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Interest rate, liquidity, and sovereign risk: derivative-based VaR

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Interest rate, liquidity, and sovereign risk: derivative-based VaR

Interest rate,
liquidity

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Abstract

Purpose – The purpose of this paper is to study connections between interest rate risk and credit risk and investigate the inter-risk diversification benefit due to the joint consideration of these risks in the banking book containing sovereign debt.

Design/methodology/approach – The paper develops the historical derivative-based value at risk (VaR) for assessing the downside risk of a sovereign debt portfolio through the integrated treatment of interest rate and credit risks. The credit default swaps spreads and the fixed-leg rates of interest rate swap are used as proxies for credit risk and interest rate risk, respectively.

Findings – The proposed methodology is applied to the decade-long history of emerging markets sovereign debt. The empirical analysis demonstrates that the diversified VaR benefits from imperfect correlation between the risk factors. Sovereign risks of non-core emu states and oil producing countries are discussed through the prism of VaR metrics.

Practical implications – The proposed approach offers a clue for improving risk management in regards to banking books containing government bonds. It could be applied to access the riskiness of investment portfolios containing the wider spectrum of assets beyond the sovereign debt. The approach represents a useful tool for investigating interest rate and credit risk interrelation.

Originality/value – The proposed enhancement of the traditional historical VaR is twofold: usage of derivative instruments' quotes and simultaneous consideration of the interest rate and credit risk factors to construct the hypothetical liquidity-free bond yield, which allows to distil liquidity premium.

Keywords Liquidity risk, Emerging markets, Interest rate, Diversification benefit, Diversified VaR, Sovereign debt

Paper type Research paper

1. Introduction

The two most important risks faced by financial institutions in their banking book are credit risk and interest rate risk. Financial industry regulators traditionally address the credit risk

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as the most relevant for the banking book. Nevertheless, recently, the awareness of the regulators has also become focused on the interest rate in the banking book. For example, the Basel Committee on Banking Supervision has recently issued “Standards for Interest Rate Risk in the Banking Book” [Basel Committee on Banking Supervision (BCBS), 2016], alerting financial institutions on possible negative impacts of interest rate changes on their balance sheets and profitability.

Although these two risks are intrinsically interdependent, there remains a tradition in the finance industry to keep dividing the overall risk relative to the banking book into credit risk and interest rate risk. Under such approach, both risks are treated independently, even though fixed-income exposures depend simultaneously on both credit risk and interest rate. Thus, such independent risk evaluation can potentially result in mismanagement of risk.

To highlight a necessity of the joint risk consideration, much of recent academic research turns to analyzing interdependence between these two risk categories, namely, CR and IRR (Drehmann *et al.*, 2010; Hartmann, 2010; Gubareva and Borges, 2016; among others). Interaction between CR and IRR categories has already attracted considerable attention (Kiesel *et al.*, 2002; Tang and Yan, 2010). Many researchers nowadays analyze the complexity of IRR and CR interaction (Chen *et al.*, 2013 and references therein).

The study of CR and IRR interaction is addressed from both, empirical (Lin and Sun, 2007; Landschoot, 2008; Boulkeroua and Stark, 2013) and theoretical (Miloudi and Moraux, 2009; Piazzesi and Schneider, 2010; Neal *et al.*, 2013; Jermann and Yue, 2013) perspectives. The common finding of these researches is that CR and IRR are intrinsically related to each other and hardly separable. The above-mentioned authors address integrated risks dynamics analyzing individual bond yields or bond indices data.

Nevertheless, there is a lack in studies of interrelation of CR and IRR based on credit default swaps (CDS) spread used as proxies for CR component in bond yields (Garcia and Yang, 2009; Tang and Yan, 2010). This paper seeks to apply the derivative instruments such as CDS and interest rate swap (IRS) to research the interdependence between the CR and IRR. The used historical value at risk (VaR) technique distinguishes this research from others, mainly using VaR approaches based on Monte Carlo simulation of future scenarios.

It is worth noting that VaR is continuing to be a technique widely applied in the risk management. To have a brief grasp on the subject, a few recent publications could be consulted (Wong, 2013; Kao, 2015; Jarrow, 2017).

The presented work summarizes the newly performed research. Its theoretical aspect resides in the proposal of a new derivative-based VaR approach, while it is empirical in a sense that historical time series of the quotes relative to the derivative instruments are used. It sheds a new light on the interaction of credit risk and interest rate risk and its implications for risk management.

This research focuses on the interdependence between IR and credit risk in fixed-income banking books consisting of sovereign bonds issued by a set of developing countries. The proposed herein approach is based on historical VaR technique, widely used in banking industry (Pérignon and Smith, 2010), which allows for uncovering empirical complexities of interest rate and credit spread behavior.

With regard to Europe, inside our sample, there is a subset of non-core European monetary union (emu) member states. It is worth mentioning an extensive recent literature linking sovereign credit risk to structural discrepancies between core and periphery emu countries. Much recent research is focused on reassessing of emu's core-periphery framework (Wortmann and Stahl, 2016; and references therein) and on connections between the structural changes and the determinants of sovereign CDS spreads (Westphal, 2015;

Kirschenmann *et al.*, 2016). The dynamics of non-core European sovereign credit risk receives a special attention in our analyses.

It is also worth mentioning a recently increasing interest in relationship between oil prices and sovereign credit risk, especially while assessed through the CDS market (Sharma and Thuraisamy, 2013; Dauvin, 2016; Hooper, 2016; Wegener *et al.*, 2016; Naifar *et al.*, 2017). Among considered in our research developing economies, there are some oil producing countries. We study whether the oil price influences the sovereign risk premia, as this could be of relevance for the question of interpreting diversified VaR metrics. Hence, our empirical investigations partly focus on interrelation between oil prices and sovereign CDS spreads.

