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Financial convergence on emerging markets: the case of CEE countries

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Abstract

This paper investigates information embedded in the most liquid derivative instruments regarding the scope of convergence reported on the financial market in the emerging CEE countries. We present a proposal of the index that measures the scale of convergence between local and global derivative prices. The financial convergence index (FCI) encompasses a basket of prices that are remarkable for evaluation of the current state of converging economies. The study covers OTC foreign exchange and interest rate markets, as these segments are the most liquid areas of emerging markets. Moreover, we analyse the connection between derivatives pricing and broad market equity indices. The index provides evidence of a divergence process observed in the course of the financial crisis and presents a similar pattern to equity benchmarks.

Keywords: financial convergence, CEE derivative markets, financial crisis

JEL: G01, G10, G14, G15

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1 Introduction

Financial markets in emerging countries are usually less liquid and more volatile than those in developed countries. Despite this, due to satisfactory expected returns and a liberal currency law allowing for two-way capital flows, emerging markets are popular among foreign investors, generating sizeable capital inflows and providing additional liquidity for the local markets. In consequence, the share of non-residents, both in investment portfolios and in the process of market making, is significant. As a result of this, emerging markets are sensitive to changes of global sentiment, which can increase risk aversion on the market due to contagion effects (Pritskel 2001; Pericoli, Sbarcia 2003; Serwa, Bohl 2005). The process of capital outflow is usually far more dramatic than the opposite, which creates a permanent environment of asymmetrical risk (Hwang, Pedersen 2004; Bond, Satchel 2006; McCauley 2012).

In response to this, market players provide liquidity in various hedging tools, offering the neutralisation of such risks. The prices of these tools are sensitive to the changing expectations of forecasted market scenarios. A rising probability of extreme movements of rates or liquidity squeeze increases the cost of hedging. On the other hand, price movements caused by the growing uncertainty are an indicator of market stress and can be perceived as a barometer of the current market sentiment.

In the era of financial turmoil impacting on the global economy, the research referring to market sentiment measures is remarkable. The early works were focused on the stock market with evidence of underreaction and overreaction of investors (Barberis, Shleifer, Vishny 1998). A few years before the crisis, some indicators of financial stress were elaborated (Illing, Liu 2003). In line with a rise of liquidity and credit risk in the first year of the subprime crisis, one study looked at an IBOR-OIS[1] spread as a robust barometer of risk aversion (Taylor, Williams 2008). This spread started to become a crucial component of sentiment analysis (Holmfeldt et al. 2009). Later on, many financial stress indices (FSI) were published, such as St. Louis Fed FSI (Kliesen, Smith 2010) and Kansas City Fed FSI (Hakkio, Keeton 2009), based mainly on equity and credit markets and capturing increased uncertainty, asymmetry of information, flight to quality or flight to liquidity. The multi-factor Cleveland FSI (Oet et al. 2011) based on equity, credit, money and credit markets can be used as systemic stress monitoring and an early warning signal. The multi-country FSI (Slingenberg, de Haan 2011) summarises phenomena in various OECD countries, but its predictive power is limited to particular cases. Some indices allow an analytical framework to assess the impact of banking distress on the real economy in order to identify episodes of financial instability (Cardarelli, Elekdag, Lall 2009).

A classical approach to financial stress indices has two features: (i) from the statistical point of view it takes standardized (de-meaned), variance-weighted time series in order to equalize the influence of all index components; (ii) from the economic point of view it covers various market segments in order to capture sentiment changes for numerous instruments traded on the financial market.

Our general approach is close to that presented above, both from the statistical and economic angle. However, we propose a different set of instruments taken into account in order to capture the specifics of converging economies. A focus on converging countries requires modifications in the methodological construction of the index. Firstly, we analyse emerging markets taking into account their specific features and limited product coverage. Most of the instruments taken into account in classical stress indices are not available on emerging markets. Therefore, we take tradable OTC contracts

[1] IBOR – Interbank Offered Rate, the most common money market index; OIS – Overnight Indexed Swap, a derivative based on expected overnight (i.e. EONIA) prices.

that are liquid enough on the elected markets. Secondly, we treat the development of derivative prices as a process related to market convergence to the single currency area. This attitude comes from the specific features of non-euro EU countries that are legally obliged to convert their currencies to EUR,[2] but the post-crisis economic environment does not allow them to do so. In effect, we have a mandate to focus on instruments quoted as a spread between EUR and local currency indices (interest rates, foreign exchange indicators). Thirdly, we take instruments that are heavily traded between residents and non-residents, therefore, indirectly presenting a balance of capital flows. This approach allows us to capture the influence of global sentiment changes and the influence of risk aversion and contagion effects.

Convergence analysis was usually performed on real economics processes. Up-to-date research used to be focused on real convergence of macroeconomic figures such as inflation, public debt, and productivity (Calcagnini, Farabullini, Hester 2000; Bems, Schellenkes 2007; Kose, Otrok, Prasad 2008; Bahadir, Valev 2015). As far as financial convergence is concerned, authors assessed the level of stability and interdependence of market rates. Financial convergence was analysed as convergence of bond yields in the common currency area (Baele et al. 2004; Abad, Chuliá, Gómez-Puig 2014; Răileanu-Szeles, Albu 2015), as convergence of stock markets, credit derivatives and government bonds in emerging countries (Hristov, Rozenov 2009; Niţoi, Pochea 2016), and as convergence of currency and interest rates in frontier markets (Kozmenko, Savchenko, Kazarinov 2012).

Convergence – as used in this paper – should be understood as the measure of convergence of an emerging market to the reference of a major market in financial market terms (so not in pure macroeconomic terms). Good measures for such a purpose are the prices of derivatives that are traded particularly on emerging markets with a big share of cross-border dealing. Cross-border dealing is pointed out as one of the sources of financial convergence (for more broader analysis see Dixon 2014). The emerging currency derivatives have price patterns divergent from those observed on major markets.

In effect we obtain an index built on the basis of tradable prices that indicates the state of the given market in comparison to past observations and other markets. The index contains information about the location of the given economy on the path of financial convergence, taking into account the current sentiment recorded on the financial market.

The construction of the paper is as follows: firstly we describe the economic background giving the rationale of instruments building the index. Secondly we present the methodology and data sources, then we provide empirical evidence coming from our research and the final section concludes.

2 Economic background

The research takes into account derivative transactions which are sufficiently liquid and have an essential significance for the given market. We analyse the three largest Central and Eastern European (CEE) countries: Poland, the Czech Republic and Hungary, hence Polish zloty (PLN), Czech crown (CZK) and Hungarian forint (HUF) transactions are investigated.

