A cost-risk analysis of sovereign debt composition in CESEE

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Drawing on a newly compiled structural debt database, this article examines sovereign interest rate exposure in ten countries in Central, Eastern and Southeastern Europe (CESEE). The average maturity of sovereign debt has lengthened over time and converged across CESEE, indicating that the likelihood of sudden changes in interest rate has decreased since 2009. Using a simple theoretical model, this article identifies the drivers of this development, highlighting the role of debt managers' risk preferences.

JEL classification: H63
Keywords: debt management, interest rate risk, financial vulnerability, CESEE region

The composition of public debt affects both the costs and risks of running fiscal deficits. For instance, debt with a shorter term to maturity tends to have a lower interest rate, but is often associated with greater volatility and rollover risk. In principle, it is down to debt managers to identify such cost-risk tradeoffs, determine the acceptable level of risk and align the debt portfolio with the government's preferences (The World Bank and IMF, 2014).[2] The multitude of borrowing options and the volatility of financial markets also suggest that continuous risk monitoring and a comprehensive strategy are key in guiding sovereign borrowing decisions. Yet, in practice, public debt management efforts vary considerably (see e.g. Melecky, 2007; Cabral, 2015). Some debt agencies define strategic goals in terms of structural debt indicators, evaluate the achievement of targets periodically and continuously update their strategy based on in-depth assessments of financial and macroeconomic trends; some monitor the progression of structural debt indicators and economic variables rigorously, but do not disclose a more detailed quantitative strategy; and some follow no discernible strategy at all.

In the light of recent history, the variation in national endeavors is surprising. In the wake of the financial crisis, several European governments had to rely on third-party assistance to meet their debt obligations. In many countries, the difficulties in funding the public sector on private capital markets did not stem from imprudent borrowing decisions (Baldwin et al., 2015). Instead, the composition of public debt exacerbated the disastrous impact of the sudden hike in interest rates and, furthermore, the implied increase in funding requirements seems to have encouraged higher risk taking. De Broeck and Guscina (2011) document a shift in public debt structures toward shorter maturities, larger amounts of foreign currency debt and a greater reliance on floating interest rates following the financial crisis. As national governments are typically the largest domestic borrower, sovereign defaults have the potential to induce or amplify economic crises. In this context, effective public debt management is key to maintaining a country's financial stability.

Drawing on a newly compiled structural database, this article examines the outcomes of public debt management across countries in Central, Eastern and

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[2] *It should be noted that ministries of finance are typically responsible for deciding what to spend funds on, while debt agencies decide on how the spending is to be financed.*

Southeastern European (CESEE). Risk to a government's debt stock emanates from multiple sources, including uncertainty in the path of interest and exchange rates (market risk), unanticipated cash flow obligations (liquidity risk), nonperformance of borrowers (credit risk), nondelivery of contracted obligations (settlement risk) and other forms of risk that most organizations face but that are particularly severe for a debt management agency (operational risk).[3] The analysis investigates the cost-risk tradeoff involved in deciding on the debt portfolio's maturity structure. I define risk as the one-step ahead variance in the composite interest rate on short- and long-term bond obligations and costs as its expected value. By quantifying the potential magnitude of sudden fluctuations in interest rates, this article provides an initial comparative assessment of the costs, risks and risk preferences implicit in the structure of sovereign debt portfolios for several CESEE countries[4], which is intended to support the evaluation of financial vulnerabilities across the region.

The empirical findings reveal that interest rate risk, as defined above, has decreased in most of the countries under review. The average maturity[5] of public debt has lengthened over time and converged across the region. At the same time, the volatility of domestic bond yields has decreased or remained constant in most CESEE countries. This suggests that the impact of sudden interest rate hikes on local markets is less of a concern today than it was shortly after the financial crisis. Both debt management decisions (such as a lengthening of maturities) and changes in funding conditions (such as a decrease in the volatility of bond yields) may have led to the observed decrease in interest rate risk. On the basis of the insights of a simple theoretical model that identifies some of the drivers behind an optimal maturity decision, the empirical analysis disentangles the change in interest rate risks accordingly. The results suggest that the widespread decline in the relative costs of long-term borrowing has contributed significantly to the reduction in interest rate risk. Importantly, the analysis also suggests that changes in risk preferences have affected the conditional variance of interest payments both positively and negatively.