Using IRS rates and sovereign CDS spreads as proxies for the interest rate and sovereign credit risk, respectively, the research aims to reconstruct the interest rate and credit spread components in the sovereign bond yields.

The inter-risk diversification effects are studied by computing risk-specific VaR metrics, then constructing their sum representing the undiversified VaR figure, and by comparing it to the respective diversified VaR metrics obtained by taking into account multi-risk factors, i.e. historical moves in interest rate and credit spread, simultaneously.

The challenge of studying joint distribution of interest rate and credit risk factors at long time horizon is aspired. For a chosen set of developing sovereign debt exposures, it is demonstrated that interest rate changes affect default probabilities. Different regimes of such interdependence are studied, especially prior and after the recent global financial crisis. Addressing time variations in sovereign credit risk, we study changes in spreads and yields over a 1-year long time intervals, differently from a major trend when authors mainly focus on explaining short-term daily variations (Jeanneret, 2015).

Recently, liquidity effects on sovereign yield and spread fluctuations attracted a lot of academic attention (Monfort and Renne, 2014; Herrero and Mencia, 2015; and Fontana and Scheicher, 2016). Following this stream of research, the next objective of the present work is a comparison of a joint evaluation of interest rate and credit spread, based on the time series of quotes of the respective derivative instruments, with another historical VaR technique, widely used in the banking sector, which is based on bond yields. As a result of this comparison, it is possible to quantify a liquidity component in a sovereign bond yield.

Finally, the proposed and applied herein derivative-based joint downside risk evaluation further advances the use of derivatives, such as IRS and CDS, in researching the interdependence among multiple risk factors.

This paper is organized as follows. Section 2 presents the methodology. Section 3 describes the data. The empirical results are discussed in Section 4. Section 5 concludes the paper.

2. Methods

2.1 Historical value at risk

The basis element of the methodology is a VaR technique based on historically observed data series, known as historical VaR. At any of its variations, VaR describes the maximum loss, which is not exceeded in a given holding period, with a given elevated probability, denominated confidence level. Mathematically, historical VaR is calculated as a percentile of the distribution of the incurred losses. Targeting different aspects of financial management, VaR can be calculated for different holding periods and different confidence levels.

This paper uses a VaR holding period of one year, as this is a time horizon widely used in financial industry. It is worth noting that banks and financial institutions frequently choose the 99.9 per cent confidence level, as it is compatible with an investment grade rating. Hence, the 99.9 per cent confidence interval is chosen for the VaR calculations in this research.

Two different lengths of historical data arrays are used in the presented herein VaR calculations, namely, of 5 and 7 years. It is important to highlight that 5-year long array of data is a commonly required regulatory minimum, while 7-year intervals widely used within the financial sector, also represent a frequently met choice.

2.2 Risk-specific, undiversified and diversified value at risk

In finance, the diversified exposures are generally considered to be less risky than undiversified ones. This is true be it related either to a diversity of portfolio assets or to variety of risk factors to which the portfolio is exposed. When there is a negative impact in value due to a crystallization of one of the risks, other risks are expected to become less harmful, and this is usually confirmed by historical observations. Thus, the volatility of the profit and loss is somewhat reduced.

So, usually when risk managers calculate VaR, they try to compute the diversified VaR, which takes into account this diversification benefit effect. When possible, they also try to compute the so-called risk-specific VaR figures, and the undiversified VaR which is but the sum of the risk specific VaR computed, while the risk factors are analyzed as stand-alone, without taking into consideration any interrelation between the involved risks.

When all these metrics are available, the most thoughtful risk management decision can be taken. It is important that the diversified VaR figure takes into account the effect of the inter-risk diversification benefit. It means that, in theory and in practice, the interdependence between the involved risks may result in the reduced diversified VaR while compared to the undiversified one. In other words, the imperfect correlation between the risks makes negative impacts be not as great as could be implied from the composition of the risk-specific VaR figures.

In respect to the fixed-income banking books, many financial institutions use the diversified VaR as a risk metrics, which support their investment and risk management decisions. Still such diversified VaR figures are based on bond price or bond yield time series. So it is not very clear what is the exact contribution of the risk-free interest rate moves and how credit spread widening affects the value of the bond portfolio because usually both components vary simultaneously producing the combined effect reflected in the yield or price.

The approach exposed below uses IRS and CDS quotes as proxies for the interest rate and credit risk factors. It permits to accurately compute the risk-specific VaR figures, the undiversified VaR and the diversified VaR and hence allows for better risk management decisions.

2.3 Interest rate risk-specific value at risk based on interest rate swap quotes

One of the commonly used approaches to IR risk assessment in banking books is the historical interest rate risk-specific VaR. The time series of IRS fixed-leg rate is used to gauge variations of the interest rate related risk factor. These variations affect asset values through the discount factors used in the net present value (NPV) calculation. The impact in value of a 5Y maturity bond caused by a one-year move in the interest rate, *ceteris paribus*, could be written as:

$$\Delta NPV_{IR,1Y}(d) = \left\{ \frac{[1 + y(d)]^5}{[1 + y(d) + \Delta IR_{1Y}(d)]^5} - 1 \right\} \times F \quad (1)$$

where $y(d)$ stands for the bond yield, $\Delta IR_{1Y}(d)$ represents a change in the risk-free interest rate occurred during the year preceding the date d , and F stands for the bond face value. As

the interest rate derivative quotes are used to compute the changes in NPV , herein $\Delta IR_{1Y}(d)$ stands for the 1-year change in the USD denominated IRS fixed rate at 5Y point of the term structure (Bloomberg ticker *USSW5*). The formula for $\Delta NPV_{IR_{1Y}}(d)$ represents a result of capitalization into the future at the rate $y(d)$ and the subsequent discounting of the future value to the present moment at the rate $y(d) + \Delta IR_{1Y}(d)$ that incorporates the change in the risk-free interest rate over occurred over one year.