After their accession to the European Union in 2004, these three CEE countries preserved their local currencies, but started to be perceived as economies heading towards the single currency area. In consequence, market participants discriminated these countries from common emerging markets.

[2] The "legal obligation" comes from the accession treaty, but this obligation is, in practice, very weak due to the unspecified time period for euro adoption.

The convergence process was treated as a stabilisation anchor and the market started to forecast a transition path of local markets to the Eurozone. As a result, higher volumes were recorded on the long end of local yield curves as investors bet on the Euro adoption horizon.

The financial crisis of 2007–2009 followed by solvency problems in peripheral EU economies caused the launch of contradictory processes. Divergence phenomenon accompanied the former convergence path, making prices of assets vulnerable to financial stress. Consequently, the local yield curve started to diverge from EUR benchmarks.

Emerging markets are characterised by the asymmetry of risk that comes from the vulnerability of local assets to the financial crisis. Therefore, market users expect higher yields that are biased by a significant risk premium coming from increased volatility and the skew of price returns. The volatility may indicate a higher probability of extreme movements. Moreover, the skew makes some hedging strategies more valuable than others – in effect the hedge against local currency depreciation is especially overpriced. Apart from that, the liquidity of the local market and creditworthiness of local counterparties or issuers are usually smaller than those recorded on the global markets. This causes sizeable spreads between local bond and derivative prices due to the limited credibility and liquidity of local securities.

Moreover, the financial crisis eroded the credibility of market players and activated structural changes on money markets. As a result, one started to observe an increasing cost of foreign currency liquidity for local agents that is manifested in the imbalance of demand on the currency swap market. Secured financing supersedes the unsecured deposit market and the quality of collateral is perceived as an important pricing factor (Bianchetti 2010). In consequence, the spread between unsecured and secured yields widened and can be perceived as one of the key indicators of liquidity cost.

Having in mind the described phenomena, the authors focused on the financial products encompassing demand and supply variability coming from the perception of the current sentiment and the scope of the financial stress. The current sentiment is a key driver of trends observed on emerging markets, i.e. carry trading activities are observed if the sentiment is good and deleveraging if the sentiment is bad (Çağlayan, Pintér 2013; Pappa 2014). The chosen set of derivative instruments ensures sufficient “two way” liquidity coming from significant activity both of local and foreign banks.

2.1 Analysed instruments

The following time series are taken as a basis for the index:

– cross-currency basis swap (5 year),
– Treasury bonds asset swap (5 year),
– convergence spread (5 year interest rate swap 5 year forward rate),
– implied foreign exchange volatility (1 year at-the-money, ATM),
– risk reversal for currency options (1 year 25-delta).

The five derivative prices embedded in the index are adequate for emerging markets because:

– they are liquid enough[3] due to a significant share of London-based financial institutions in the turnover and efficient market making supported by local banks;

[3] See Table 9 in the Appendix for the volume details according to the BIS Triennial Central Bank Survey 2016.

– they represent two main risks regarding non-euro converging economies: interest rate risk and foreign exchange risk; three proposed instruments represent IR risk (basis swap, asset swap and convergence spread) and two FX risks (ATM volatility and risk reversal);

– the higher the prices of all five instruments, the worse the sentiment observed in the market; an improvement of the sentiment means tighter convergence to a major market (in the case of CEE countries, the reference market is the core Eurozone);

– they behave in an asymmetrical way: they rise sharply if risk aversion emerges and drop slowly when market sentiment improves.

A cross-currency basis swap (CCBS) is a deal with initial and final exchange of capital in both currencies. The cost of capital is measured in IBOR terms[4] modified by a spread in basis points (so-called basis spread). The spread shows an imbalance between the demand and supply for both currencies resulting from the liquidity exposure of residents in foreign currencies and non-residents in the local currency. Moreover, the spread reveals the inequality of market participants in credit terms and can be influenced by carry trading and short selling on the currency market.

After the Lehman collapse, emerging markets show the following feature: major currencies are lent to local players with premium in connection with the short liquidity exposure of resident banks in low yield foreign currencies arising mostly from the Swiss franc mortgages on their books. As a result, there is a negative basis spread imposed on the local IBOR rate paid in interest payments by local currency borrowers (thus foreign currency lenders). The higher the risk aversion on global markets, the higher the basis spread in absolute terms.[5]

Treasury bond asset swap shows a difference between local currency Treasury bond yields and interest rate swap (IRS) prices for a given maturity. In general, Treasury bond yields are the lowest on the particular market taking into account the credit quality of the issuer and very high liquidity of this security. On emerging markets, the situation is different: the credit rating of emerging economies is lower than the average rating of global international banks and the liquidity of sovereign debt is limited due to the lower supply and weakness of market makers. Consequently, in some cases bond yields are higher than swap rates, especially on the long end of the curve. In such a situation the asset swap is positive. The deterioration of market sentiment causes emerging market bonds to be less attractive and augments these phenomena. One should note that in the literature (Matei, Cheptea 2012; ECB 2016) a bond spread above the benchmark is usually a key object of analysis on the sovereign debt market. It might be used for a common currency area, but in respect to different local currencies, the asset swap reveals more information regarding credit and liquidity risk irrespective of the general level of the yield curve in the given economy.

The convergence spread is calculated as the difference between forward yields in the local and foreign currency. In converging economies, foreign currency is always related to a single currency area to which a given country is a candidate for. The yields are usually taken from IRS prices. The higher the probability of local currency conversion on a forward date, the lower the divergence between IRS forward quotations should be. For CEE countries, the convergence spread was continuously contracting after the EU accession. This process was brought to an abrupt halt by the Lehman collapse. Rising risk aversion increased the gap between emerging currencies and EUR interest rates. Moreover,

[4] IBOR terms means reference to Interbank Offered Rate (Euribor, Libor etc.).

[5] In February 2015, due to quantitative easing in the Eurozone and the discussion related to the restructuring of foreign currency mortgages, a shift to positive basis spreads on some CEE markets has been observed.

the deterioration of the creditworthiness of the Eurozone after the Greek default (2012) diminished the probability of a smooth conversion of PLN, CZK and HUF to the euro.

Implied foreign exchange volatility is the key factor for pricing foreign exchange (FX) options and it reveals the expected price instability on the currency market. Emerging market currencies are characterised by higher and instable volatility, which encompasses a risk premium for non-normality of daily returns. Both realized and implied volatilities are usually strictly correlated with the level of the local currency rate (Eichengreen, Hausmann 1999; Guimaraes, Karacadag 2004). The weaker the emerging currency is, the higher the prices of options are due to the rise in volatility. Hence, risk aversion provoking local currency depreciation causes volatility jumps that are usually faster than volatility drops. Market liquidity is focused on option strategies called "zero-delta straddles" that allow to maximise volatility exposure.