The article is structured as follows: The first section clarifies in a simple theoretical model the cost-risk tradeoff associated with the structure of the government debt portfolio, characterizing the basic properties of an optimal maturity structure and the optimal response to dynamics in the yield curve. To highlight the role of debt structure, the model takes the level of debt as given, determined by fiscal policy, and thus examines optimal behavior from an independent debt management perspective. Drawing on the model's insights, section 2 introduces the new structural debt database, outlining the empirical approach to measuring interest rate risk across countries. Section 3 provides a structural interpretation of the empirical findings, discussing costs, risks and debt managers' implicit risk preferences. Section 4 concludes.

[3] *The World Bank and IMF (2014) summarize and explain these risks in more detail.*

[4] *This article examines the magnitude and drivers of interest rate risk in Bulgaria, Croatia, the Czech Republic, Hungary, Poland, Romania, Russia, Slovakia, Slovenia and Turkey.*

[5] *Strictly speaking, the empirical findings are based on the debt portfolio's average term to refixing (ATR). If all debt is issued at a fixed interest rate, which is a reasonably good approximation for the countries under review, this measure is equivalent to the average term to maturity (ATM). For the sake of simplicity, this article refers mainly to ATM.*

1 Theoretical considerations

Over time, the theoretical literature on debt management has highlighted a range of goals (for a summary, see de Haan and Wolswijk, 2005). Early contributions focused on the potential stabilizing impact of structural debt decisions on business (Tobin, 1963) and taxation (Barro, 1999). Debt management was thus viewed as being closely linked to monetary policy. With the rise of New Keynesian models, which suggest that the business cycle can be managed solely with the short-term policy rate, the instrumental character of debt management vanished from the theoretical literature (Zampolli, 2012). Missale (2000) introduced risk minimization as an explicit objective in the context of the newly introduced fiscal frameworks. A common theme in these contributions is that interest payments should be contingent on the state of the economy and thereby smooth government outlays.

In practice, however, debt management agencies focus primarily on stabilizing government debt. The widespread mandate is to minimize sovereign funding costs with a view to containing risk at a prudent level. This section develops a simple model, describing the basic features of a maturity structure that would achieve the double objective of minimizing costs and the risk stemming from interest rate dynamics. Given the dominance of fixed-coupon bonds, the model disregards the issuance of variable rate debt and thus interchangeably uses the expressions "average term to refixing," "average term to maturity" or simply "average maturity." It also disregards the issuance of foreign currency obligations in order to confine the analysis to interest rate risk.

1.1 Basic setup

Consider a sovereign issuing two types of fixed-coupon bonds that differ only in terms of their maturity: one matures next year, while the other matures in *N* years. The overall financing needs are determined by fiscal policy, constant and normalized to 1. Debt managers decide on the share of obligations *(1–α)* that are rolled over each year. The remaining obligations are distributed evenly between *N* bonds, issued in *N* distinct years to ensure a smooth redemption profile. These assumptions imply that the composite interest rate paid in period *t* follows the weighted average

$$R_t = (1-\alpha) i_t^s + \frac{\alpha}{N} \sum_{j=1}^{N} i_{t+1-j}^l , \qquad (1)$$

where α denotes the share of long-term debt, i_t^s is the interest rate paid on short-term obligations and i_t^l is the period *t* interest rate on long-term obligations. The parameter α also determines implicitly the average term to maturity *(ATM)* of the debt portfolio: a share *(1–α)* matures next year, while the remaining obligations mature in 1 to *N* years. The *ATM* is therefore derived from

$$ATM = (1-\alpha) * 1 + \alpha \frac{1}{N}(1+2+\cdots N) = 1 + \alpha \frac{N-1}{2} , \qquad (2)$$

after issuing this period's debt. A simple example explains why maturity structure plays a role in tempering the impact of interest rate dynamics: Suppose that the entire debt portfolio consists of ten-year bonds $(\alpha = 1, N = 10)$. The average maturity is then five and a half years, and one-tenth of the debt portfolio is rolled over each year. By contrast, if all the debt is financed with one-year bonds, the average maturity is exactly one year, and the entire portfolio is rolled over each year. Prevailing conditions on the sovereign bond market thus have less of an impact the longer the average maturity of the debt portfolio. The model formalizes this basic insight regarding the relation between maturity structure and risk.