For each chosen date d , $\Delta NPV_{IR_{1Y}}(d)$ is calculated using the 1-year long time window, which precedes this date d . Moving along the orderly arrangement of consecutive dates, the corresponding array of the value impacts is obtained. Using this array of the value impacts $\Delta NPV_{IR_{1Y}}(d)$, the risk-specific VaR for the IR risk with a confidence level of 99.9 per cent could be written as follows:

$$VaR_{IR} = C_{99.9\%}(\text{Array}[-\Delta NPV_{IR_{1Y}}]) \quad (2)$$

where C stands for centile, or percentile, indicating the threshold below which a 0.1 per cent percentage of the observed value impacts fall. This is but the absolute value of the negative impact whose probability to occur is less than 1 out of 1,000 that corresponds to the probability value of 0.1 per cent.

2.4 Credit risk-specific value at risk based on credit default swaps quotes

One of the commonly used approaches to credit risk assessment in banking books is the historical credit risk-specific VaR. Similarly, to the IR case, the impact in value of a 5Y maturity bond caused by a one-year move in credit spread could be written as:

$$\Delta NPV_{CS_{1Y}}(d) = \left\{ \frac{[1 + y(d)]^5}{[1 + y(d) + \Delta CS_{1Y}(d)]^5} - 1 \right\} \times F \quad (3)$$

where $\Delta CS_{1Y}(d)$ stands for a change in the credit spread occurred during the year preceding the date d . As the credit risk derivative quotes are used to compute the changes in NPV , herein $\Delta CS_{1Y}(d)$ stands for the one-year change in the USD denominated CDS spread of a chosen country at 5Y point of the term structure. Constructing the array of the value impacts, the risk-specific VaR for the credit risk with a confidence level of 99.9 per cent could be written as follows:

$$VaR_{CS} = C_{99.9\%}(\text{Array}[-\Delta NPV_{CS_{1Y}}]) \quad (4)$$

which is the absolute value of the negative impact whose probability to occur is less than 1 out of 1,000 or 0.1 per cent.

2.5 Derivative-based undiversified value at risk for the banking book

Undiversified VaR is a sum of the individual risk-specific VaRs:

$$VaR_{Undiversified} = VaR_{IRR} + VaR_{CS} \quad (5)$$

2.6 Derivative-based diversified value at risk for the banking book

Diversified VaR takes into account the inter-risk diversification effect. The newly proposed approach to joint IR and credit risk assessment is based on the integrated treatment of these risks. Under the proposed diversified VaR technique, the impact in value of a 5Y maturity

bond caused by the joint dynamics of a one-year interest rate move and the respective one-year credit spread move could be written as follows:

$$\Delta NPV_{CS\&IR_{1Y}}(d) = \left\{ \frac{[1 + y(d)]^5}{[1 + y(d) + \Delta CS_{1Y}(d) + \Delta IR_{1Y}(d)]^5} - 1 \right\} \times F \quad (6)$$

In this way, the diversified VaR accounting for the joint impact of IRR and CR is:

$$VaR_{Diversified} = C_{99.9\%}(Array[-\Delta NPV_{CS\&IR_{1Y}}]) \quad (7)$$

The comparison of $VaR_{Undiversified}$ and $VaR_{Diversified}$ sheds light on the interrelation between IR and credit risk for any chosen geography. It is expectable that $VaR_{Diversified}$ is inferior to the $VaR_{Undiversified}$ due to the risk diversification benefit. The origin of risk diversifications for IR and credit risk resides in a fact that the more impactful 1-year long value destroying changes in the interest rate and credit spread occur over different time windows, thus attenuating the dynamics of their composition. It is also worth noting that the difference between $VaR_{Undiversified}$ and $VaR_{Diversified}$ varies as a function of the holding period length and of the extension of the employed time series.

2.7 Yield-based diversified value at risk for the banking book

The yield time series-based calculation of the impacts in the value of the fixed-income securities portfolio is also one of the methods used across the financial sector to quantify the diversified VaR. Under this yield-based approach, the impact in value of a 5Y maturity bond caused by a one-year move in the bond yield (BY) could be written as:

$$\Delta NPV_{BY_{1Y}}(d) = \left\{ \frac{[1 + y(d)]^5}{[1 + y(d) + \Delta y_{1Y}(d)]^5} - 1 \right\} \times F \quad (8)$$

where $\Delta y_{1Y}(d)$ stands for a change in the bond yield occurred during the year preceding the date d . Constructing the array of the value impacts, the diversified VaR with a confidence level of 99.9 per cent based on the bond yield time series could be written as follows:

$$VaR_{BY} = C_{99.9\%}(Array[-\Delta NPV_{BY_{1Y}}]) \quad (9)$$

Although such integrated yield-based approach may seem to present benefit of a relative simplicity in comparison to the proposed herein conjoint IRS- and CDS-based approach, it also presents a certain weakness from the theoretical point of view, as possible impacts originated by interest rate and credit spread moves could be either reduced or amplified, by the liquidity component present in the yield. Thus, the implicit consideration of a liquidity component during the quantification of the diversified VaR following the bond yield-based approach could potentially lead to eventual mismanagement of the portfolio risks.

2.8 Distilling liquidity premium

The proposed herein derivative-based technique to risk assessment used along with the yield-based technique offers a possibility to track historical behavior of the liquidity premium in the yield, i.e. to quantify the bond specific liquidity risk. Plotting the sum of IRS

fixed rate and the CDS spread allows constructing a graph of a liquidity-free yield. The difference between the observable bond yield and the liquidity-free yield, obtained from IRS rates and CDS spread based inputs, is nothing but liquidity premium, serving as a reward for the money supplied for the bond.

