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Cost-Risk Optimization Changes in Public Debt Management and its Impact on CDS Pricing in CEE Countries

[Změny v optimalizaci nákladů a rizik při řízení veřejného dluhu a jejich dopad na tvorbu cen CDS v zemích střední a východní Evropy]

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Abstract: Using local projection (LP) method, we assess Credit Default Swap (CDS) changes in the Central-East European countries. Cost-risk optimization in public debt management refers on the fine-tuning the ratio of capital import and foreign currency denominated borrowing to domestic funds. Literature defines closeness centrality as an indicator which highlights the relative importance of an asset within a network, estimated by a quarterly minimum spanning tree graph. We show that CDS changes are driven not only by the foreign exchange shocks but also by foreign currency debt and funding as well as the closeness indicator which signs a network-bias. We also find evidence that relative isolation better describes the Czech sovereign debt market. Thus, this paper makes a new contribution to the debate of public debt funding strategies, while highlighting the importance of network-biases.

Keywords: CDS, contagion, network-effect, public debt, small and open economies.

JEL classification: F31, E52, E58, D85, D53, C58

Introduction

The European Union places great emphasis on the Member States' gross government debt, its characteristics, and appropriate debt management (Lentner et al. 2021). A government's debt portfolio is typically the largest and most complex portfolio in a given economy, and its proper management is a crucial task. Risk ratings of sovereign debt are also used by international credit rating agencies, but they may be highly subjective or lag behind rapid fundamental and market developments (Simon–Simon-András 2019).

Public debt management is the activity of creating and implementing a strategy that helps to meet the financing needs of the public sector at the lowest possible medium- to long-term cost, without excessive risk-taking. There is an inverse relationship between the cost and risk of funding sources, with a reduction in the cost of the public debt portfolio being achieved while increasing its riskiness. In managing sovereign debt, these two factors should be combined to optimise the portfolio of assets used for financing (IMF 2014).

In addition to cost-risk optimisation, policy makers can also set other objectives, such as improving the efficiency of the domestic government bond market. The government should ensure that the government's debt and its growth rate are on a sustainable path and that it can meet its debt obligations even in adverse circumstances. For this reason, the appropriate design of the debt portfolio structure is a key issue, as an inadequately structured debt structure (poor

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maturity structure, high interest rate and currency risk) can lead to serious problems, as the sub-prime crisis has also highlighted (IMF 2014).

CDS guarantees the repayment of capital in the event of a bond default,, and acts as an appropriate expression of the debtor's credit risk (Török 2022). Similarly, on sovereign bond markets, the CDS spread is seen by investors as a key instrument to make a country credit-risk partially or fully comparable and transferable (Eysell et al. 2013, Török 2022, Fontana-Scheicher 2016). CDS spreads and CDS bases vary in line with market perceptions about credit risk and can therefore be considered as an appropriate proxy indicator for credit risk (Fontana-Scheicher 2016, Yang et al. 2023). Open and small economies are more exposed to foreign markets and liquidity movements, since they rely more on capital import, especially in key currencies (Georgiadis-Zhu 2021, Frankel 2011). Meanwhile there is a link between a country's fiscal constraints and its credit risk of its riskier firms, where a deterioration of sovereign CDSs can have widespread effects on the financing of an already fragile corporate sector (Hasan et al. 2023). The characteristics of CDS markets and the factors that affect sovereign spreads have been the subject of a large body of research (Sakba-Perretti 2019, Hassan et al. 2015, Coudert-Gex 2013, Ammer-Cai 2011, Arce et al. 2013).

Our paper further expands this topic by focusing on the impact of cost-risk optimization in public debt management on CDS spreads on selected open and small economy sample (Czechia, Hungary and Poland) between 2009 Q1 and 2023 Q1. The sample of Central-East European (CEE) economies faced different experiences during the 2008 global financial crisis: while Hungary had to turn towards IMF funding and improve its domestic funding channels during the 2010s, Poland had only an option of using the IMF's Precautionary Credit Line, while Czechia remained largely unaffected. We employed the local projection model and compared it to a vector autoregressive model's impulse response functions and variance decompositions. Moreover, this study explores the association between foreign exchange rate, network biases as well as public debt's relative size, foreign currency and funding exposures. The inclusion of network bias gives us a valuable insight into the country-specific contagion impacts, which was higher in countries with more external funding. Furthermore, with the adaptation of the time-variant minimum spanning tree graph method (following Kiss et al. 2024), we were able to have more precise results than just focusing on correlations alone.

This study contributes to the growing empirical literature by validating the importance of the domestic retail public debt funding, by highlighting the recent developments in the cost-risk optimisation strategies which were converging towards this. This approach was robust against the shocks of the early 2020s since none of the sample countries had to apply for IMF funding. The remainder of this paper is structured as follows. Section 2 focuses on the literature review of the debt portfolio management, its funding targets and practice to introduce the theoretical model. Section 3 describes the data, the sample countries and explains the methods. Section 4 presents the results of the local projection method. Finally, Section 5 concludes the paper and provides policy implications.

1 Theoretical Background

1.1 Public debt portfolio risks and their management

The cost of public debt is made up of two factors: one is the expected cost (typically identified with debt service over the medium to long term), the other is the potential real economic costs (may arise from situations in which the government is unable to meet its obligations under the debt) (Tóth 2020). The most significant risks for sovereign debt portfolios are related to market risk, which includes interest rate, foreign exchange, refinancing risks (which are linked to market conditions), while liquidity, settlement, and operational risks are more likely to be considered transaction-level or technical risks. As Ambrocio and Hasan (2021) suggested, political ties to the advanced key economies also have a significant role in the determination of sovereign borrowing conditions.

Market risk arises from changes in market conditions, which may increase the cost of public debt. The most significant are interest rate and foreign exchange risks. Interest rate risk is the risk arising from changes in market interest rates. This applies to both domestic and foreign currency liabilities. For floating rate debt items, the cost of servicing the debt changes immediately, while for fixed rate items, the effect of changes in interest rates is observed at renewal. This risk is typically quantified in terms of duration, weighted average time to refixing (ATR) and the proportion of floating rate debt (IMF 2014).

Foreign exchange risk is the risk arising from fluctuations in foreign exchange rates. Debt elements denominated in or indexed to foreign currencies increase the volatility of debt service. Indicators used to measure risk may include the ratio of foreign currency denominated debt to total debt and the ratio of short-term external debt to foreign currency reserves (IMF 2014).