For the sake of simplicity, I assume that long- and short-term bond yields are random variables with stationary means. Their average difference, the term spread, is positive and denoted by $b = i^l - i^s$. Arbitrage opportunities imply a correlation between deviations across the yield curve. I denote the variance in long- and short-run bond yields by σ_l^2 and σ_s^2 respectively, and their covariance by $\beta\sigma_s^2$. It follows that the average interest rate (the costs) and the one step-ahead variance (the risk) in the composite interest rate read

$$c(\alpha) = i_s + \alpha b \quad \textit{and} \quad r(\alpha) = (1 - \alpha e)^2 \sigma_s^2 + \left(\frac{\alpha}{N}\right)^2 \sigma_l^2 \, , \tag{3}$$

where $e = 1 - \frac{\beta}{N}$ captures the relative sensitivity of interest payments associated with long- and short-term debt.[6] This system of equations represents the typical cost-risk tradeoff in debt management decisions: by increasing the maturity of public debt, debt managers increase average funding costs, $c'(\alpha) > 0$, as the yield curve is upward sloping. At the same time, a longer maturity reduces the likelihood of deviations from the target value, $r'(\alpha) < 0$, because a smaller share of debt needs to be rolled over each period.[7] It follows that, as the maturity lengthens, the composite interest rate becomes more stable and predictable, but increases in magnitude. Given that this tradeoff applies, by construction, to all values of α, the debt portfolio is efficient. Preferences determine optimality.

1.2 The optimal maturity structure

From the theoretical literature on the optimal maturity structure, I assume that debt managers pursue a mean-variance objective.[8] Preferences regarding cost-risk combinations thus follow

$$U(c, r) = \delta c(\alpha) + (1 - \delta) r(\alpha),$$

where δ represents the relative weight debt managers place on minimizing costs. A balanced choice of α requires the marginal rate of transformation between costs

[6] *To arrive at risk, note that* $R_t - E[R_t|t-1] = (1-\alpha)w_t^s + \frac{\alpha}{N}(\beta w_t^s + w_t^l) = (1 - e\alpha)w_t^s + \frac{\alpha}{N} w_t^l$, *where* w_t^k *is the idiosyncratic error of* k*-term bond yields in period* t*. Squaring this expression gives the second part of equation (3).*

[7] *An increase in unambiguously reduces the variance in the next period's interest rate if the sensitivity of long-term yields is sufficiently lower than that of short-term yields. The exact condition is* $\frac{\alpha}{N^2}\sigma_l^2 < e(1 - \alpha e)\sigma_s^2$. *As* N *tends to infinity, this condition merely requires a positive variance in short-term bond yields.*

[8] *The mean-variance objective can be interpreted as a second order approximation to a more general preference function in relation to interest rates.*

and risk to be aligned with debt managers' indifference curves. With linear preferences, this condition can be rearranged to give the optimal maturity structure as an explicit function of risk preferences and basic properties of the yield curve:

$$\alpha^* = \frac{(1-\delta)e\sigma_s^2 - \frac{1}{2}\delta b}{(1-\delta)\left(e\sigma_s^2 + \frac{\sigma_l^2}{N^2}\right)}. \tag{4}$$

The nonnegativity of short- and long-term bond volatility implies that this condition is sufficient. The equation provides a number of intuitive and useful insights. It shows that the optimal maturity structure is, as expected, a decreasing function of the relative weight placed on cost minimization, a decreasing function of the yield curve's slope and an increasing function of the volatility of both short-term and long-term bond yields. Notably, parallel shifts in the yield curve leave marginal incentives unchanged. The yield curve's intercept therefore does not affect the optimal maturity structure in this simple setting.

Note that this simple model neglects general equilibrium effects in that debt managers' choice of maturity structure does not affect the yield curve. While standard economic theory would support this claim from the perspective of exploiting arbitrage opportunities, the assumption might not hold true in practice. The annex thus provides an extension of the model, allowing for supply effects. The analysis suggests that portfolio-rebalancing effects, i.e. an increase in the term spread in response to a lengthening of average maturity, rationalize shorter optimal maturity structures owing to the increase in the marginal costs of long-term debt.