Interest rate,
liquidity

3. Data and scope of application

The developed herein derivative-based methodology of integrated IR and credit risk evaluation is applied to the data on sovereign debt of developing countries. The country selection is aligned with the FTSE Global Equity Index Series Country Classification (FTSE International Limited, 2014), which distinguishes four emerging markets (EM) statuses, namely, advanced emerging, secondary emerging, frontier, and unclassified. The research is centered on three former categories, namely, advanced emerging, secondary emerging and frontier markets.

Advanced EM comprise ten countries: Brazil, Czech Republic, Hungary, Malaysia, Mexico, Poland, South Africa, Taiwan, Thailand and Turkey. As for Taiwan there is no CDS data, this country is excluded from the analyses. Hence, the final number of considered countries is nine.

Secondary EM consist of 11 countries: Chile, China, Colombia, Egypt, India, Indonesia, Pakistan, Peru, Philippines, Russia and UAE. As for India and UAE there is no CDS data, these countries are excluded from the analyses. Instead of UAE, the Emirate of Dubai, being a part of UAE and possessing sufficiently long CDS spread series is included. Hence, the final number of considered countries is ten.

Frontier markets category contains 26 countries. But CDS data coverage for this group is less extended. Thus, only the restricted universe of 11 countries is considered, namely, Bahrain, Cyprus, Estonia, Lithuania, Morocco, Romania, Serbia, Slovakia, Slovenia, Tunisia and Vietnam.

To make the scope of the paper more restricted, it focuses on 5 year (5Y) point in the term structures of yields and spreads, as this is the most tradable and the most liquid term. CDS quotes for USD denominated instruments are used due to the two reasons. First, such instrument is much more liquid than CDS denominated in other currencies. Second, this choice facilitates comparison of credit risks data and results across diverse countries, as they are quoted on the same basis. As a proxy for the USD denominated risk-free interest rate, an IRS rate at 5Y point (Bloomberg ticker: USSW5) is used.

For the sake of comparative analyses of the derivative-based approach and the approach based on USD denominated bonds yields, the yield curves downloaded from Bloomberg terminal are used for the two selected countries: Colombia and Peru. The yields of the sovereign zero coupon bonds with 5Y maturity are described by the following Bloomberg tickers: Colombia – F80305Y and Peru – I30305Y.

4. Results and discussion

4.1 Derivative-based undiversified versus diversified value at risk applied to emerging markets sovereign debt

This section presents the findings related to interdependence between interest rate and credit risk. Using CDS spreads and IRS rates as proxies for the CR- and the IRR-related components in bonds yields, respectively, historical VaR with 99.9 per cent confidence level is calculated as for December 31, 2014. The 5Y and 7Y lengths of time series are used for this exercise.

The comparison of undiversified VaR with the proposed herein diversified VaR allows for determining a diversification benefit as a difference between these two estimates in the six tables below, two tables for each of three developing countries' categories. This analysis is performed on a country-by-country basis, and also on the equally weighted category's

sub-portfolio basis, evidencing in this way a presence of a diversification benefit due to diversity of used geographies.

Tables I–VI evidence that the VaR figures depend on the historical length of time series used. Nevertheless, some common patterns could be observed. Analyzing VaR calculations for the equally weighted model portfolios for advanced EM, secondary EM and frontier markets for simultaneously both, 5Y- and 7Y-length periods, the diversified VaR is significantly lower than the undiversified VaR.

Comparison of VaR calculations performed for the three EM categories indicates that the debt of the less advanced markets is less sensible to the IRR. On the other hand, it could be inferred that the less advanced is the market to which belongs the issuer of a sovereign debt, the greater is idiosyncratic sovereign credit risk, which cannot be diversified off by eventual opposite dynamics in interest rates.

As the historical data sample spreads over the apogee of the world financial crisis between September 2008 and March 2009, both diversified and undiversified VaR calculations results in higher figures for 7Y-long time series than for the respective 5Y-long time series as the latter do not capture the entire history of the crisis development.

The diversified VaR values are lower if compared to credit risk-specific VaR considered as stand-alone. This fact indicates that for 5Y- and 7Y-long VaR series, the interest rate downtrend dynamics mitigate the credit spread widening.

4.2 Value at risk studies of non-core emu sovereign credit risk

Here, a subset of non-core European monetary union member states is subject to the separate analysis aimed at discovering whether certain structural characteristics of peripheral emu countries could explain eventual differences between the sovereign credit risk dynamics of the subset and the aggregate behavior of the emerging market countries in general.

Our non-core emu subset is composed of the following four states: Czech Republic, Estonia, Slovakia and Slovenia. These countries lying to the east of the core emu countries already were a part of our derivative-based VaR studies. Tables VII and VIII present the results for 5Y- and 7Y-long VaR series.

Tables VII and VIII evidence that dynamics of sovereign credit risk of the non-core emu subset does not represent any considerable difference from the all the sample of the analyzed here emerging countries (Tables I–VI). It is especially so for the 5Y-long time series used to calculate VaR metrics for December 2014.

Thus, the analyzed data cover the so-called European sovereign crisis of 2010. Although sovereign debt markets in a number of emu states came under unprecedented stress from the first half of 2010 onward, our VaR analysis does not show that these structural changes in fact resulted in a considerable increase of sovereign credit risk of the analyzed four non-core emu countries.

