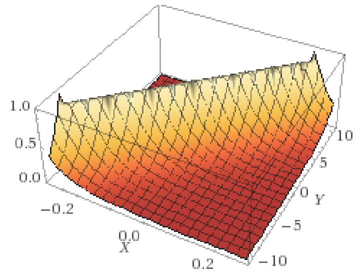
[12] However, this mechanism works both ways: even if industrial performance relative to Germany weakens, the integration parameter will remain high as long as export performance also weakens in comparison to German export performance.

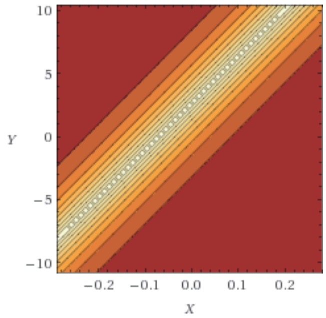
3D and contour plots for interpreting the integration parameter in the three-instrument case

Country	*3D plot*	*Contour plot*
Bulgaria		
Minimal "fiscal"		
Maximal "fiscal"		
Croatia		
Minimal "fiscal"		
Maximal "fiscal"		

Czech Republic

Minimal “fiscal”





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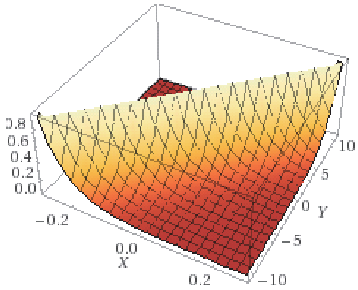
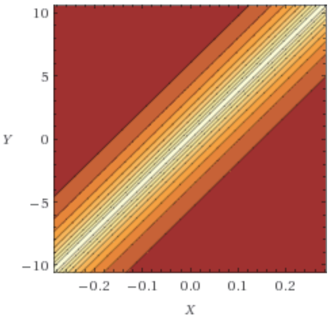
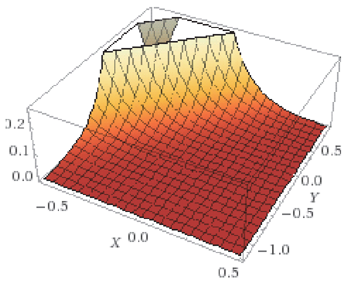
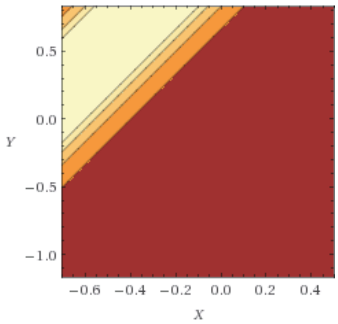




Hungary

Minimal “fiscal”





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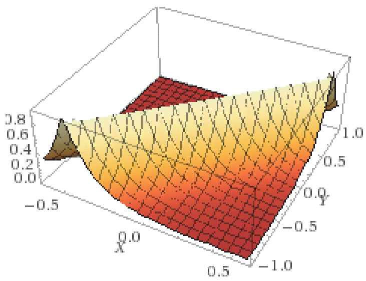
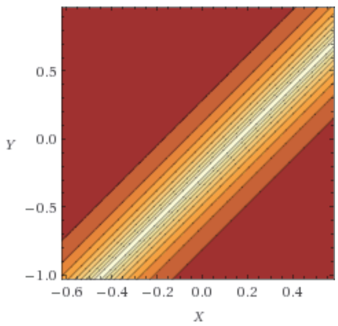
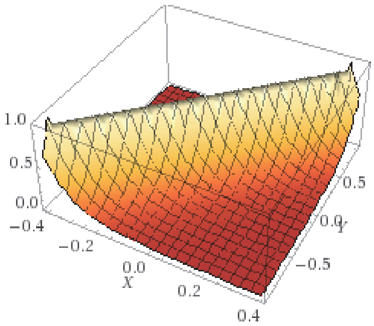
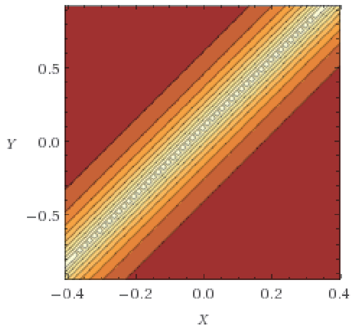




Latvia

Minimal “fiscal”