1.3 Implications for the assessment of interest rate risk

Structural debt indicators are widely used to gauge the degree of risk exposure. For instance, the maturity structure often serves to evaluate the degree of interest rate and/or rollover risk, with longer maturities perceived to be less risky. Structural indicators are a simple and effective tool for understanding risk developments within a country and over a limited time horizon. However, more generally, interest rate risk is the result of both active debt management decisions (the maturity structure) and market conditions (the volatility and structure of the yield curve):

$$r = f(\alpha, \sigma_s^2, \sigma_l^2).$$

Accordingly, the evaluation of interest rate risk requires at least estimates of the volatility of short- and long-term bond yields, in addition to information on the maturity structure. The theoretical model implies that more general developments in domestic financing conditions also impact indirectly on the degree of interest rate risk, as the optimal maturity structure is itself a function of basic properties of the yield curve and risk preferences. Interest rate risk can thus be viewed as the combined effect of local market characteristics and preferences:

$$r^* = g\left(\sigma_s^2, \sigma_l^2, b, \delta\right).$$

Accordingly, the same ATM could imply different degrees of effective interest rate risk, depending on the volatility of the underlying yield curve. Structural indicators may therefore be misleading measures for evaluating risk across countries or across a longer time horizon, where the underlying volatility plausibly changes.

2 Empirical analysis

2.1 Conceptual issues

The empirical analysis draws on the insights of the theoretical model and develops standardized risk measures that incorporate information on four drivers of risk: the volatility of short-term bonds, the volatility of long-term bonds, the term spread and risk preferences. In order to compile these measures and decompose risk accordingly, time-varying estimates of the parameter vector $(\sigma_s^2, \sigma_l^2, b, \delta)$ are needed. I proceed in four steps:

1. Time-varying estimates of short- and long-term bond yields are derived from both a simple regression analysis and nonparametric methods (see below for details). This step directly provides an estimate of the time-varying slope *b*.
2. A Cholesky decomposition of the estimated residuals identifies the structural shocks, where the order is derived from the theoretical model.
3. A local linear ridge regression on the (squared) structural residuals provides a flexible and time-varying estimate of the volatility of short- and long-term bond yields. The optimal bandwidth is determined via cross-validation (see below for details).
4. Combining time-specific information on the average maturity, volatility and slope of the yield curve with the theoretical model (equations (1) to (4)), finally, gives a time-varying estimate of the implicit weight placed on cost minimization, δ.

Interest rate risk then follows from the definition given above, while the decomposition employs a simple linearization. Note that observable yields reflect both investors' relative demand for long- and short-term bonds, and debt agencies' supply thereof. A structural decomposition of interest rate risk explicitly identifies changes in debt managers' risk preferences. Changes in investors' risk preferences, by contrast, work indirectly through a change in marginal costs; they are not identified and not constrained in this analysis.

2.2 Regression specification

Short- and long-term bond yields typically move in similar directions. To exploit efficiency gains in the estimation, I allow for correlation in residuals and examine the determinants of short- and long-term bond yields in a dynamic panel seemingly unrelated regression (SUR) approach. The estimating equation reads

$$y_{it} = y_{i,t-1} + \mu + \beta x_{it} + \tau_{it} + \epsilon_{it},$$

where the dependent variables are one- and ten-year generic bond yields, the vector *x* captures its drivers and the coefficient matrix is constant across countries. I drop the restriction and allow the coefficients to differ across countries when quantifying interest rate risk. The intercept vector is country- and yield-specific to control for heterogeneity in time preferences and the vector τ_{it} controls for country- and yield-specific time trends of the third order (compare the progression of yields in the descriptive section below). The error-vector is independent and identically distributed across time, but not countries. I allow for a fully flexible country-specific covariance pattern between the unobservable components in one- and ten-year bond yields and estimate the system of equations with a feasible generalized least squares (GLS) approach, thereby increasing the efficiency of short- and long-term elasticity predictions. Given the extensive time dimension *(T=29)*, the bias in dynamic regression specifications (Nickell, 1981) should be less of a concern in this context. The estimation results seem to confirm this conjecture.