The asymmetry of the volatility behaviour and the interdependence between volatility and price changes have an influence on risk reversal transactions. A risk reversal is the simultaneous trade in two out-of-the-money options, one with a high and the other with a low strike price of which one is bought and the other is sold. Usually both options have the same expected probability of exercise. On emerging FX markets, one observes excess demand on the high strike options as market players are eager to hedge against a currency crisis. In order to reduce hedging costs, participants write low strike options entering zero cost strategies. Such activity is mostly in line with long exposure in local high--yielding assets. Consequently, volatility for high strike options is relatively higher than for low strike contracts. Risk reversals are priced in volatility terms and reveal a difference between risk related to the contracts betting on the appreciation and the depreciation of the local currency. Thereby, its quotation shows an implied skew of daily returns distribution and is an indicator of the probability of a currency crisis in the emerging country.

Both the level of implied volatility for at-the-money options and the volatility differential embedded in risk reversal prices for out-of-the-money options are negatively correlated with the market sentiment. In the days of financial crisis a significant rise of both prices on emerging currency markets was recorded.

Taking into account the economic character of all of the above-described instruments, an index built up on the basis of their prices should be an indicator of the current market sentiment, a measure of the scope of risk aversion and a coefficient revealing the current level of financial stress.

For all three CEE countries, we assume the euro market as a benchmark reference level. Therefore, EUR/PLN, EUR/CZK and EUR/HUF pairs are analysed both for currency and interest rate instruments.[6] In comparison to emerging currencies, the euro is perceived as a currency that is not so strongly affected by the risk aversion process. This makes its pricing pattern (a structure of prices of EUR instruments) more symmetric and less biased than that of local emerging currencies.[7]

If we assume that financial market convergence on an emerging market is a process of price patterns convergence to levels observed on mature markets, then we look for the proxy of such price patterns. The five elected derivatives are a good measure of price discrepancies, showing the scope of "existing divergence" of local markets against major reference markets.

To summarise the economic rationale for the chosen derivative instruments, we present their features in Table 1.

[6] Moreover, a basket portfolio analysis performed for PLN, CZK and HUF reveals minimization of the variance for EUR based currency pairs in the analyzed countries.

[7] Evidence for such an assumption is provided by the low scope of the non-normality of daily returns of EUR major cross FX rates and the limited range as well as unstable sign of basis spread or risk reversal against other major currencies.

3 Methodology and data sources

We construct the financial convergence index (the FCI) that takes into account all 5 components described in the previous section. It is worth noting that the Pearson correlation coefficients between daily changes of the components of the FCI indicate a rather weak relationship between the interest rate components and a rather strong relationship between the foreign exchange components of the index (see Table 2). However, the correlation coefficients do not describe a full interdependence between the prices of financial instruments due to high short-term volatility generated by noise trading. Therefore, we applied the cointegration analysis between the FCI components. We examined the relationship between the convergence spread and other components and separately between interest rate or foreign exchange components only. The results clearly indicate that with a 5% significance level the variables for all relationships are cointegrated. Furthermore some relations are very firmly cointegrated with very low p-values, significantly below 1%.

The methodology of the construction of the index is as follows:

1. We take the daily time series of each of the prices in nominal terms and calculate their first differences.

2. We calculate the standard deviation of each of the differences for the recent 120 observations.[8]

3. For each day we calculate the weight for each difference in line with the following formula:

$$w_j(i) = \frac{\frac{1}{\sigma_{ij}}}{\sum_{1}^{n} \frac{1}{\sigma_{nj}}} \tag{1}$$

where:

$w_j(i)$ – a weight of i asset on the date j,

σ_{ij} – standard deviation of the first differences of i asset on the date j,

σ_{nj} – standard deviation of the first differences of n asset on the date j.

4. We calculate the weighted change of the basket by applying weights to all daily differences.

5. We calculate the new index value by adding the above figure to the previous value of the index.

Volatility weighing equalises the influence of each price factor to the sentiment index.

The construction of the index is as follows:

$$\begin{aligned} FCI_j = FCI_{j-1} &+ \Delta BS_j \times W_j(BS) + \Delta AS_j \times W_j(AS) + \Delta AV_j \times W_j(AV) + \\ &+ \Delta RR_j \times W_j(RR) + \Delta CS_j \times W_j(CS) \end{aligned} \tag{2}$$

where:

FCI_j – index for a given date j,

AS_j – asset spread for a given date j,

BS_j – basis spread for a given date j,

CS_j – convergence spread for a given date j,

AV_j – ATM volatility for a given date j,

RR_j – risk reversal for a given date j.

[8] The historical data not older than 1 calendar year were taken into account, as based on our analysis, financial time series longer than 1 year become non-stationary. In order to use the most recent data as well as to incorporate sufficient information content, we decided to use 120 recent observations, which is based on our best estimate.

Currency based deals (i.e. implied volatility and risk reversal) are measured for direct quotations. Interest rate deals (i.e. asset spread, basis spread and convergence spread) are presented as the difference of rates calculated in basis points against the underlying asset. All prices of the analysed instruments are quoted in percentage points or basis points, so they are homogenous. Moreover, all generate the I(1) process, so their first differences are stationary. In the long run, the time series are mean reverted and some (interest rate spreads) can show negative values, so a simple difference is more adequate than a logarithmic return. As a result, differences have the same units as levels.

We analyse the index bias from the initial value, which is set at zero. Index values above zero show stronger convergence in comparison with the beginning of the analysis. A negative index value suggests an opposite process, in which a given financial market diverges from the single currency market area.

The indices for all three currencies were calculated for the period from November 2007 to December 2014 in order to grab both crisis and tranquillity periods. On the emerging markets, the analysed period was affected by a few strong disturbances like the Lehman bankruptcy (September 2008) and the Greek default (March 2012).

All time series are taken from Bloomberg, therefore they represent "good levels"[9] for mid-market closing prices. The data were thoroughly revised in order to eliminate outliers (bad ticks) and gaps with the assistance of the Thomson Reuters database in a cross-checking procedure.

4 Empirical evidence

Looking at the chart presenting all three indices (Figure 1) we can clearly see that the Czech economy presents the utmost convergence to the Eurozone, having a positive index value in relation to the starting date. The indices for Poland and Hungary show a similar level of convergence that is substantially lower than that for CZK. After the bankruptcy of Lehman Brothers, the FCI for Poland and Hungary behaved in a similar manner, plummeting until March 2009. The fall of the FCI for Hungary was substantially sharper than that for Poland. However, after the Fed launched the quantitative easing programme, the FCI for Hungary recovered to a level similar to the FCI for Poland.