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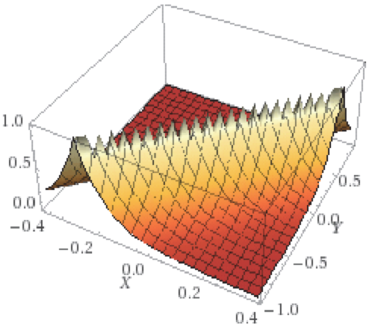
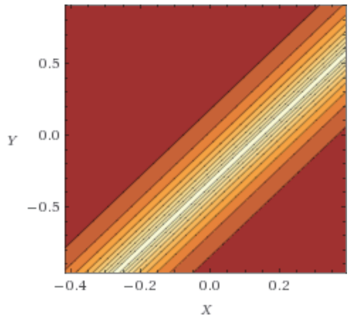
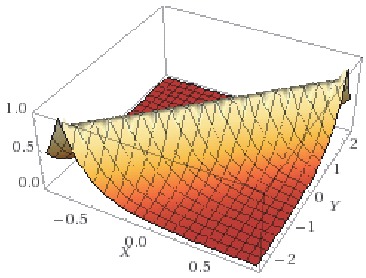
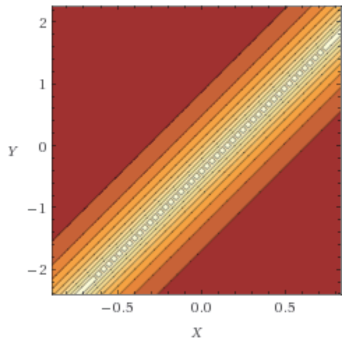




Lithuania

Minimal “fiscal”





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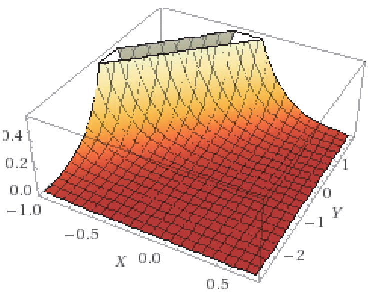
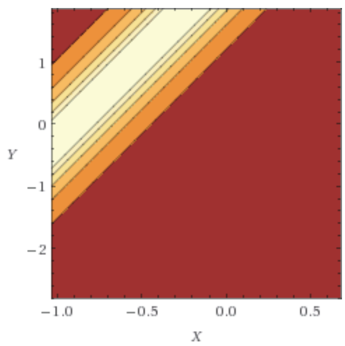
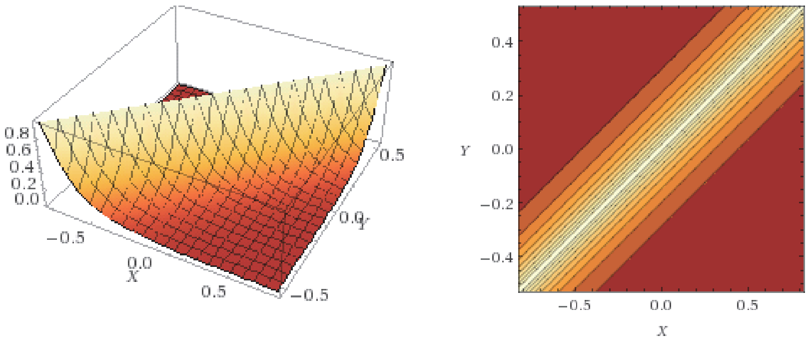




Poland

Minimal “fiscal”