The refinancing risk arises when debt is renewed, and involves the risk that renewal of debt is only possible at higher cost or, in extreme cases, not at all. Relevant indicators may be the ratios of debt with 12, 24 and 36 months remaining maturity (IMF 2014).

External vulnerability can also be relevant for public debt management, but the indicators used in this area tend to measure the external vulnerability of the economy as a whole. For the general government, the external debt of the public sector as a share of GDP, the average interest rate on external debt, and the (external) debt service ratio (Supriyadi 2014). In addition, it may be worth examining what percentage of the total external debt of the economy is accounted for by the government's external indebtedness, and the relationship between the evolution of the external vulnerability of the general government and the external vulnerability of the rest of the economy. The latter can help to draw much more solid conclusions. Indeed, it is not clearly a successful action if the government increases domestic financing in the management of public debt in a way that forces the other sectors of the economy to rely on external sources, without reducing the external vulnerability of the economy. On the other hand, as pointed out by Molnár and Regős (2019), excessive reliance on domestic resources can divert resources from investments in other sectors, thus having a negative impact on the national economy.

1.2 Changes in funding strategies

In the case of the Hungarian public sector, reflecting previous vulnerabilities, the focus has been on internal financing and strengthening retail financing (Kolozsi-Hoffmann 2016, Gór-Holecz et al. 2016, ÁKK 2016). In the Czech Republic since 2011, the objectives have included increasing the role of retail and non-profit organisations in public debt financing, which has led to the creation of specific schemes more attractive to this segment and the launch of a new electronic trading platform to facilitate this (MoF CZ 2010). In the case of Poland, in addition to short-term cost minimisation, the Ministry of Finance has had to consider long-term objectives (such as possible accession to the Eurozone) in managing the debt portfolio, and diversification of the investor base has been important (MoF PL 2015). Diversification of the investor base (and even opening up to the public) can reduce refinancing risk.

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The two crises had a very differential impact on public debt management strategies: while the subprime crisis has led to a shift from turbulent foreign exchange financing, the COVID crisis did not have such an impact, but there was a rise in sovereign premium which increased further after 2021 due to global inflationary effects (Alipanah et al. 2022). This may be a consequence of the fact that the 2007-2009 crisis hit public finances in a more vulnerable state, as interest rates were near zero at the beginning of the COVID epidemic. (Table 1).

Table 1: Summary of funding targets, related to cost-risk optimisation

		Hungary	Czechia	Poland
FX risk	% of debt in FX denomination	gradual decrease from max. 50% to 10-20%	from 2012 15%	within the range of 20-30%
	share of euro from FX debt	min. 95%	no	min. 70%
Refinancing risk	Duration (years)	2007-2018: 2-3.5Y	no	no
	ATR (years)	2019-: 2.75-5.5Y	5.25-6.5Y	4-5Y
	% of short-term	no	max. 20%	no
	% due in 5Y	no	2012-: max 70%	no
Interest rate risk	% of fixed rate	within the range of 60-90%	no	no
	% of fixed in FX denomination	within the range of 56-90%	no	no
	% of fixed for 1Y	no	30-40%	no
	Duration (years)	no	no	2007-2013: within the range of 2.5-4Y
	ATR (years)	no	2011-: within the range of 4-6Y	2013-: within the range of 2.8-4.2Y

Source: authors' edition

During the sample period, the public debt management institutions have made minor and major changes to their strategies. The main objective of the activity, cost-return optimisation, remained unchanged, but had to be adapted to changing market conditions. This was also reflected in changes in the value of the target indicators, especially in the case of Hungary. Hungarian debt management had the highest risk tolerance among the sovereign debt management institutions, while Poland the Czech Republic were able to finance their sovereign debt even under stricter rules than the other countries. Of course, these targets were also influenced by the fact that the countries studied had different starting positions and different levels of indebtedness.

During the subprime crisis and in the years that followed, debt portfolios were typically financed only with more risky sources by national public debt management institutions, although which risks increased and to what extent is not a consistent picture. Nowadays, risk measures have been adjusted to pre-crisis levels and, for example in the case of Hungary, debt portfolios are safer than before the 2008 crisis.

In terms of the structure of debt portfolios, the COVID crisis had a much smaller impact than the subprime crisis. So not only were there minor adjustments in targeting systems (despite the more rigorous indicator systems used by national debt management agencies), but also the increase in debt risks was only moderate. Currency risk and refinancing risk have increased slightly in all three countries, while interest rate risk is mixed, with an improving trend in Hungary, for example.

Thus, it can be argued that the two crises have had different effects on public debt management, which may be due to different market conditions and more stable public finances.

1.3 Changes in debt portfolios

The link between debt portfolio characteristics and CDS spreads has been the subject of several studies. There is a positive relationship between exchange rate appreciation and the reduction of default risk (Mellios–Paget-Blanc 2006, Ramos-Francia–Rangel 2012). Other studies have found an increasing effect of net external debt on CDS spreads (Cantor–Packer 1996, Aizenman et al. 2013, Ho 2016), while the increase in public debt as a share of GDP was positively associated with default risk.

In our study, we focus on the relationships highlighted above. Complemented by the relationship between the share of foreign debt denominated in foreign currency, the share of foreign funding (non-resident debtors) and the share of short-term debt with the CDS spread. Higher values of these variables reflect to higher risk, as they are increasing the CDS spread.

Looking at the situation of each state separately (Table 2) in the case of Hungary, the debt management has consistently met its repeatedly adjusted targets. The Czech Republic had stricter rules on debt management, but for the most part it was able to comply with them. The ATM indicator was outside the target range in 2 years, while the ATR indicator pointed to higher than desirable risk in 2017. The proportion of debt elements repricing within a year moved out of the target range in 2019, in the riskier direction (Table 4, 5, 6). Currency risk exceeded the target in 2013, but on the one hand, this is still considered low at the regional level, and on the other hand, during this period the exchange rate of the Czech koruna was pegged to the euro, so essentially the debt portfolio did not run real currency risk.