Panic on the financial markets after the collapse of Lehman Brothers caused a sharp increase of the volatility observable on the FX market. Moreover, a crisis of confidence deteriorated the creditworthiness of CEE government bonds and increased the cost of financing in the foreign currencies for financial institutions, which respectively caused an increase in the asset swap spread and the basis spread. The FCI for the Czech market was characterised by different behaviour in this most hectic period of the financial crisis. The index was very volatile but did not suffer a decrease in relation to the starting date. Comparing the behaviour of index components with the two other indices, we can clearly see that the low interest rates in the Czech crown (very closely converged to the Eurozone) did not expose the domestic banks to the financing in foreign currencies, which held the basis spread relatively stable during the turmoil on the financial markets.

During another phase of the financial crisis related with the deterioration of the creditworthiness of the countries from the PIGS group (Portugal, Italy, Greece, Spain), the increase in risk aversion had a negative influence on the FCI indices, but the general impact was not significant. A much greater impact on the FCI indices was generated by the downgrade in the US rating from AAA level in August

[9] "Good level" is a phrase describing a non-transactional price representing a value convergent with dealable rates.

2011, which caused a decline in the stock market. With the improvement of the market sentiment and the price increase observed on the stock market in the following months, the FCI indices also increased, indicating the progressive convergence process.

4.1 Cointegration analysis

With analysing the relationship between the indices, we cannot use the simple Pearson correlation coefficient, as it might be misleading due to an exaggerated emphasis on short-term changes with less attention to long-term tendencies. Moreover, the first differences are not normally distributed, which admittedly does not disqualify a correlation coefficient, but can affect its value and the results of testing its significance. Therefore in order to examine the relationship between the indices, we applied time series analysis tools to investigate the occurrence of a cointegration. The time series that both generate the I(1) process are cointegrated if there is a stationary linear combination between them. The occurrence of a cointegration relationship between two (or more) time series suggests the presence of a long-term and stable equilibrium.

According to the Granger's representation theorem, each cointegrated time series has a representation in the form of an error correction mechanism (Engle, Granger 1987). The augmented Dickey-Fuller (ADF) and KPSS test results confirmed that the indices generate I(1), so their first differences are stationary. The same level of integration allows us to examine whether the series are cointegrated. To examine the cointegration between the analysed variables in order to estimate the error correction model (ECM), we used the Engle-Granger method (1987). The main advantage of this method is its simplicity. It is based on the estimate of regression coefficients between variables in a model describing the long-term relationship using an ordinary least squares method (OLS). The next step is to check the stationarity of the residual term using the ADF test. If the residual term is stationary, then the variables are cointegrated and the vector of OLS parameter estimates is the cointegration vector. Finally, we can apply the cointegration vector into our ECM model describing the short-term relationship and estimate its coefficients with the OLS method.

We analyse the cointegration between the time series of the local FCI and the respective equity indices (therefore WIG20 for Poland, BUX for Hungary and PX for the Czech Republic). Moreover, we check the cointegration of the FCI with the VIX volatility index (for details see: Whaley 2000). The estimates of the regression coefficients for the basic equations using the OLS method are presented in Table 6 (Appendix). The evaluation of the regression coefficients indicate a statistical significance at a level equal to 1%. We decided to conduct cointegration analysis holding the assumption that the constant term will not be included. There are various studies analysing the role of a constant term and linear terms in cointegration analysis. In our paper we decided not to focus on types of test specification, but on the robustness of the obtained results, and that is why we have applied the simple form of cointegration test excluding the constant term.

The stationarity of the residual term is examined using the ADF test. The ADF test was conducted for the maximum significant number of lags. The test results indicate that the process generated by the residual terms is stationary with a 5% significance level (Table 6). Such a result thus confirms that the analysed variables – financial convergence indices for Poland, the Czech Republic and Hungary – are first-order cointegrated with corresponding equity indices and the VIX index.

4.2 Granger causality

As the next step in our research, causality analysis is conducted in order to examine whether the FCI for PLN, CZK and HUF are leading indicators for equity indices and the VIX index. To verify our hypothesis the Granger causality test is used with the Lagrange multiplier under F-distribution. Tests were computed for the first differences of the variables which are stationary variables. The results are presented in Table 7 (Appendix).

The results indicate that the FCI indices are not useful in forecasting stock indices. The Lagrange multiplier test statistics are below the critical value of a 5% significance level, implicating that there is no evidence to allow the rejection of the null hypothesis. In other words, the lagged observations of the FCI are not useful in forecasting the stock indices value. We have also examined the inverse relationship. The Granger causality test showed that the WIG20 and BUX index are leading indicators for *FCI_PLN* and *FCI_HUF*. This relationship does not also hold for *FCI_CZK*.

We have also examined the relationship between the VIX and the FCI. Here the results are consistent, which means that the VIX index is useful in forecasting all of the FCI values. The above test results lead to the conclusion that stock markets from Poland and Hungary are indicating the convergence process between those economies and the Eurozone. Increased risk appetite on the stock markets indicates a positive trend in the real economy and increases its ability to converge to the Eurozone. A similar conclusion comes from the relationship between the VIX index and the FCI. As global instability drops, risk appetite increases, leading to a positive trend on the global and emerging stock markets. Further analysis indicates that *FCI_HUF* is the leading indicator for *FCI_CZK* and *FCI_PLN*.

4.3 Error correction mechanism

The subsequent step in our analysis is the estimation of a short-term model with an error correction mechanism. We apply the cointegration vector from the long-term model into the ECM model. Now the condition of the same order of integration of each variable is met.

The estimates of the regression coefficients for the ECM model using the OLS method brings us the following general form of the model:

$$\Delta Y_t = \alpha_1 \times \Delta X_t + \alpha_2 \times (Y_{t-1} - \beta \times X_{t-1}) + \varepsilon_t \tag{3}$$

The calculated coefficients are presented in Table 3 (Appendix).

The evaluation of the regression coefficients was conducted at a significance level equal to 10%. The ECM model was applied only for significant relationship in terms of Granger causality. In order to verify the correctness of the model, the stationarity of the residual terms was examined with the ADF test.

Based on the above-outlined methodology, we have examined the relationship between the convergence indices for different economies and major market indices for these countries as well as the VIX index. The ECM model was specified for the relationship between *FCI_PLN* with WIG20 and *FCI_HUF* with BUX. However, the ECM model for the relationship between *FCI_PLN* with WIG20 is linear regression model, and the ECM term is statistically insignificant. The ECM model has not been specified for the Czech market because of negative results of Granger causality tests. The ECM model

was also omitted for the relation between *FCI_CZK* and the VIX index because all the regression coefficients were insignificant at a 10% significant level. For all of the ECM models presented in Table 8, the ADF test confirms that their residual terms are stationary. The test result, without constant terms with a p-value under 1% significance level, suggested not to reject the null hypothesis and to consider residual terms as the I(0) process.