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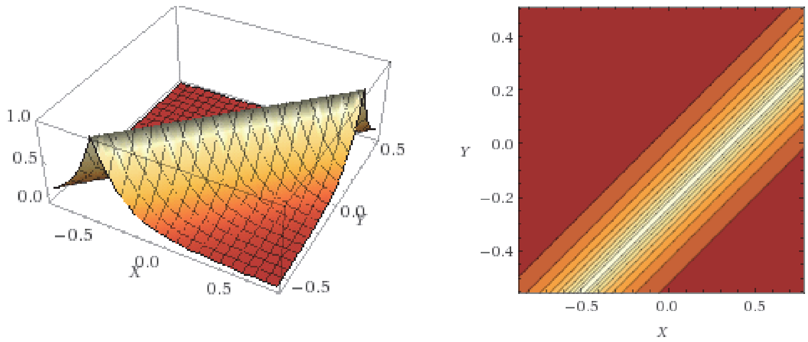
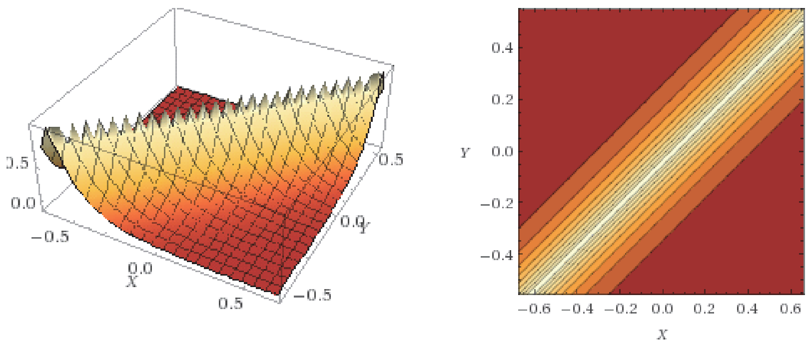


Romania

Minimal “fiscal”



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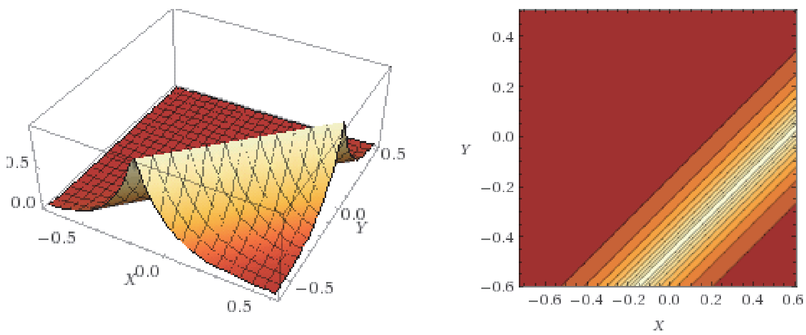
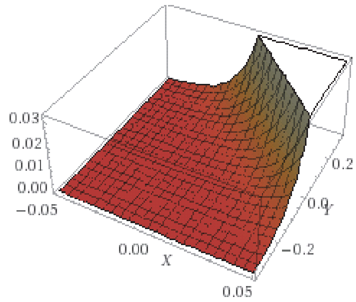
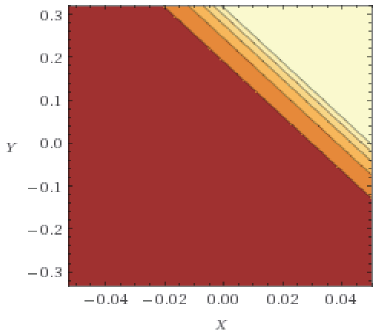


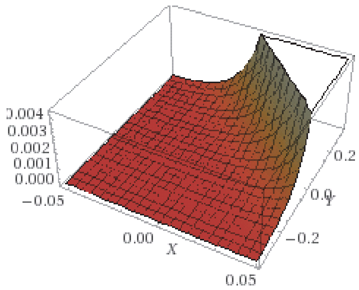
Ukraine

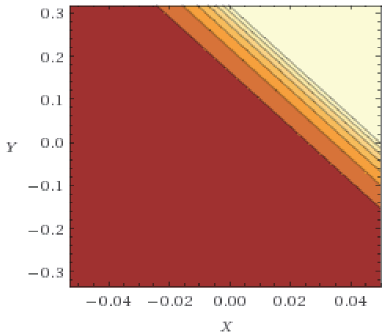
Minimal “fiscal”





Maximal “fiscal”





Note: Plots are constructed by deriving the term for the theta parameter, or for $\exp\left(-\left|\alpha_{0,i}+\alpha_i\,'X_{i,t}\right|\right)$. Because a 3D plot can only represent a case for two “instruments”, we construct two different derivations and plots: one for the minimal value of the “fiscal” variable, and one for the maximal value. This imitates the true movement of the parameter caused by changes in the “instruments”. In 3D plots, X is “industry”, Y is “compete” and the third dimension represents the parameter of integration, or theta. Darker colors represent low values of theta, and lighter colors represent high values. The direction of the light-colored line (south-west to north-east) suggests that theta increases when both “industry” and “compete” increase. Maximal value of the third dimension in the 3D plots suggests that theta is frequently bigger for the minimal “fiscal” variable.

Source: http://www.wolframalpha.com/.

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