For 5Y-long data series, the risk-specific credit risk VaR of the subset is found to be 9.7 per cent (Table VII), which is superior to the 6.3 per cent credit VaR figure for advanced EM portfolio (Table I), and is inferior to the 11.0 per cent figure relative to the Frontier markets (Table V). As the Czech Republic belongs to advanced EM, while Estonia, Slovakia and Slovenia belong to the Frontier markets, such result is expectable.

The most interestingly, the 7Y-long time series, covering the global financial crisis reveal that the four analyzed herein non-core emu countries suffered from the crisis more than the EM in general. For instance, the risk-specific credit risk VaR of the non-core subset is found to be 17.7 per cent (Table VIII), which is superior to both, the 13.1 per cent credit VaR figure for advanced EM portfolio (Table II) and the 17.1 per cent figure relative to the Frontier markets (Table VI).

	Brazil	Czech republic	Hungary	Malaysia	Mexico	Poland	South Africa	Thailand	Turkey	Portfolio
Risk-specific IR VaR, %	5,29	5,30	5,16	5,30	5,30	5,29	5,29	5,29	5,27	5,28
Risk-specific CR VaR, %	4,95	5,13	16,17	5,91	4,57	8,52	5,25	6,60	8,94	6,33
Undiversified VaR, %	10,24	10,43	21,33	11,21	9,87	13,81	10,54	11,89	14,21	11,65
Diversified VaR, %	8,84	4,86	12,86	7,08	6,45	7,31	9,60	7,29	10,20	6,23
Diversification benefit, %	1,40	5,57	8,47	4,13	3,42	6,50	0,94	4,60	4,01	5,42

Interest rate,
liquidity

Table I.
VaR metrics for
advanced EM as of
December 2014 with
5Y-long time series

Table II.
VaR metrics for
advanced EM as of
December 2014 with
7Y-long time series

	Brazil	Czech republic	Hungary	Malaysia	Mexico	Poland	South Africa	Thailand	Turkey	Portfolio
Risk-specific IR VaR, %	α	5,28	5,15	5,29	5,29	5,27	5,27	5,28	5,26	5,27
Risk-specific CR VaR, %	β	11,98	19,81	10,30	15,31	15,17	13,80	9,49	12,08	13,01
Undiversified VaR, %	$\gamma = \alpha + \beta$	17,26	24,96	15,59	20,60	20,44	19,07	14,77	17,34	18,28
Diversified VaR, %	δ	8,89	8,31	7,02	11,58	10,43	9,60	7,22	10,08	8,93
Diversification benefit, %	$\varepsilon = \gamma - \delta$	8,37	8,98	8,57	9,02	10,01	9,47	7,55	7,26	9,35

	Chile	China	Colombia	Dubai	Egypt	Indonesia	Pakistan	Peru	Philippines	Russia	Portfolio
Risk-specific IR VaR, %	5,31	5,31	5,30	5,21	5,13	5,27	4,86	5,30	5,29	5,28	5,22
Risk-specific CR VaR, %	4,08	6,00	4,75	3,66	17,30	7,73	10,67	4,86	5,88	16,81	5,82
Undiversified VaR, %	9,39	11,31	10,05	8,87	22,43	13,00	15,53	10,16	11,17	22,09	11,04
Diversified VaR, %	5,76	6,35	6,62	4,41	17,09	10,25	10,31	6,89	5,17	17,20	6,40
Diversification benefit, %	3,63	4,96	3,43	4,46	5,34	2,75	5,22	3,27	6,00	4,89	4,64

Interest rate,
liquidity

Table III.
VaR metrics for
secondary EM as of
December 2014 with
5Y-long time series

Table IV.
VaR metrics for
secondary EM as of
December 2014 with
7Y-long time series

	Chile	China	Colombia	Dubai*	Egypt	Indonesia	Pakistan	Peru	Philippines	Russia	Portfolio
Risk-specific IR VaR, %	5.30	5.29	5.29	n.a.	5.11	5.26	4.86	5.29	5.27	5.27	5.21
Risk-specific CR VaR, %	9.96	8.64	12.70	n.a.	23.83	21.38	47.23	13.90	10.44	26.01	14.83
Undiversified VaR, %	$\gamma = \alpha + \beta$	13.93	17.99	n.a.	28.94	26.64	52.09	19.19	15.71	31.28	20.04
Diversified VaR, %	δ	6.14	8.74	n.a.	17.76	16.32	47.50	9.94	6.29	22.66	10.98
Diversification benefit, %	$\varepsilon = \gamma - \delta$	9.12	7.61	n.a.	11.18	10.32	4.59	9.25	9.42	8.62	9.06

Note: *No 7Y-long series of CDS spread available

	Bahrain	Cyprus	Estonia	Lithuania	Morocco	Romania	Serbia	Slovakia	Slovenia	Tunisia	Vietnam	Portfolio
Risk-specific IR VaR, %	α	5.18	4.89	5.30	5.27	5.25	5.18	5.12	5.14	5.20	5.20	5.16
Risk-specific CR VaR, %	β	11.09	43.00	4.52	5.97	8.33	11.08	9.94	17.37	6.80	12.68	11.00
Undiversified VaR, %	$\gamma = \alpha + \beta$	16.27	47.89	9.82	11.24	13.58	16.26	15.06	22.51	12.00	17.88	16.16
Diversified VaR, %	δ	10.44	41.04	4.72	5.55	7.05	7.52	9.29	15.66	8.07	11.98	10.02
Diversification benefit, %	$\varepsilon = \gamma - \delta$	5.83	6.85	5.10	5.69	6.53	8.74	5.77	6.85	3.93	5.90	6.14

Interest rate,
liquidity

Table V.
VaR metrics for
frontier markets as of
December 2014 with
5Y-long time series

Table VI.
VaR metrics for
frontier markets as of
December 2014 with
7Y-long time series