5 Conclusions

The analysis of the financial convergence index (FCI) for Poland, the Czech Republic and Hungary, as well as the evidence coming from the stock indices WIG20, PX, BUX and the global volatility indicator VIX, confirmed that the variables generate the I(1) process. Furthermore, the convergence indices for the three economies are cointegrated with the local stock market indices and the VIX index, which means that an equilibrium relationship between these time series exists in the long term. These results show that in line with a lower risk aversion an improvement of the investment sentiment in the stock market can be observed, which is accompanied by lower volatility and higher liquidity recorded on the financial market. The presented indices, which are based on the prices of financial instruments, confirm that the change of relative prices in the financial market results in a parallel shift in investors' perception of the convergence process, which can be assessed by the level of risk aversion and the current market sentiment.

The methodology adopted in the construction of the index as well as the evidence referring to sentiment perception are genuine in relation to other publications examining this topic. In reference to other financial stress indices, the financial convergence index not only measures the investors' sentiment, but for most it shows the scope of divergence between the local economy and the major reference market. The relationship inferred from the studies shows that the level of convergence is dependent on the level of the risk aversion observed on the market.

The FCI can be tailored for an individual country with the qualification that the analysed economy is on the way of converging to the common economic area. The index shows how the episodes of financial stress affect the market participants' perception of the level of convergence in relation to the base period.

The causality analysis showed that the FCI is not a leading indicator for stock markets. However, the inverse dependence is true, except for the relation recorded on the already converged Czech market. Furthermore, the VIX index as a measure of global risk sentiment can be considered as a leading indicator for the convergence process in the Eurozone. Our analysis showed that the FCI is a proxy of market risk aversion and investors' sentiment.

The construction of the financial convergence index is an adequate analytical tool for CEE emerging markets, as it measures volatility-weighted prices of derivative instruments typical for hedging asymmetrical risks on such markets. These instruments are liquid enough and are widely traded between residents and non-residents, so their prices present the actual market sentiment. Non--residents use them in order to speculate or hedge on the local emerging market for proprietary trading or on behalf of their clients (hedge funds) and residents are market makers or use derivatives for managing off-balance exposures and structural liquidity as well as capital adequacy ratios. The higher the scope of risk aversion, the higher the divergence seen on derivatives prices. Moreover, CEE emerging

countries are strictly connected with the Eurozone as being EU members outside of the Eurozone – therefore, instruments comparing local currency performance versus the performance of the euro are adequate from the analytical standpoint.

The FCI is more appropriate for CEE emerging markets than up-to-date developed financial stress indices (FSI), as many instruments taken into account for FSI are not liquid or are non-existent on local emerging markets (such as exchange traded futures, CDS or VIX style products). Hence, OTC cross--border derivatives are a good choice and focus on the interest rate and foreign exchange markets that represent two key risk factors for small open economies with the local currencies. The FCI is a genuine idea in which the underlying instruments and methodology are tailored for the purpose of sentiment and risk assessment.

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Appendix

Table 1
The characteristics of the emerging market OTC derivatives

Instrument	Underlying risk	Representation	Risk measure	Emerging price pattern
Cross--currency basis spread	Liquidity	Secured loan market	A measure of imbalance between supply and demand on a loan market secured by the other currency. The demand comes from foreign currency mortgage loans that must be hedged by local banks	Basis spread may be large and usually has a fixed sign (foreign currency is borrowed with premium vs lending local currency)
Asset spread	Interest rate curves	A relative measure of the reliability of local sovereign debt	A measure of risk aversion and lack of liquidity on the local bond market	Asset spread is usually positive, i.e. bond yield is over swap yield (as reliability of a local issuer is rather low)
Convergence spread	Interest rate curves	The expected path of local interest rates vs global interest rates	A pure measure of reliability of a convergence process of the local economy that encompasses the probability of a local currency conversion to the euro	For prevailing emerging markets convergence spreads are high and have a constant sign (local yields are higher than reference ones)
ATM volatility	Foreign exchange	Expected instability of a local currency rate	A measure of expected instability of daily FX returns taking into account non-normality of the distribution	Implied volatility is volatile and diverges from realised volatility (is quoted with premium due to non-normality of distribution of daily returns)
Risk reversal	Foreign exchange	Expected probability of a currency crisis	A measure of expected skew (asymmetrical price dynamics)	Risk reversal is significant and has a stable sign (high strike options are much dearer in volatility terms than low strike options)

Table 2
Correlation matrix for index components for PLN, CZK and HUF

	PLN				
	basis swap 5Y	asset swap 5Y	AV	RR	FWD
Basis swap 5Y	1	-0.0831	0.0053	0.0250	0.0379
Asset swap 5Y	-0.0831	1	-0.0148	-0.0187	-0.0268
EUR/PLN AV	0.0053	-0.0148	1	0.9150	0.5058
EUR/PLN RR	0.0250	-0.0187	0.9150	1	0.4739
PLN over EUR FWD	0.0379	-0.0268	0.5058	0.4739	1
	CZK				
	basis swap 5Y	asset swap 5Y	AV	RR	FWD
Basis swap 5Y	1	0.0073	0.0025	-0.0009	0.0145
Asset swap 5Y	0.0073	1	-0.0048	-0.0246	0.0422
EUR/CZK AV	0.0025	-0.0048	1	0.8950	0.2795
EUR/CZK RR	-0.0009	-0.0246	0.8950	1	0.2644
CZK over EUR FWD	0.0145	0.0422	0.2795	0.2644	1
	HUF				
	basis swap 5Y	asset swap 5Y	AV	RR	FWD
Basis swap 5Y	1	0.0702	0.0188	0.0238	0.0298
Asset swap 5Y	0.0702	1	0.0409	0.0514	-0.0107
EUR/HUF AV	0.0188	0.0409	1	0.9625	0.2628
EUR/HUF RR	0.0238	0.0514	0.9625	1	0.2178
HUF over EUR FWD	0.0298	-0.0107	0.2628	0.2178	1

Notes:
AV – implied foreign exchange volatility (1 year at-the-money, ATM),
RR – risk reversal for currency options (1 year 25-delta),
FWD – convergence spread (5 year interest rate swap 5 year forward rate).
Calculated on first differences.