Term structure models suggest that the interest rate, the risk of default and the expected loss given default are the key determinants of bond yields (Liu et al., 2009). In the long run, the interest rate is a function of economic growth, households' time preferences, risk-free investment opportunities abroad and exchange rates. In the short run, monetary policy and inflation shocks are likely to play a role (Poghosyan, 2012). Accordingly, the explanatory vector comprises public debt and deficit as a share of government revenue to proxy for the risk of default. It also includes five macroeconomic variables: GDP growth, inflation, the three-month interbank rate, the real effective exchange rate and the share of nonperforming loans (NPL) in total loans, controlling for differences in contingent liabilities. In constructing the underlying series, I draw on quarterly information from IMF, Eurostat, Bloomberg and wiiw datasets, and perform seasonal adjustments using the U.S. Census Bureau's *X-13ARIMA-SEATS* method.

2.3 Nonparametric estimation of yields and yield volatility

Debt management agencies potentially rely on estimation methods that provide a more continuous update of the costs and interest rate risk associated with sovereign debt portfolios. Moreover, the decomposition of sovereign interest rate risk is based on a linear approximation that is valid only for small changes in interest rate risk. To overcome the challenge of discrete jumps in linear regression estimates, I rely on a nonparametric estimation method to determine the smooth function *f(t)* in

$$y_{it} = f_i(t) + \epsilon_{it},$$

where y_{it} is the yield on government bonds (short- or long-term) of country i in year t. I employ the local linear ridge estimator (as proposed by Seifert and Gasser, 1996; 2012), which approximates the unknown function *f(t)* locally with a linear regression line. More specifically, the estimator minimizes a weighted difference between observed yields and a linear function locally. Observations around the predicted value receive more weight than distant ones, and a bandwidth parameter determines the size of the neighborhood considered in the minimization. In contrast to simpler local linear regressions, a "ridge parameter" ensures that the slope of the local regression line is not too steep. I use a cross-validation approach to set the optimal bandwidth, i.e. I choose the bandwidth $h*$ such that

$$h^* = arg\,min_h \sum_{j \epsilon T} \left[y_{ij} - f^*_{i,-j}(j)\right]^2,$$

where $f^*_{i,j}$ is the predicted value of country i's yield in year j, using a local linear ridge estimator based on country-specific yield information that excludes year j. Furthermore, I use the optimal ridge parameter as proposed by Seifert and Gasser (2000) for normally distributed errors. With this approach, the smooth prediction of short- and long-term bond yields is uniquely determined and does not entail an arbitrary parameter.

I estimate the structural volatility of short- and long-term bond yields by relying on the same nonparametric technique. More specifically, after identifying structural residuals (using a Cholesky decomposition), I obtain an approximation to the function *g(t)* in

$$s_{it}^2 = g_i(t) + \epsilon_{it},$$

where s_{it} is a structural residual in country i in year t. I determine the optimal bandwidth using cross-validation and set the ridge parameter to its theoretical optimum for a normal distribution. The annex presents the results of the regressions.

2.4 Data source: sovereign structural debt database

The main information source of the present analysis is a newly compiled dataset that summarizes public debt structures for 14 countries across the CESEE region. The dataset covers Albania, Bulgaria, Croatia, the Czech Republic, Hungary, Macedonia, Montenegro, Poland, Romania, Russia, Serbia, Slovakia, Slovenia and Turkey. The database is based on Bloomberg's DDIS function, which has recorded public sector obligations differentiated according to the type of debt (bonds versus loans), the type of coupon (fixed versus floating) and the currency of issuance on a quarterly basis since the fourth quarter of 2009. Granular information on redemption profiles enables the calculation of a range of structural indicators, including the average term to maturity of total debt and of domestic and foreign currency obligations, as well as the currency composition of total debt and the average term to refixing (ATR) of bond obligations. Notably, the magnitude of the debt recorded by Bloomberg is highly consistent with that of other data sources,[9] suggesting that the derived structural indicators provide an accurate depiction of sovereign debt structures across CESEE.