Table 2: Summary of achieving funding targets

		Hungary	Czechia	Poland
FX risk	% of debt in FX denomination	2007-2012: from 28.4% to 40.6%; 2013-2019: decrease to 17.7%; 2020-: increase to 25.2%	within the range of 7.51-22.05%	within the range of 21.99-35.5%
	share of euro from FX debt	near 100%	no	within the range of 66.88-83.47%
Refinancing risk	Duration (years)	within the range of 2.1-3.1Y	no	no
	ATR (years)	within the range of 3.7-4.6Y	within the range of 5-6.6Y	within the range of 4.63-5.49Y
	% of short-term	no	gradual decrease from 19% to 10.8%	no
	% due in 5Y	no	within the range of 42.6-62%	no
Interest rate risk	% of fixed rate	within the range of 63.6-87%	no	no
	% of fixed in FX denomination	within the range of 58.9-80.2%	no	no
	% of fixed for 1Y	no	within the range of 21.2-37.5%	no
	Duration (years)	no	no	2007-2013: within the range of 3.5-3.8Y
	ATR (years)	no	within the range of 4-5.9Y	2013-: within the range of 3.6-4.0Y

Source: authors' edition

The image is less homogeneous for Poland. The degree of foreign exchange risk was typically higher than desired, although the share of foreign currency debt did not exceed 35.5%. However, for renewal (ATM) and interest rate (average time to maturity, ATR) risks, the debt portfolio characteristics were close to the safer half of the target range, sometimes exceeding it. There was a marked deviation in the average time to maturity of foreign debt, with the indicator ranging between 6 and 8.5 years instead of the target of 4.5-5 years.

In terms of the structure of debt portfolios, the COVID crisis had a much smaller impact than the subprime crisis. So not only were there minor adjustments in targeting systems (despite the more rigorous indicator systems used by national debt management agencies), but also the

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increase in debt risks was only moderate. Currency risk and refinancing risk have increased slightly in all three countries, while interest rate risk is mixed, with an improving trend in Hungary, for example.

Thus, it can be argued that the two crises have had different effects on public debt management, which may be due to different market conditions and more stable public finances.

1.4 Credit Default Swap (CDS) pricing

Credit Default Swap (CDS) is defined as financial instrument which provides insurance to the buyer against the default of a particular debtor. Therefore, the buyer of the CDS makes periodic payments to the originator for the right to sell the underlying bonds for face value once the credit event occurs (Kocsis – Nagy 2011). According to Hull (2018), this means that the CDS should represent the ratio of total payments from the buyer of the derivative to the notional principal of the underlying asset. The CDS can be valued (1) by the following steps: from the present value of the expected payments it is necessary to deduct the present value of the expected payoff and the accrual payment. From the empirically known hazard rate (λ) we can assume the probability of default ($(Q(t) = 1 - e^{-\bar{\lambda}(t)t}$. With a discount factor ($\frac{1}{(1+r)^t}$) from a risk-free rate (r) and the expected payments (s), we can calculate the first (1a) step:

CDS (1): $\sum_{t=1}^{t=T}(1 - Q_t)s(\frac{1}{(1+r)^t});$ (1a)

For the present value of the expected payoff (1b), we need to define a recovery rate (h):

CDS (2): $\sum_{t=1}^{t=T}(Q_t)(1 - h)(\frac{1}{(1+r)^t});$ (1b)

Meanwhile accrual payments ($d * s$) arise (1c) due to the spread payments s are made in arrears (d):

CDS (3): $\sum_{t=1}^{t=T}(Q_t)(d * s)(\frac{1}{(1+r)^t});$ (1c)

By focusing on the ratio of the CDS to the principal (s), we will get the following equation for valuation (1):

$$s = \frac{\sum_{t=1}^{t=T}(Q_t)(1-h)(\frac{1}{(1+r)^t})}{\sum_{t=1}^{t=T}(1-Q_t)\left(\frac{1}{(1+r)^t}\right)+\sum_{t=1}^{t=T}(Q_t)(d)(\frac{1}{(1+r)^t})} \quad (1)$$

Please note, that even if we are estimating the default probabilities from the CDS market data ($\bar{\lambda} = \frac{s(T)}{1-h}$) none of the debtor-related fundamentals (like: relative size of debt or funding strategy, etc.) will be recognized there!

The variation in CDS spreads across countries is high, as they are strongly affected by general market conditions and crises (Doshi et al. 2017, Sakba–Perretti 2019, Hassan et al. 2015, Coudert–Gex 2013). Meanwhile, Peltonen et al. (2014) highlighted the high degree of market interconnectedness of the CDS market counterparties, which adds further institutional vulnerabilities. As Kocsis and Monostori (2016) points on, projections about multiple factors (real, external, banking and institutional) can be responsible for such CDS movements on the emerging economies, therefore this problem will be further assessed by our theoretical model.

1.5 Theoretical Model

For small economies, openness is necessary for capital import especially in reserve currencies, what makes them more dependent towards global liquidity changes and key central bank decisions (Frankel 2011, Davis 2015, Magas 2018). To model (1) the changes of credit default swap (ΔCDS_t) in the sample open and small countries, the following variables were taken into consideration: while the relative size ($\frac{debt}{GDP}_t$), share of foreign currency denomination ($Curr_t$) and the ratio of foreign investors ($Foreign_t$) were reflecting on the fragility of the debt itself, as well as the external imbalance of the economy was approximated by the foreign exchange rate (FX_t) and the network-effect (CL_t).
The relative size of the debt ($\frac{debt}{GDP}_t$) itself would not increase the expected default probability, until it is financed in domestic currency and savings, since the government could use monetary funding as a last resort. However, emerging economies can be characterized by different capital-to-output ratios, inefficiency of capital allocations, foreign currency borrowings and current account deficits at the same time as well (Hassan and Zhang, 2021), making them more prone to external shocks.

Such external shocks can be approximated well by the changes of a floating foreign exchange rate, since it must reflect the overall funding and inflationary status of the economy. However, as the CDS_t is a publicly traded asset, it was necessary to include its network-related biases – since some of its changes can be the result of changes in a neighboring economy's CDS_t, and not in the anticipated domestic fundamentals. Using a time-variant correlation would necessitate the inclusion of a whole correlation matrix, but this could be circumvented by the estimation of the time-variant closeness centrality form a quarterly minimum spanning tree graph. Since this metric captures the relative importance of each country-node, its increase can highlight a deeper CDS-market integration, while its decrease reflects on its fragmentation.
Meanwhile, dummy-variables had to be added to represent exogeneous shocks (recession in the Eurozone and in the US, financial aid in the Eurozone from ESM funds to mitigate the sovereign debt crisis and the appearance of the COVID-19 pandemic) and structural changes (new president at the national bank) in the sample economies.

$$\Delta CDS_t = \beta_1 \Delta FX_t + \beta_2 \Delta CL_t + \beta_3 \Delta \frac{debt}{GDP}_t + \beta_4 \Delta Curr_t + \beta_5 \Delta Foreign_t + d_t \quad (1)$$

We can anticipate that a depreciation would increase the CDS, as investors are closing some of their long-positions in the domestic currency ($\beta_1 < 0$). Similarly, higher foreign currency funding ($\beta_4 > 0$) and more external funding ($\beta_5 > 0$) reliance ads more risk to the debt. However, the relative size of the debt can be completely neutral if this change is not rapid ($\beta_3 \approx 0$). Meanwhile, the network-bias can show us the signs of contagion if the CDS increases due to deeper market integration ($\beta_2 > 0$) or divergence if it react more on the fragmentation ($\beta_2 < 0$).