Table 3
FCI statistics for first differences

Index	Mean	Standard deviation	Skewness	Kurtosis	JB test
FCI_PLN	-0.00077897	0.031705	-0.855	32.198	76 977.2
FCI_CZK	0.00098473	0.078672	15.94	470.09	1.64374×10^{7}
FCI_HUF	-0.00073246	0.065817	0.722	43.837	142 439

Table 4
ADF and KPSS test results for first differences of the indices (analysis of stationarity)

Index	Test	Test results		
		lag	test statistic	p-value
FCI_PLN	ADF test with constant term	17	-7.76799	2.362×10^{-12}
FCI_CZK	ADF test with constant term	3	-20.3945	4.494×10^{-48}
FCI_HUF	ADF test with constant term	30	-5.63069	8.793×10^{-7}
		lag	test statistic	critical value
FCI_PLN	KPSS	17	0.511536	0.743
FCI_CZK	KPSS	3	0.045648	0.743
FCI_HUF	KPSS	30	0.288982	0.743

Note: critical value given for 1% significance level.

Table 5
Regression models and ADF test statistics for the residual terms

Variables	Regression model	ADF test for residual term		
		lag	t-Student	p-value
		PLN		
CS with *CCBS, AS, AV, RR*	A	19	-2.60032	0.00903
CS with *CCBS, AS*	B	21	-2.43379	0.01446
RR with *AV*	C	15	-2.94943	0.00310
		CZK		
CS with *CCBS, AS, AV, RR*	D	18	-2.39508	0.01607
CS with *CCBS, AS*	E	18	-2.47873	0.01277
RR with *AV*	F	12	-2.08269	0.03581
		HUF		
CS with *CCBS, AS, AV, RR*	G	19	-2.19035	0.02746
CS with *CCBS, AS*	H	19	-2.09045	0.03514
RR with *AV*	I	10	-3.48761	0.00048

Notes:
CS – convergence spread; *CCBS* – cross currency basis spread; *AS* – asset swap; *AV* – ATM volatility; *RR* – risk reversal.
A: $CS = 0.00466 \times CCBS + 2.5842 \times AS + 0.156 \times AV + 0.0464 \times RR + \varepsilon_t$
B: $CS = 0.02566 \times CCBS + 0.9496 \times AS + \varepsilon_t$
C: $RR = 0.319403 \times AV + \varepsilon_t$
D: $CS = 0.0023313 \times CCBS + 0.05056 \times AS + 0.00971 \times AV - 0.04592 \times RR + \varepsilon_t$
E: $CS = 0.00110097 \times CCBS + 0.09385 \times AS + \varepsilon_t$
F: $RR = 0.290811 \times AV + \varepsilon_t$
G: $CS = 0.008802 \times CCBS + 0.4908 \times AS + 0.23646 \times AV + \varepsilon_t$
H: $CS = 0.01523 \times CCBS + 0.98554 \times AS + \varepsilon_t$
I: $RR = 0.35397 \times AV + \varepsilon_t$
p-value given for test without constant term.

Table 6
Regression models and ADF test statistics for the residual terms

Variables	Regression model	ADF test for residual term		
		lag	t-Student	p-value
*WIG*20 with *FCI_PLN*	$FCI\_PLN = -0.000648 \times WIG20 + \varepsilon_t$	7	-2.91539	0.003459
PX with *FCI_CZK*	$FCI\_CZK = -0.001080 \times PX + \varepsilon_t$	8	-2.64285	0.007973
BUX with *FCI_HUF*	$FCI\_HUF = -0.000108 \times BUX + \varepsilon_t$	7	-2.36008	0.017660
FCI_PLN with *VIX*	$FCI\_PLN = -0.062380 \times VIX + \varepsilon_t$	22	-1.93088	0.051150
FCI_CZK with *VIX*	$FCI\_CZK = 0.042680 \times VIX + \varepsilon_t$	18	-2.00782	0.042810
FCI_HUF with *VIX*	$FCI\_HUF = -0.90260 \times VIX + \varepsilon_t$	22	-2.67502	0.007251

Note: p-value given for test without constant term.

Table 7
Granger causality test results

Relation	LMF statistic	Result
Δ*FCI_PLN* → Δ*WIG*20	0.9190	no causality
Δ*FCI_CZK* → Δ*PX*	1.0656	no causality
Δ*FCI_HUF* → Δ*BUX*	2.5928	no causality
Δ*WIG*20 → Δ*FCI_PLN*	7.5904	causality
Δ*PX* → Δ*FCI_CZK*	1.0417	no causality
Δ*BUX* → Δ*FCI_HUF*	3.0438	causality
Δ*VIX* → Δ*FCI_PLN*	9.7366	causality
Δ*VIX* → Δ*FCI_CZK*	3.5361	causality
Δ*VIX* → Δ*FCI_HUF*	3.8283	csausality
Δ*FCI_PLN* → Δ*VIX*	1.4194	no causality
Δ*FCI_CZK* → Δ*VIX*	2.0403	no causality
Δ*FCI_HUF* → Δ*VIX*	3.2859	causality
Δ*FCI_PLN* → Δ*FCI_CZK*	0.9002	no causality
Δ*FCI_CZK* → Δ*FCI_PLN*	1.4486	no causality
Δ*FCI_PLN* → Δ*FCI_HUF*	2.2936	no causality
Δ*FCI_HUF* → Δ*FCI_PLN*	4.5918	causality
Δ*FCI_CZK* → Δ*FCI_HUF*	2.2072	no causality
Δ*FCI_HUF* → Δ*FCI_CZK*	4.4779	causality

Note: critical value given for 5% significance level is equal to 2.6099.

Table 8
Error correction models and ADF test statistics for the residual terms

Variables	ECM model	Model statistics		
		variable	*p*-value	R^2
FCI_PLN with *WIG*20*	A	$\Delta WIG20$	4.47×10^{-6}	0.013305
		ECM	0.1862	
FCI_HUF with *BUX*	B	ΔBUX	4.76×10^{-18}	0.043721
		ECM	0.0682	
FCI_PLN with *VIX*	C	ΔVIX	0.0008	0.022940
		ECM	1.53×10^{-8}	
FCI_HUF with *VIX*	D	ΔVIX	4.08×10^{-15}	0.045140
		ECM	3.51×10^{-7}	

Notes:
A: $\Delta FCI\_PLN_t = 0.0000958 \times \Delta WIG20_t + \varepsilon_t$
B: $\Delta FCI\_HUF_t = 0.00004208 \times \Delta BUX_t - 0.002296 \times (FCI\_HUF_{t-1} + 0.000108 \times BUX_{t-1}) + \varepsilon_t$
C: $\Delta FCI\_PLN_t = -0.001180 \times \Delta VIX_t - 0.00478 \times (FCI\_PLN_{t-1} + 0.062380 \times VIX_{t-1}) + \varepsilon_t$
D: $\Delta FCI\_HUF_t = -0.005720 \times \Delta VIX_t - 0.0078 \times (FCI\_HUF_{t-1} + 0.090260 \times VIX_{t-1}) + \varepsilon_t$