	Bahrain*	Cyprus*	Estonia	Lithuania	Morocco*	Romania	Serbia	Slovakia	Slovenia	Tunisia	Vietnam	Portfolio
Risk-specific IR VaR, %	α	n.a.	5.29	5.25	n.a.	5.16	5.11	5.26	5.12	5.19	5.19	5.20
Risk-specific CR VaR, %	β	n.a.	28.62	27.56	n.a.	23.92	17.27	11.36	17.33	16.34	17.09	17.09
Undiversified VaR, %	$\gamma = \alpha + \beta$	n.a.	33.91	32.81	n.a.	29.08	22.38	16.62	22.45	16.06	21.53	22.29
Diversified VaR, %	δ	n.a.	25.29	24.53	n.a.	19.68	14.11	9.17	15.65	14.43	12.58	13.52
Diversification benefit, %	$\varepsilon = \gamma - \delta$	n.a.	8.62	8.28	n.a.	9.40	8.27	7.45	6.80	1.63	8.95	8.77

Note: *No 7Y-long series of CDS spread available

The undiversified 7Y-long VaR figure and diversified 7Y-long VaR figure are superior to the corresponding metrics of advanced EM and frontier markets. On the contrary, the diversification benefit of the non-core emu states portfolio of 8.3 per cent is less than the diversification benefits for EM in general. This reveals an existence of a superior non-diversifiable sovereign risk component in the non-core emu countries.

This feature could be explained by the fact that sovereign risk in EM in general varies rather with USA market uncertainty, while non-core emu sovereign risk additionally suffers from structural imbalances between the leading emu core and the following emu periphery.

Interest rate,
liquidity

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4.3 Value at risk studies of the relationship between oil prices and sovereign credit risk

Among considered in our research EM, there are some oil producing countries, such as Brazil, Malaysia and Russia. In this subsection, the oil price influences on the sovereign risk premia is addressed considering the interrelation of the Russian sovereign risk dynamics and time behavior of Brent oil prices.

Figure 1 presents the comparative behavior of Brent oil price versus 5Y Russian sovereign CDS spread.

The curves depicted in Figure 1 behave in an opposite mode, inducing to conclude that there is an inverse relation between the oil prices and CDS spread, which is observable over the whole analyzed time interval. As Russian sovereign CDS spread is but a measure of creditworthiness of Russian government debt, the hikes in oil prices seem to reduce the perceived riskiness of the sovereign debt of this oil producing country.

This situation becomes even more evidenced when the correlation coefficient is considered. Figure 2 presents the time dynamics of the 120-days correlation coefficient between the Russian sovereign 5Y CDS spread and the Brent barrel price.

Figure 2 evidences that the correlation coefficient between the oil price and the Russian sovereign CDS is predominantly negative. The average value of the correlation coefficient, -0.23 , is also depicted in Figure 2 by dotted line. This result also corroborates with the statement that positive oil price shocks lead to lower sovereign CDS spreads, and vice versa.

Another important insight on this subject could be obtained by comparing VaR metrics of Russian sovereign debt as per 5Y CDS, calculated according to equations (3) and (4), and VaR metrics relative to the investment in oil commodity of Brent type, which was

Table VII.
VaR metrics for non-core emu states as of December 2014 with 5Y-long time series

		Czech republic	Estonia	Slovakia	Slovenia	Portfolio
Risk-specific IR VaR, %	α	5,30	5,30	5,28	5,14	5,26
Risk-specific CR VaR, %	β	5,13	4,52	11,79	17,37	9,70
Undiversified VaR, %	$\gamma = \alpha + \beta$	10,43	9,82	17,07	22,51	14,96
Diversified VaR, %	δ	4,86	4,72	9,21	15,66	8,61
Diversification benefit, %	$\varepsilon = \gamma - \delta$	5,57	5,10	7,86	6,85	6,35

Table VIII.
VaR metrics for non-core emu states as of December 2014 with 7Y-long time series

		Czech Republic	Estonia	Slovakia	Slovenia	Portfolio
Risk-specific IR VaR, %	α	5,29	5,29	5,26	5,12	5,24
Risk-specific CR VaR, %	β	13,36	28,62	11,36	17,33	17,67
Undiversified VaR, %	$\gamma = \alpha + \beta$	18,65	33,91	16,62	22,45	22,91
Diversified VaR, %	δ	8,31	25,29	9,17	15,65	14,61
Diversification benefit, %	$\varepsilon = \gamma - \delta$	10,34	8,62	7,45	6,80	8,30

Figure 1.
Oil price vs 5Y
Russian sovereign
CDS spread, January
2003 to March 2017

calculated as a percentile of the oil price changes. [Figure 3](#) allows for comparative analysis of these two metrics expressed in percentage terms.

The VaR metrics presented in [Figure 3](#) were calculated with 99.9 per cent confidence level using 5Y-long historical series. As could be seen in [Figure 3](#), over the period November 2005 – November 2014, the credit VaR, representing sovereign risk of Russian government debt, was almost half a value of the VaR relative to the investment in oil. This is a plausible result as during those times the revenues from oil export represented roughly a half of Russian GDP.

But, since the end of 2014, the situation is changed; the credit VaR relative to investments in Russian sovereign debt is less than a third of the VaR relative to oil price changes. This situation could also be interpreted by taking into account the international sanctions imposed on Russia by the international community in response to Crimea events.

These sanctions had a lateral impact on Russian economy, provoking decoupling of the Russian sovereign risk from its very strong oil dependence by diversifying the economy over many other economic activity sectors, which were not so active prior to the sanctions. So-called import substitution effects resulted in fact in diminishing of sovereign risk, as the economy became less vulnerable to oil price shocks.