2 Data and Methods

2.1 Data

This study analysed the quarterly data of 3 EU member states (namely: Czechia, Hungary) between 2009 Q1 and 2023 Q1, due to CDS data availability. Mainly the Eurostat, Refinitiv Eikon and national treasury databases were used to acquire the data for further analysis. Table 3 presents the list of explanatory variables, their abbreviations, and their source.

Table 3: Data sources

Variable	Notation	Source
Credit default swap	CDS_t	Refinitiv Eikon
Foreign exchange rate	FX_t	Refinitiv Eikon
closeness in the minimum spanning tree market graph	Cl_t	authors' calculation
the relative size of the public debt as the ratio of nominal GDP	$\frac{debt}{GDP_t}$	Eurostat
Foreign currency denomination ratio of the public debt	$Curr_t$	Treasury data
Foreign investors' share on the public debt market	$Foreign_t$	Treasury data
recession in the US (1: recession in the US)	$d_{rec,US,t}$	National Bureau of Economic Research
recession in the Eurozone (1: recession in the EZ)	$d_{rec,EZ,t}$	European Commission Business Cycle Clock
ESM funding to any eurozone member state (1: recession in the EZ)	$d_{rec,ESM,t}$	European Stability Mechanism
COVID-19 pandemic (1: after 2019 Q4)	$d_{rec,Covid,t}$	Google trends
Changes in the presidency of the Hungarian national bank (1: after 2013 Q1)	$d_{rec,MNB,t}$	authors' calculation

Source: author' computation

2.2 Sample economies

Hungary introduced its +/-15% pegged exchange regime and inflation targeting monetary policy in 2001, which was followed by a floating one in the spring of 2008. Unfortunately, the global financial crisis (GFC) in the same years Autumn created a serious liquidity crisis, what was resolved from an IMF GRA fund allocation until the country was able to go back to fully market funding in 2013 (Sági & Ferkelt 2020).

Poland, which introduced the inflation targeting and the floating regimes earlier in 1998 did not needed immediate IMF funding during the GFC, only Flexible Credit Line was provided to reassure markets due to its reserve-like characteristics (Bakker & Klingen 2008), but funds were never drawn.

Meanwhile Czechia was also an early adopter of both the inflation targeting and the floating regimes in the late 1990s, had to introduce and maintain an upper ceiling of the CZK to avoid excessive application between 2013 and 2017 to avoid deflationary effects. This highlights the negative impacts of otherwise good fundamentals during turbulent time periods.

2.3 Time-varying minimum spanning tree graph

Correlation has a time-variant nature, therefore this paper estimates Spearman's correlation ($\rho_{i,j,t}$) to capture not just linear but monotonic relationships for each quarter from its daily time series. To map a more realistic interlinkages, the three country sample was also extended with Slovakia (to represent the whole region), Germany and the USA since global funding conditions are guided by their capital markets.

Instead of working with the quarterly correlation matrices, or studying the graph itself (as Peltonen et al. 2014), a minimum spanning tree graph was estimated for each quarter (with Kruskal's algorithm from the distance matrix $D = \frac{[\sqrt{2(1-P)}]+[\sqrt{2(1-P)}]'}{2}, P_t = [\rho_{i,j,t}]$), which could provide its country-specific centralities to describe the structure of this network. Betweenness measures the "bridge-making" nature for each node, degree measures the number of links to other nodes and closeness captures the range of collaboration among the nodes (Samitas et al. 2022, Kiss et al. 2024).

We need a dynamically changing input variable to any regression model to minimize statistical biases in the residuals, therefore closeness centrality (2) seems an appropriate choice. It also represents the importance of the specific CDS relative to other CDSs in the network of N with a changing value from quarter-to-quarter. This centrality is estimated as the average shortest distance ($d(V_iV_j)$) from V node (currency) i to all the other j nodes.

$$C(V_i) = \frac{(N-1)}{\sum_{j=1}^{n} d(V_iV_j)} \quad (2)$$

2.4 VAR

The vector autoregressive (VAR) model is a statistical model that captures the linear relationship between multiple time series variables, where they are modeled as a function of their own past values and the past values of the other variables in the system. This procedure captures the dynamic interactions for a set of K time series variables $y_t = (y_{1t}, \dots, y_{Kt})'$. The basic model (3) of order p VAR has the following form (Lütkepohl 2005):

$$y_t = \mu + A_1 y_{t-1} + \cdots + A_p y_{t-p} + u_t \quad (3)$$

Where μ is a vector of constants, the A_i's are (KxK) coefficient matrices and $u_t = (u_{1t}, \dots, u_{Kt})'$ is an unobservable error term, assumed to be a zero-mean independent white noise process with a time-invariant, positive definite covariance matrix: $u_t \sim (0, E(u_t, u_t'))$. To estimate the optimal lag length, Akaike Information Criteria (AIC) was minimised, but to avoid autocorrelation biases, the lack of autocorrelation in the residuals was tested with LM test as well.

We can convert the residual model to a structural one by $u_t = A^{-1}e_t$. Then, under zero short-run (Cholesky) restrictions, it is assumed that some of the coefficients in the A-matrix are zero (in the short run, first period the shock hits), providing the following identification-matrix (Table 4).

Table 4: A-matrix structure containing short-term effects

		Shock				
		ΔFX_t	ΔCL_t	$\Delta \frac{debt}{GDP}_t$	$\Delta Curr_t$	$\Delta Foreign_t$
Variable	FX_t	a_{11}	0	0	0	0
	ΔCL_t	a_{21}	a_{22}	0	0	0
	$\Delta \frac{debt}{GDP}_t$	a_{31}	a_{32}	a_{33}	0	0
	$\Delta Curr_t$	a_{41}	a_{42}	a_{43}	a_{44}	0
	$\Delta Foreign_t$	a_{51}	a_{52}	a_{53}	a_{54}	a_{55}

Source: Authors' edition

Impulse response function (IRF) shows how each of the endogenous variables will respond to the shock of the others, indicating the impact of an upward unanticipated one-unit change in the "impulse" variable on the "response" variable over the next several periods. Variance decomposition quantifies the proportion of the forecast error variance for each variable that can be attributed to exogenous shocks to other variables - indicating how much information each variable contributes to the other variables in the autoregression.