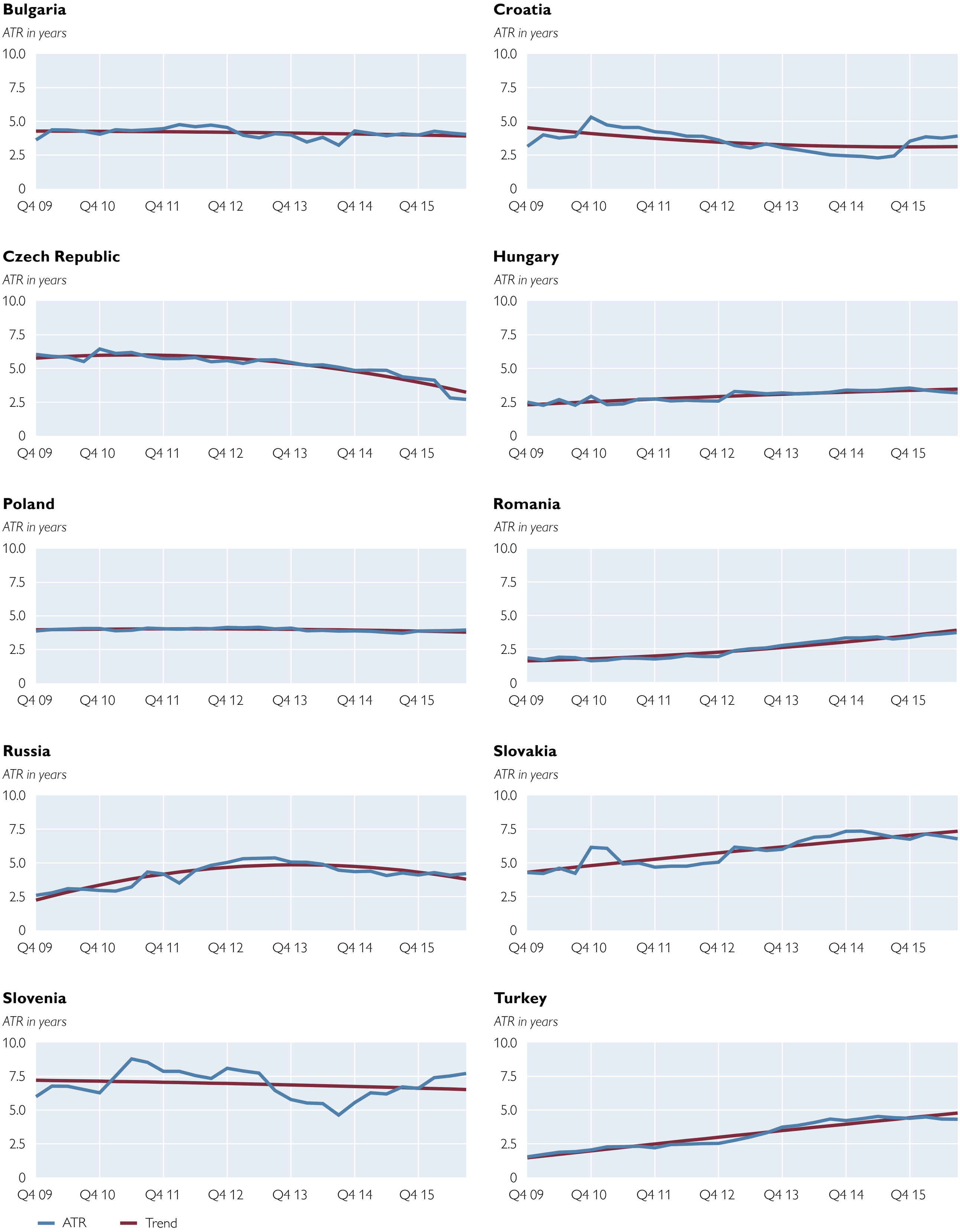
Chart 1 illustrates the progression of country-specific ATRs on domestic currency bonds.[10] The ATR increased for the Romanian, Russian, Slovakian and Turkish debt portfolios, but less so for the Hungarian debt portfolio; and it decreased notably for the Czech Republic's outstanding bonds. Assuming constant volatility in the underlying bond markets, this would indicate a reduction of risk in the former group and an increase in risk in the latter. On average, the ATR lengthened from three and a half years in 2009 to four and a half years in 2016. It is therefore

[9] *On average, the country-specific deviation between the debt recorded by Bloomberg and the debt recorded by the IMF's financial indicators lies at around 2%. With an average deviation of 8%, the database reveals the largest inconsistency for Slovenian debt.*

[10] *While other indicators follow directly from the information provided, the calculation of the ATR requires a few assumptions as it is based on a distinction between variable and fixed-coupon payments. A differentiation between variable and fixed-coupon bonds is available for total obligations, but it is not available for domestic currency obligations. Specifically, I assume that term loans are issued exclusively in foreign currencies and the ratio of domestic to foreign maturities is equivalent to the ratio of domestic to foreign refixing periods.*

Chart 1

Average maturities



Source: Bloomberg, author's calculations.

likely that risk has fallen across CESEE. Furthermore, a regression indicates that the standard deviation of refixing periods across countries has decreased over time, down from 1.8 percentage points in 2009 to 1.3 percentage points in 2016. While there are still large differences in refixing periods, their dispersion appears to have converged.