Thus, using data from Russian sovereign CDS and Brent oil price time series, it is demonstrated that positive oil prices dynamics can alleviate the sovereign credit constraints. But simultaneously, there is some evidence that financial markets give a premium to oil producing countries, which are trying to diversify their economies, by decreasing sovereign debt spreads.

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Figure 2.
Correlation between
oil price and 5Y
Russian CDS spread,
January 2003 to
March 2017

Figure 3.
VaR Metrics: Russian
debt as per 5Y CDS
vs oil price,
November 2015 to
November 2016

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18,4

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4.4 Changing interdependence between interest rate and credit risk: long time horizon

Interdependence between IRR and CR varies according to diverse phases of the business cycle. During the periods of capital migration from risky to safe assets, defined as flight-to-quality, the CR spreads of the former increase while the yields of the latter drop. Such joint behavior of these risk factors took place during the recent financial crisis, when interest rates dropped and simultaneously the average creditworthiness of debt issuers, including sovereign EM governments, deteriorated too. These circumstances are rather common and expectable, as crashes and recessions usually always coincide with downward tendency in interest rates dynamics (Gubareva and Borges, 2016).

Tables IX and X present the results for the two very distinct periods in the recent history, namely, prior and after the pick of the global financial crisis. The selected set of 16 developing countries is considered herein as only for these countries the necessary length of historical CDS spread quotes is available.

Comparison of the Tables IX and X leads to the conclusion that the diversification benefits of the joint consideration of the interest rate and CR are more significant for the 2004-2008 period.

Still, the proposed herein derivative-based diversified VaR technique accounts correctly for the higher riskiness of the pre-crisis period.

4.5 Comparative analysis of the diversified value at risk: derivative-based versus yield-based

To quantify VaR of fixed-income portfolios, many financial institutions use historical series of the respective bond yields. Table XI envisages comparing this yield-based methodology, to the proposed herein derivative-based *diversified VaR* approach. Additionally, the derivative-based undiversified VaR is also included for the comparative analyses.

Based on calculations used 5 year long time series, Table XI demonstrates that the liquidity conditions originate impacts of different degree on bonds of the considered countries. For example, in the case of the Brazilian and Mexican debt, no material impact could be observed on the yield-based VaR from liquidity conditions, as its figures are quite similar to the derivative-based diversified VaR.

Country	Risk-specific IR VaR, % α	Risk-specific CR VaR, % β	Undiversified VaR, % $\gamma = \alpha + \beta$	Diversified VaR, % δ	Diversification benefit, % $\varepsilon = \gamma - \delta$
Brazil	7,42	20,38	27,80	16,72	11,08
Chile	7,80	12,99	20,79	8,80	11,99
China	7,80	11,20	19,00	7,54	11,46
Colombia	7,54	19,36	26,90	15,65	11,25
Hungary	7,81	22,86	30,67	19,31	11,36
Malaysia	7,79	18,34	26,13	14,47	11,66
Mexico	7,75	21,93	29,68	18,33	11,35
Peru	7,55	19,85	27,40	16,06	11,34
Philippines	7,46	25,93	33,39	22,59	10,80
Poland	7,80	11,51	19,31	8,20	11,11
Romania	7,70	25,80	33,50	20,54	12,96
Russia	7,69	36,69	44,38	33,92	10,46
Slovakia	7,81	9,79	17,60	7,45	10,15
South Africa	7,75	23,73	31,48	20,17	11,31
Thailand	7,80	17,57	25,37	13,75	11,62
Turkey	7,56	24,99	32,55	21,62	10,93
Portfolio	7,69	19,85	27,54	16,08	11,46

Table IX.
5Y-Long pre-crisis
time series VaR for
December 2008

Table X.
5Y-Long post-crisis
time series VaR for
December 2013

Country	Risk-specific IR VaR, % α	Risk-specific CR VaR, % β	Undiversified VaR, % $\gamma = \alpha + \beta$	Diversified VaR, % δ	Diversification benefit, % $\varepsilon = \gamma - \delta$
Brazil	5,29	4,95	10,24	8,84	1,40
Chile	5,31	4,08	9,39	5,76	3,63
China	5,31	6,00	11,31	6,35	4,96
Colombia	5,30	4,67	9,97	6,62	3,35
Hungary	5,16	16,17	21,33	12,86	8,47
Malaysia	5,30	5,91	11,21	7,08	4,13
Mexico	5,30	4,57	9,87	6,45	3,42
Peru	5,30	4,86	10,16	6,89	3,27
Philippines	5,29	5,88	11,17	5,14	6,03
Poland	5,29	8,53	13,82	7,31	6,51
Romania	5,18	11,08	16,26	7,52	8,74
Russia	5,28	7,56	12,84	7,60	5,24
Slovakia	5,28	11,79	17,07	9,21	7,86
South Africa	5,29	5,25	10,54	9,60	0,94
Thailand	5,29	6,60	11,89	6,30	5,59
Turkey	5,27	8,94	14,21	9,64	4,57
<i>Portfolio</i>	<i>5,28</i>	<i>6,26</i>	<i>11,54</i>	<i>5,66</i>	<i>5,88</i>

Table XI.
5Y Time series VaR:
derivative-based vs
yield-based,
December 2014

	Brazil	Colombia	Mexico	Peru	Turkey
Derivative-based undiversified VaR, %	10,24	10,05	9,87	10,16	14,21
Derivative-based diversified VaR, %	8,84	6,62	6,45	6,89	10,20
Yield-based VaR, %	8,70	8,56	6,49	7,56	11,77

For Colombian and Turkish debt, the liquidity risk acts rather as an amplifier of the impacts of interest rate and credit spread components, substantially increasing in this manner the yield and resulting in the increase in the *yield-based VaR* of the Colombian and Turkish sovereign debt.