2.5 Local Projection

Based on Jordà (2005), Local projection (LP) methods can be estimated by simple least squares and are robust to the misspecification of the dynamic data generating method, what often happens in the VAR models and such errors are will compound with the forecast horizon of the

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IRF. LP is based on sequential regressions with the endogenous variable shifted several steps ahead, as its IRF is the difference between two forecasts.
For the LP method, we have to project y_{t+s} onto the linear space, generated by the $(y_{t-1} + \cdots + y_{t-p})'$ as it follows (4):

$$y_{t+s} = \alpha^s + B_1^{s+1} y_{t-1} + \cdots + B_p^{s+1} y_{t-p} + u_{t+s}^s \qquad s=0, 1, 2, \ldots, h \tag{4}$$

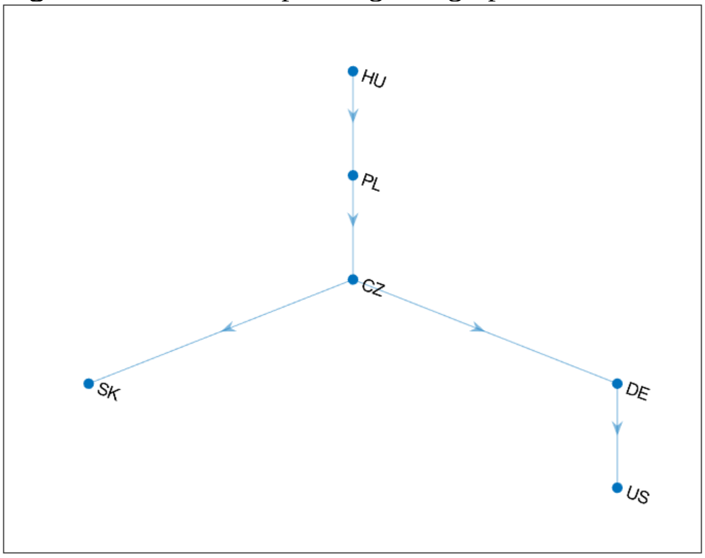
where α is a vector of constants, B_i^{s+1} are matrices of coefficients for each lag i and horizon s+1, as this collection of regressions are denoted as local projections. The impulse responses with $\boldsymbol{d_i}$ relevant experiment shocks are $\widehat{IR}(t, s, \boldsymbol{d}) = \hat{B}_I{}^s d_i$. Therefore, local projections directly estimate impulse response coefficients.

3 Results

3.1 Network

A minimum spanning tree graph, estimated on the whole sample period with the additional Slovakian (SK), Germany (DE) and US (US) data (see Fig. 1) shows that the three sample economies are represented as a single branch. It means that it is worth to analyze them alone, but not as a panel, since such country number would be insufficient for that. This result is similar to Le et al. (2022) which identified the US as a shock exporter, Germany as a shock transmitter, while our sample CEE economies were one of the most connected countries, highlighting their vulnerability.

Figure 1: Minimum spanning tree graph on the whole time-period and on the extended sample



Source: Authors' estimation, using Matlab 2023b software

Meanwhile, the time-variant closeness centrality (Fig. 2) reacted abruptly on shocks like the sovereign debt crisis of the Eurozone (started in 2010), or the Russian invasion in Ukraine (in 2022). Therefore we can assume that the relative importance of the sample markets are increasing during turbulent times mostly, suggesting the presence of a contagion-effect.

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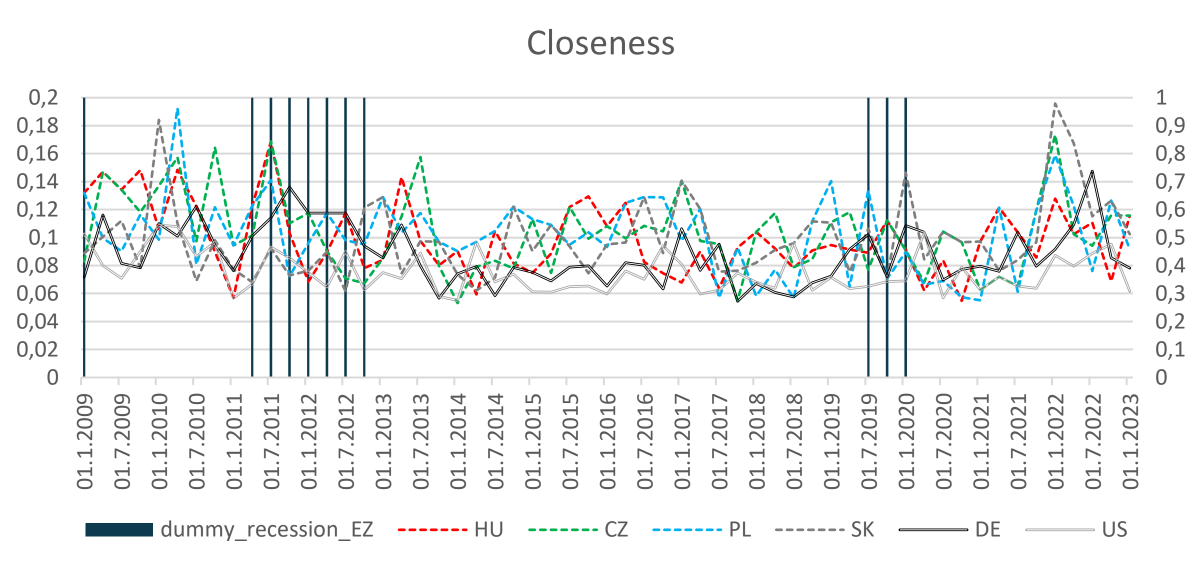
Figure 2: Time-variant closeness centrality of the extended sample



Source: Authors' estimation, using Matlab 2023b software

3.2 VAR and LP

To fit the VAR model with the designed identity matrix (specified on Table 4), we were looking for the lag number with lowest of the AIC but without residual serial correlation. As the residual serial correlation LM test shows (see Appendix 1), the optimal choice was the inclusion of 4 quarters. This specification presented also the rejection of the null hypothesis of the joint Wald-test for the LP model, meaning none of the response coefficients were jointly zero.