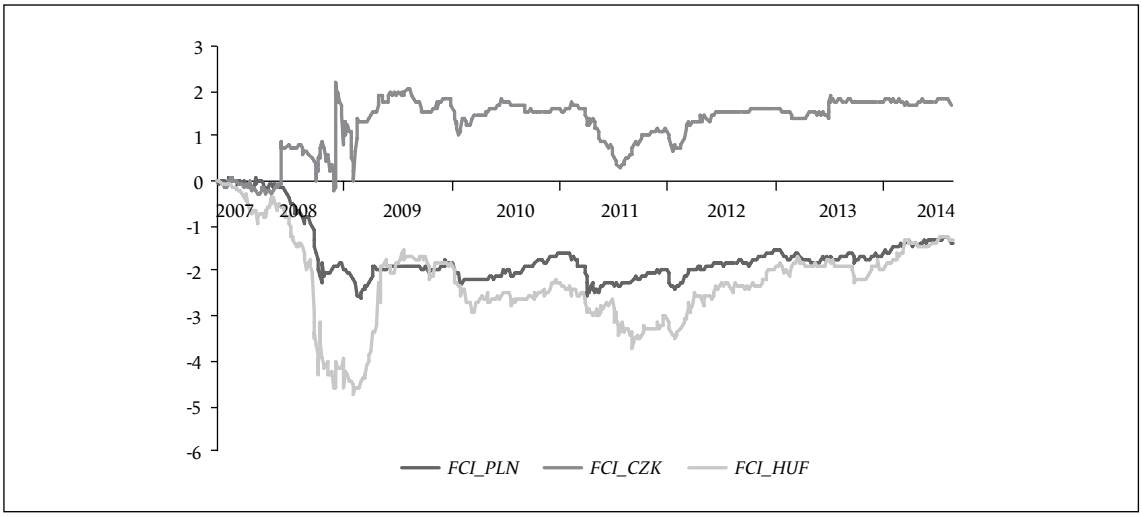
Data description:
*WIG*20 – key equity index for the Warsaw stock exchange,
PX – key equity index for the Prague stock exchange,
BUX – key equity index for the Budapest stock exchange,
FCI_PLN – financial convergence index for Poland,
FCI_CZK – financial convergence index for the Czech Republic,
FCI_HUF – financial convergence index for Hungary,
VIX – CBOE volatility index based on S&P500 options.
* ECM model for *FCI_PLN* with WIG20 is a linear regression model. ECM term is statistically insignificant.

Table 9
Average daily turnover of elected derivative instruments in the analysed CEE countries (USD bn)

Currency	Instrument			
	total FX	CIRS	options	IRS
PLN	35	0.332	0.949	3.035
HUF	15	0.107	0.609	3.763
CZK	14	N/D	N/D	1.152

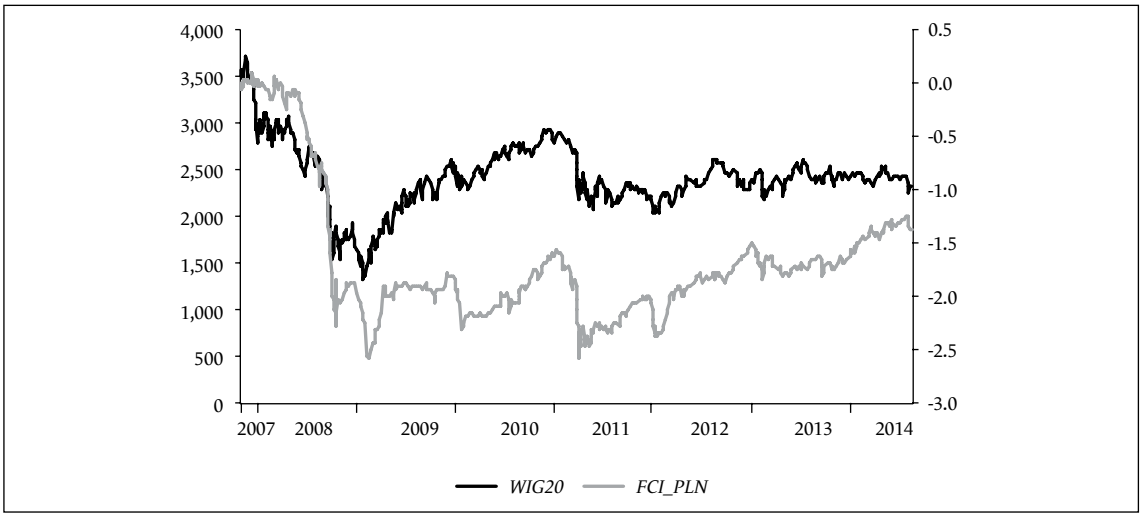
Source: BIS Triennial Central Bank Survey 2016.

Figure 1
Financial convergence indices for Poland, the Czech Republic and Hungary



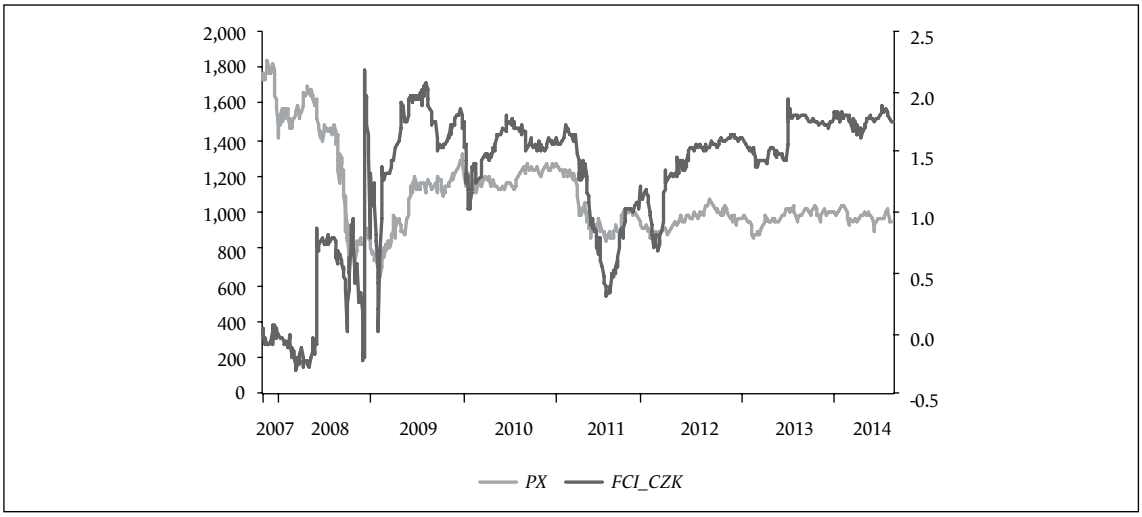
Source: Reuters.