To better understand the drivers and possible consequences of changing maturity structures, chart 2 shows the progression of ten- (purple line) and one-year (blue line) generic bond yields as reported by Bloomberg. With the exception of Russia and Turkey, average financing costs decreased considerably over the observed time span, from around 5.7% in 2009 to 2.7% in 2016. The difference in the costs of short- and long-term funding determines the marginal costs debt managers face when selecting the maturity structure. Chart 2 suggests a large degree of heterogeneity in the associated dynamics. The yield curve's slope declined notably in the Czech Republic, Russia and Slovakia, and increased slightly in Hungary. While Bulgaria, Croatia and Poland experienced some dynamics in the intercept of their domestic yield curves, the slope remained largely unchanged. On average, the difference between ten- and one-year bond yields fell from 2.2 percentage points to 1.2 percentage points.

The dynamics described are broadly in line with theoretical predictions: assuming constant risk aversion and volatility in the bond markets, the aggregate flattening of yield curves led to a reduction in the marginal costs of hedging against interest rate risk. The average maturity of public debt portfolios increased as a consequence.

3 Sovereign interest rate risk in CESEE

This section provides estimates of the costs, risk and risk preferences associated with sovereign debt portfolios across CESEE. I combine the estimated volatility of short- and long-term bond yields with the observed maturity structure to obtain a simple indication of the interest rate risk. The first order condition for an optimal maturity structure, balancing costs and risk at the margin, relates this measure to risk preferences and domestic financing conditions. Several estimation steps are necessary to arrive at the results shown below. In order to highlight the probable error margin in these predictions, I present two distinct models: a dynamic SUR model and a nonparametric estimate. The first subsection concentrates on the magnitude of the interest rate risk and on how it changes over time, while the second subsection investigates the drivers of this change.