For the Hungarian CDS (see Figure 3), foreign exchange rate, the ratio of foreign currency denominated debt, the ratio of foreign investors as well as the closeness had the highest importance, with 20-25% from the medium-term (1-5 quarters) variance decompositions (see Appendix 2). The depreciation of the Hungarian Forint had an immediate increasing effect in the CDS, what was followed by an smoother opposite correction in the second quarter (similarly to Mellios–Paget-Blanc 2006, Ramos-Francia¬Rangel 2012). Foreign exchange rate is therefore a good indicator for the Hungarian CDS since it provided the highest reactions on the short-run. This is similar to the increased foreign currency funding shocks, where more of such funding will increase the CDS significantly in the 2nd and 4th quarters, what is followed by a sudden correction in the 5th quarter. However, the absorption of foreign capital decreases the CDS in the 1st quarter, but it increases it in a similar manner during the next period. Any short-term network-related contagion will increase the CDS in the first two quarters, meaning the lack of isolation of this market. All these results are highlighting the vulnerabilities of capital import (similarly to Ho 2016, Aizenman–Jinjarak 2013, Coudert–Gex 2013). Meanwhile the debt-to-GDP ratio had poor (1% from the variance decomposition) and a contradictory negative impact – underlining that not the size but the structure of the debt what matters to the subjective market view of default probability.

Results were the complete opposite for the Czech CDS (see Figure 4), since their public debt was mainly funded from domestic currency and capital, therefore in their case the relative size represented nearly half the variance decomposition in the 1-2 quarters, with a contractionary negative impact again. Meanwhile, closeness had a negative impact in the 4th quarter with 5% weight in the variance decomposition, suggesting a relatively isolated market.

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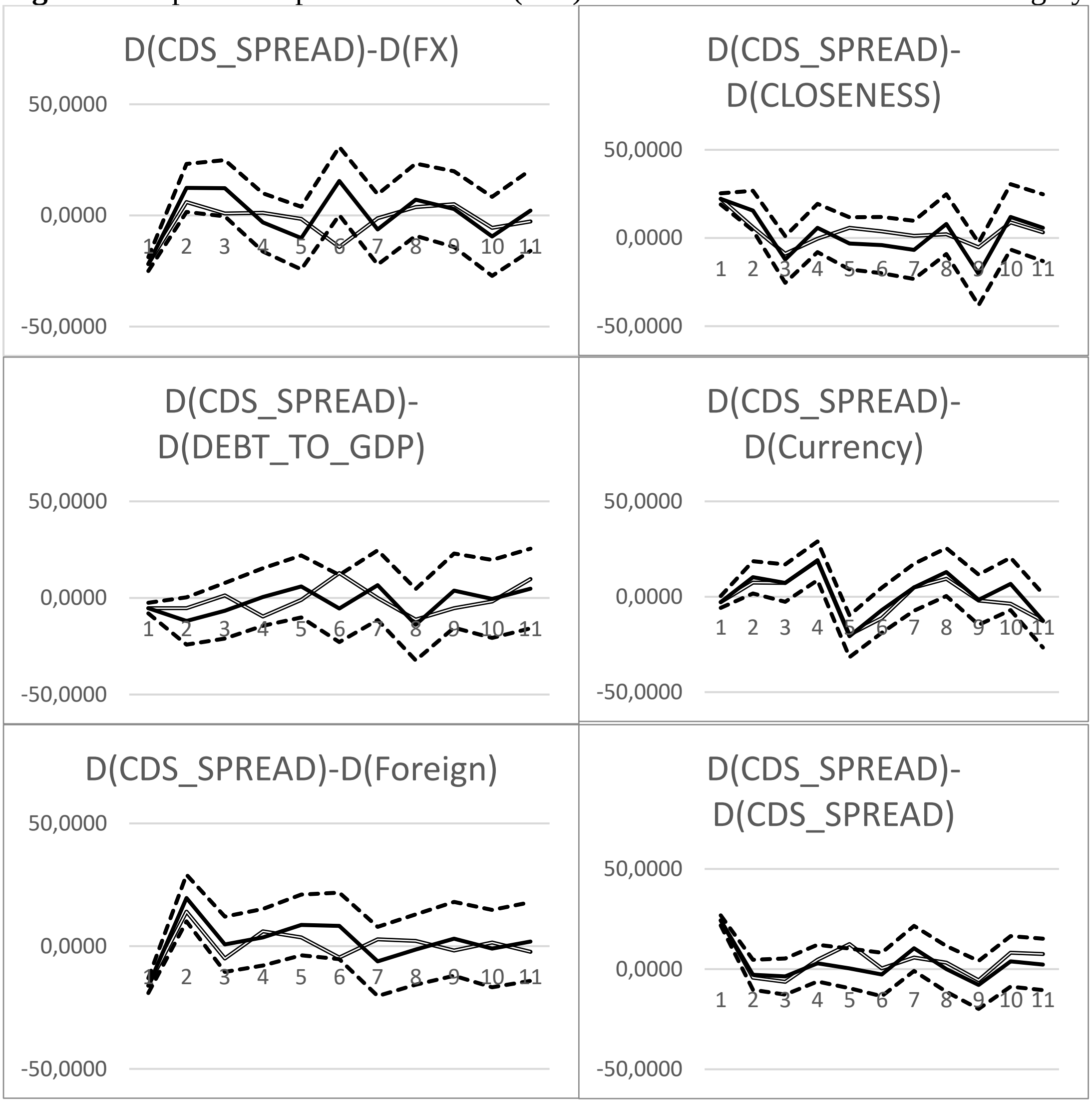
For Poland (see Figure 5), results were similar but less dramatic as for Hungary, since regardless that the depreciation of the Polish Zloty caused an immediate increase in the CDS (which was followed a small correction during the 2nd quarter) with more than 40% weight in the variance decomposition. Closeness had also a similar contagion-effect in the first quarter, but only with 8% of variance decomposition.

It is remarkable, that both the LP and VAR IRFs provided similar results, only the later ones were less stable in time.