For Peru, the liquidity component also amplifies the impacts of interest rate and credit spread components, but not so strongly as in the case of Colombia and Turkey.

To precisely explain the differences between the derivative-based and yield-based VaR, further detailed research is needed. But still the results presented in [Table IX](#) allow to infer that yield-based analyses, under certain conditions, could result into perceived creditworthiness that appears as more or less appealing than real creditworthiness as implied from the CDS spreads. Hence, such situation could lead to under- or overestimation of the overall riskiness of the sovereign exposures.

Additionally, the proposed herein derivative-based approach could be useful not only for more accurate historical VaR analysis but also for disentangling liquidity components and tracking it on a daily basis.

4.6 Liquidity premium as a difference between derivative-based and yield-based values at risk

Liquidity premium, i.e. a reward for the money supplied for the bond, can be estimated for the sovereign debt issues, as the difference between the observable bond yield and the hypothetical liquidity-free yield, constructed as the sum of the IRS rate and the CDS spread.

Exemplifying the proposed herein approach, [Figures 4-5](#) depict the liquidity elements present in the sovereign debt yields of Colombia and Peru. The liquidity element is calculated as the difference between the generic sovereign zero-coupon yield of 5Y-maturity debt, represented by the corresponding Bloomberg yield curve, and the derivative-based liquidity-free proxy, constructed as a sum of the USD-denominated IRS rate at 5Y point, namely, the USSW5 curve and the respective sovereign CDS spread for 5Y maturity debt according to the data available on Bloomberg terminal.

For example, in regards to the sovereign debt of the Colombian Government, [Figure 1](#) evidences an excess of liquidity prior to the global financial crisis, a hike of illiquidity during the apogee of the global financial crisis, and a certain lack of liquidity during the years following the global financial turmoil.

The slightly positive post-crisis values of the liquidity premium for the Colombian sovereign bonds, which could be observed in [Figure 4](#), reflect a rather moderate investors' interest in Colombian sovereign debt.

Another example of liquidity premium dynamics regarding the sovereign debt issued by the Peruvian government is present in [Figure 5](#).

[Figure 5](#) evidences an excess of liquidity of the Peruvian sovereign debt prior to the global financial crisis, similarly to the situation with the considered before Colombian debt. These situations are rather related to the pre-crisis excess liquidity on the global scale though also being influenced by idiosyncratic features of the sovereign issuers. After the illiquidity spike around the pick of the crisis, certain liquidity constrains relative to the Peruvian debt could be seen in 2008-2010 time interval. The past three years present a predominantly negative liquidity component likely reflecting high investors' interest in Peruvian government securities.

Summarizing, for the considered here examples of the two countries, Colombia and Peru, the liquidity component makes sovereign debts to appear either excessively risky in those periods when the respective liquidity premium is positive or to mask their real riskiness in the periods when the liquidity premium exhibits negative values.

Thus, the proposed herein derivative-based diversified VaR is useful for distilling liquidity premia and tracking it on a continuous basis. It is important issue as liquidity risk premia nowadays play an important role in explaining sovereign bond spreads. Thus, the current environment where there is strong demand for sovereign credit could be masking a potential structural rise in riskiness of sovereign debt.

Figure 4.
Liquidity premium in
Colombian sovereign
5Y yield, January
2004 to December
2014

Interest rate,
liquidity

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Figure 5.
Liquidity premium in
Peruvian sovereign
5Y yield, January
2004 to December
2014

5. Conclusions

This research advances a historical VaR technique for studies of IRR and CR interdependence. The use of IRS rates and sovereign CDS spreads as proxies for the interest rate and sovereign credit risk, respectively, allows reconstructing the interest rate and credit spread components in the sovereign bond yields.

Based on sovereign CDS data covering the 30 developing countries, it is demonstrated that the interest rate downtrend dynamics partly mitigates the credit spread widening, as for all lengths of the considered time series, the diversified VaR figures are found to be consistently lower than the undiversified VaR values.

It is also evidenced that the interaction between IRR and CR varies according to diverse phases of the business cycle. For instance, the negative response of credit spreads to interest rates were more pronounced in the pre-crisis period than during the post-crisis environment.

The quantification of interest rate and credit spread based on the time series of CDS and IRS quotes allowed to construct the hypothetical liquidity-free bond yield. This yield compared to the real bond yield containing a liquidity component made it possible to assess a liquidity premium in a sovereign bond yield.

With regard to European sovereign risk issues, our approach is applied to address the sovereign risk dynamics of some non-core emu states. It is evidenced that during the time of distress, the non-core emu states are more vulnerable than EM in general, as sovereign risk in EM varies rather with US market uncertainty, while non-core emu sovereign risk additionally suffers from structural imbalances between the leading emu core and the emu periphery.

Additionally, the oil price influences on the sovereign risk premia of oil producing countries are addressed considering the interrelation of the Russian sovereign risk dynamics and time behavior of oil prices. Using data from Russian sovereign CDS and oil price time series, it is demonstrated that positive oil prices dynamics can alleviate the sovereign credit constraints.

Finally, the proposed and applied herein derivative-based joint downside risk evaluation further advances the use of derivatives, such as IRS and CDS, in researching the interdependence among multiple risk factors. It could be used for quantification of the economic capital, i.e. funds to be set aside to withstand eventual negative impact due to joint action of diverse risk factors.

Last but not the least, the applicability of the proposed derivative-based diversified VaR methodology is considerably wider than the sovereign debt of EM. It can be applied to diverse portfolios containing several types of assets, more sophisticated than bonds, such as loans, credit-linked notes and total return swaps, among others. Thus, further research in this field is highly desirable for positively impacting overall efficiency of financial system. It potentially allows financial institutions to improve their risk assessment.

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