Figure 2
Financial convergence index for Poland and the WIG20 index



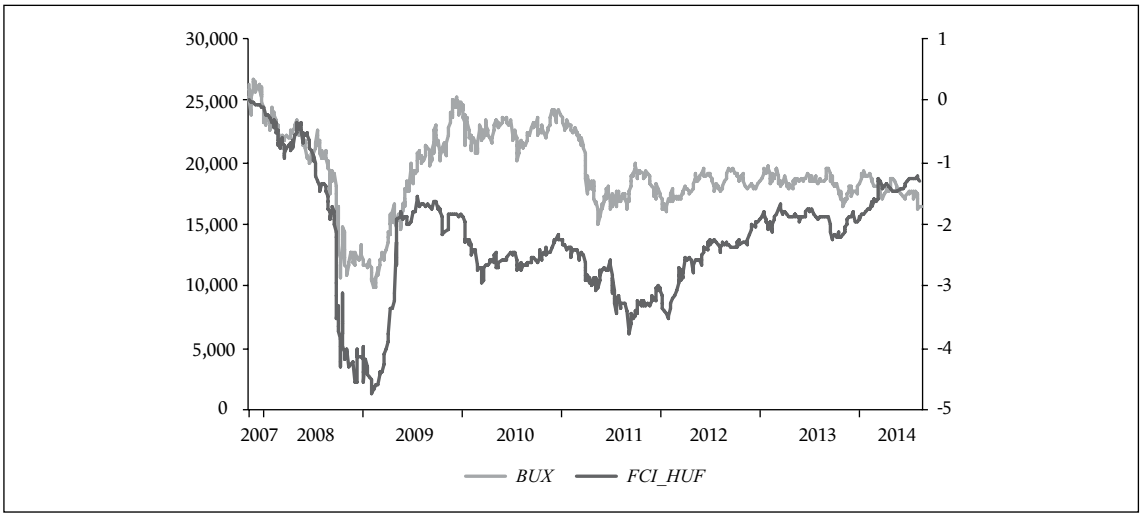
Source: Reuters.

Figure 3
Financial convergence index for the Czech Republic and the PX index



Source: Reuters.

Figure 4
Financial convergence index for Hungary and the BUX index



Source: Reuters.

Figure 5
Financial convergence index for Poland – histogram

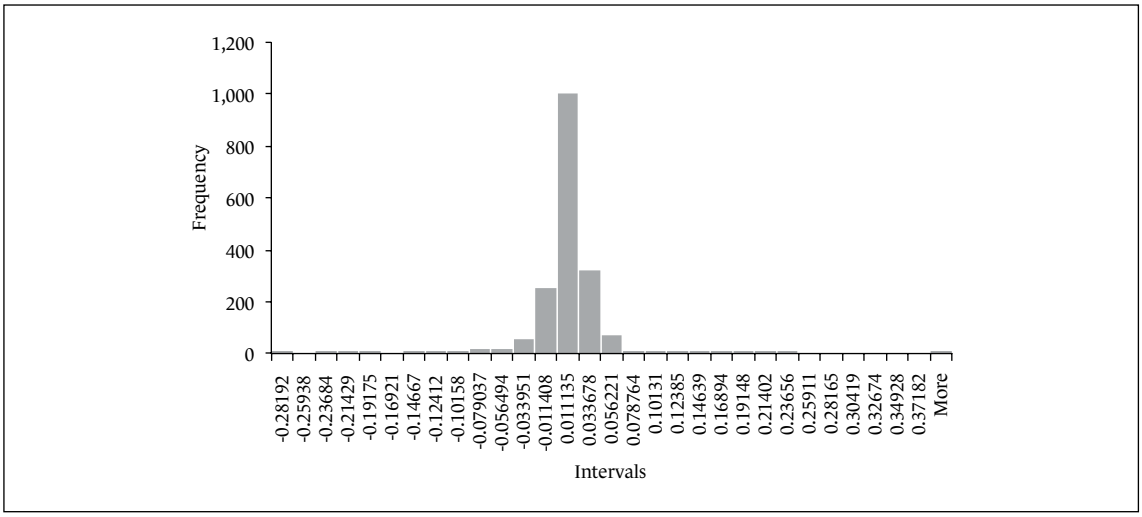


Figure 6
Financial convergence index for the Czech Republic – histogram

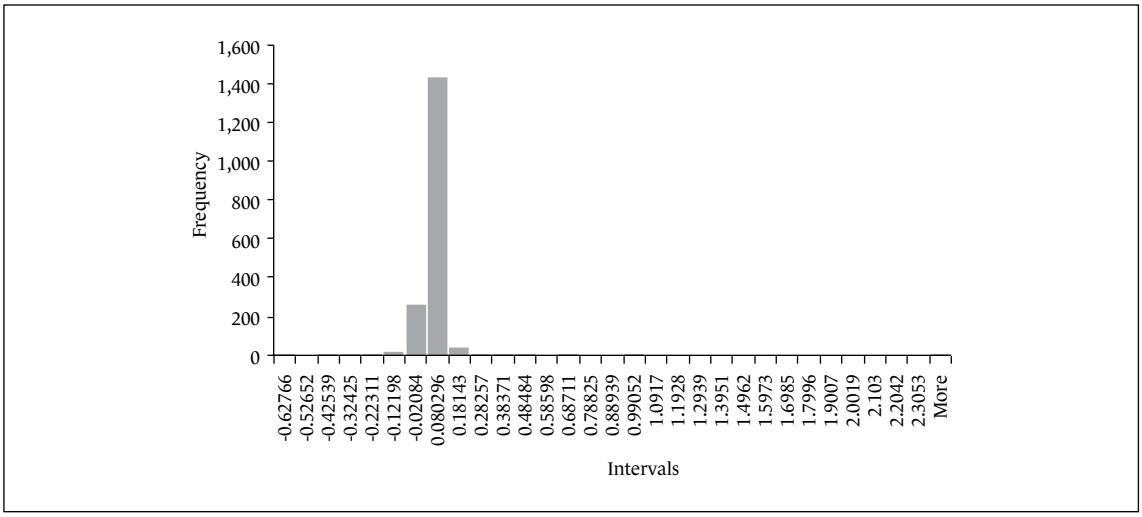


Figure 7
Financial convergence index for Hungary – histogram