Figure 3: Impulse Response Functions (IRF) from the LP and the VAR for Hungary



Notes: continuous line represents the medium line for the LP, dotted line represents 90% confidence interval for the LP, doubled like represents the medium line for the VAR IRF
Source: Authors' calculations, with Eviews 13 software

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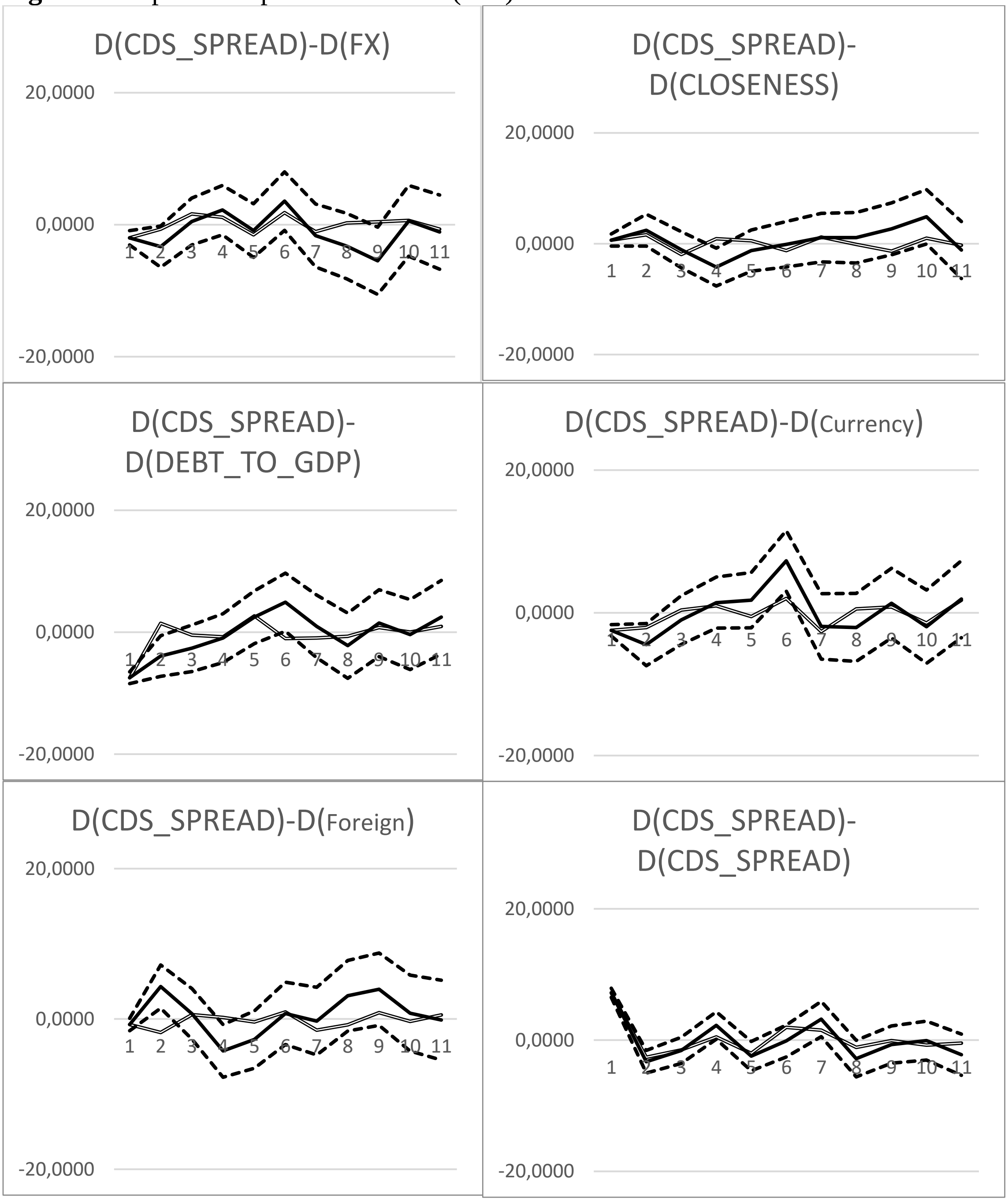
Figure 4: Impulse Response Functions (IRF) from the LP and the VAR for Czechia



Notes: continuous line represents the medium line for the LP, dotted line represents 90% confidence interval for the LP, doubled like represents the medium line for the VAR IRF
Source: Authors' calculations, with Eviews 13 software

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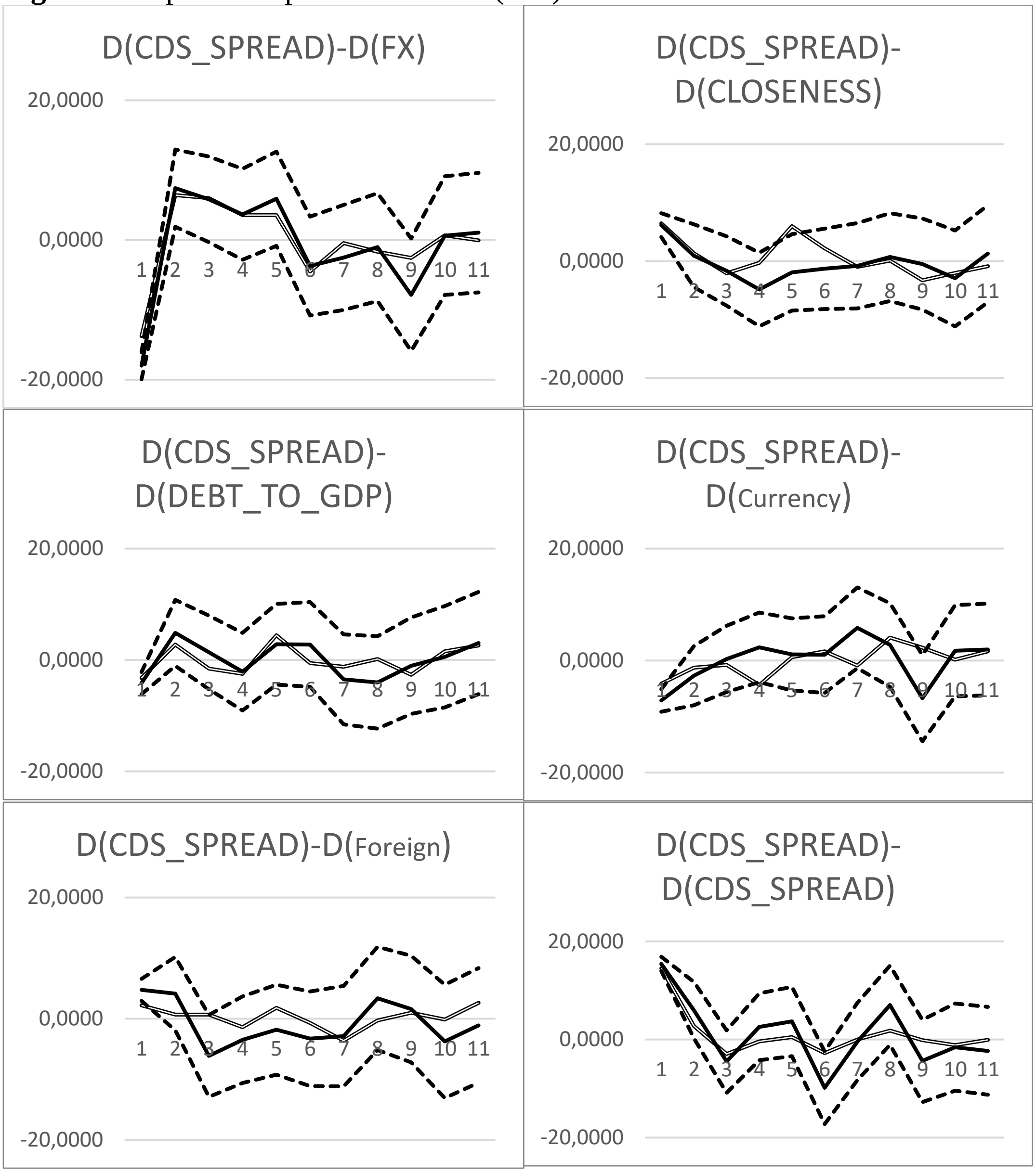
Figure 5: Impulse Response Functions (IRF) from the LP and the VAR for Poland



Notes: continuous line represents the medium line for the LP, dotted line represents 90% confidence interval for the LP, doubled like represents the medium line for the VAR IRF
Source: Authors' calculations, with Eviews 13 software)

Conclusion

This paper focused on the changes of cost-risk optimization in three open and small economies which followed different trajectories after the 2008 global financial crisis. While the Hungarian public debt management decreased its exposure towards foreign funding in general, Poland and Czechia followed its previous paths. These structural changes were also motivated by the sovereign crisis in the Eurozone at the first half of the 2010s, creating more sophisticated fiscal rules and leading to a near-zero interest rate environment on the sovereign bond markets as well. These policies were tested during the Covid-19 pandemic and the following inflationary wave, increasing their debt-service.

The main contribution of this paper was that it underlined the fragility of CDS pricing, since it was only partially affected by the aforementioned institutional changes, while other countries'

CDS developments and foreign exchange rate fluctuations had a remarkable impact both in Hungary and Poland. This result points on the weakness of using the CDS as an indicator of sovereign risk. Meanwhile the efficiency of the implemented changes in cost-risk optimization (namely funding in domestic currency and resources) were verified.

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Appendices

Appendix 1. VAR and LP diagnostics

Table A1. VAR Residual Serial Correlation LM Tests

	HU	CZ	PL
Lag	Prob.	Prob.	Prob.
1	0.0417	0.6740	0.9275
2	0.8091	0.2593	0.9208
3	0.9609	0.1807	0.7240
4	0.1997	0.2143	0.6972
5	0.5996	0.6511	0.7703

Source: Authors' estimations, Eviews 13 software

Table A2. Wald-test (Joint) of the LP

	HU	CZ	PL
D(CDS_SPREAD)-D(FX)	0,0000	0,0240	0,0000
D(CDS_SPREAD)-D(CLOSENESS)	0,0000	0,2846	0,0027
D(CDS_SPREAD)-D(DEBT_TO_GDP)	0,1112	0,0000	0,1029
D(CDS_SPREAD)-D(Currency)	0,0005	0,0000	0,0000
D(CDS_SPREAD)-D(Foreign)	0,0000	0,1384	0,0189
D(CDS_SPREAD)-D(CDS_SPREAD)	0,0000	0,0000	0,0000

Source: Authors' estimations, Eviews 13 software

Appendix 2. Variance decompositions

Hungary

Period	S.E.	D(FX)	D(CLOSENESS)	D(DEBT_TO_GDP)	D(Currency)	D(Foreign)	D(CDS_SPREAD)
1	43.06	25.77	26.49	1.48	0.41	13.95	31.89
2	47.18	23.09	23.74	2.53	2.78	20.49	27.37
3	49.25	21.22	25.05	2.40	4.73	19.82	26.77
4	54.28	17.51	20.63	5.13	16.34	17.58	22.79
5	59.58	14.60	18.09	4.29	24.74	14.95	23.33
6	63.85	17.62	16.11	7.81	24.61	13.54	20.31
7	64.38	17.38	15.88	7.68	24.77	13.50	20.80
8	66.30	16.71	15.08	10.10	25.42	12.84	19.86
9	67.19	16.83	15.31	10.46	24.83	12.56	20.01
10	68.64	16.79	16.34	10.10	24.08	12.08	20.60
11	71.04	15.82	15.46	11.33	25.65	11.38	20.36

Source: Own editing

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Czechia

Period	S.E.	D(FX)	D(CLOSENESS)	D(DEBT_TO_GDP)	D(Currency)	D(Foreign)	D(CDS_SPREAD)
1	10.89	3.35	0.36	46.99	5.09	0.47	43.75
2	11.75	3.20	2.21	41.90	7.40	2.76	42.53
3	12.15	4.80	4.61	39.41	7.02	2.82	41.34
4	12.31	5.53	5.04	38.75	7.48	2.78	40.43
5	12.87	6.47	4.77	39.74	7.01	2.63	39.38
6	13.42	7.80	5.21	37.12	8.69	2.90	38.28
7	13.97	7.79	5.53	34.72	11.57	3.83	36.56
8	14.06	7.72	5.46	34.47	11.55	4.10	36.69
9	14.20	7.66	6.23	34.11	11.66	4.36	35.98
10	14.35	7.71	6.61	33.41	12.41	4.32	35.54
11	14.52	7.75	6.48	33.04	13.58	4.36	34.79

Source: Own editing

Poland

Period	S.E.	D(FX)	D(CLOSENESS)	D(DEBT_TO_GDP)	D(Currency)	D(Foreign)	D(CDS_SPREAD)
1	21.77	39.94	8.82	2.21	3.63	1.04	44.37
2	23.12	43.14	8.16	3.40	3.52	1.01	40.77
3	24.22	45.40	8.18	3.50	3.31	1.00	38.61
4	25.04	44.52	7.68	4.26	6.14	1.24	36.17
5	26.43	41.75	12.00	6.63	5.56	1.59	32.48
6	27.11	42.44	12.05	6.35	5.66	1.58	31.93
7	27.41	41.54	11.91	6.40	5.65	3.29	31.23
8	27.82	40.67	11.55	6.21	7.64	3.20	30.73
9	28.37	39.93	12.45	6.85	8.01	3.20	29.56
10	28.52	39.57	12.82	7.09	7.93	3.17	29.43
11	28.82	38.76	12.64	7.77	8.08	3.93	28.82

Source: Own editing