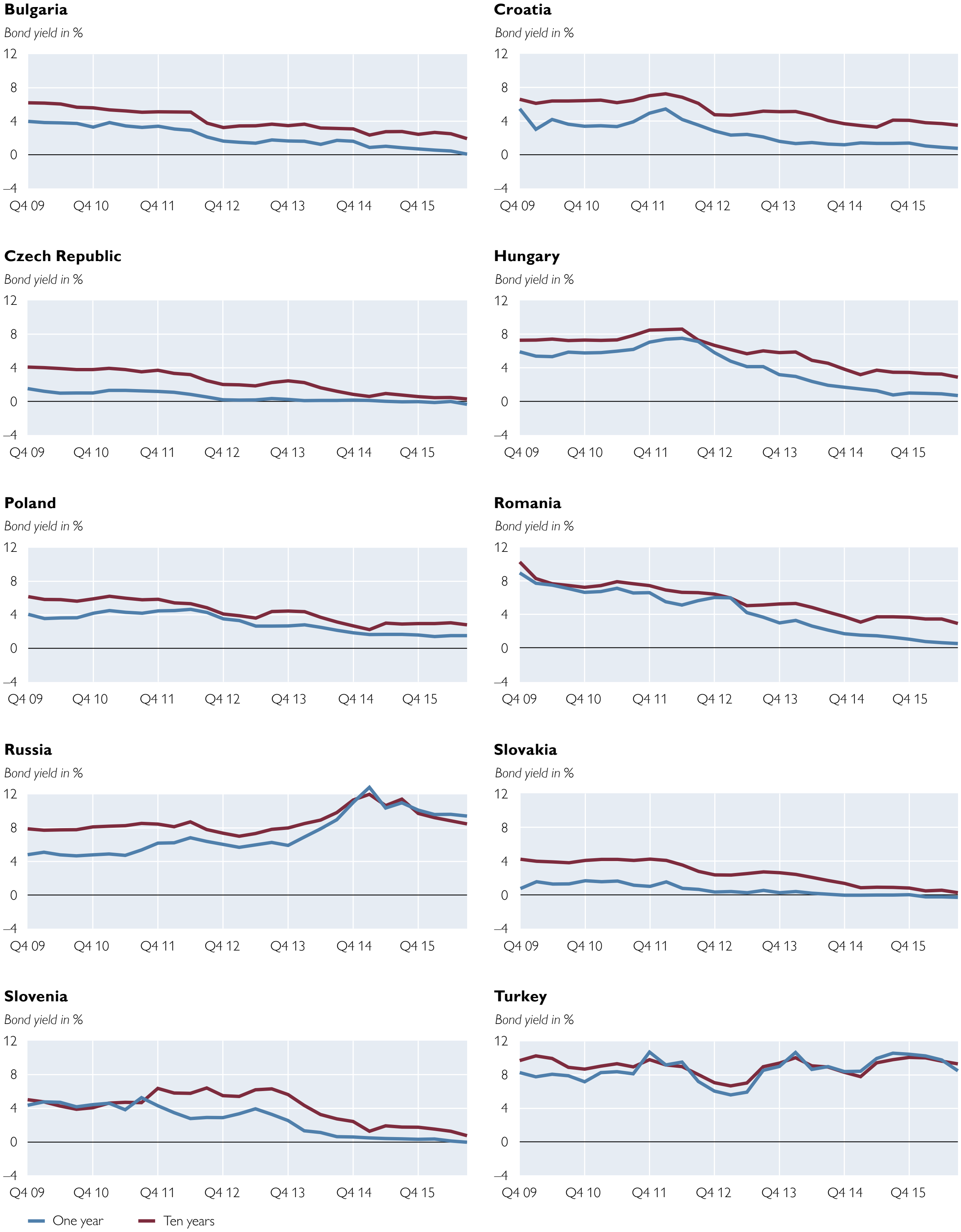
3.1 The magnitude of sovereign interest rate risk

Chart 3 illustrates the realized cost-risk tradeoffs across the observed CESEE countries. The horizontal axis represents average expected interest costs, while the vertical axis depicts the standard deviation of the composite interest rate (rather than its variance). The black diamonds are country-specific average values resulting from the dynamic (light blue) and nonparametric (dark blue) model; the horizontal and vertical black lines represent sample averages; the panels differentiate between years.

Chart 3 highlights that both the risk of sudden interest rate dynamics and the expected interest rate have decreased over time, when aggregated across CESEE. Between 2010 and 2015, risk fell from an average standard deviation of slightly below 0.3 percentage points to around 0.18 percentage points. Deviations from

Chart 2

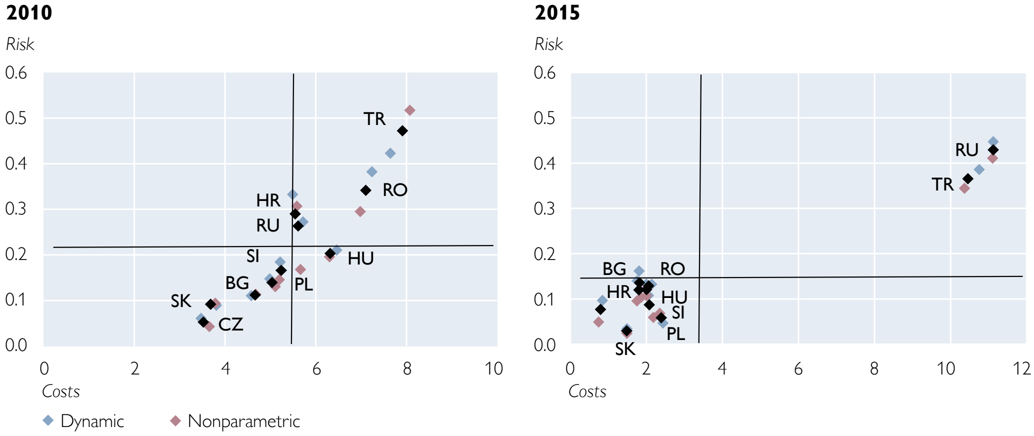
Yield curves



Source: Bloomberg, author's calculations.

Chart 3

Costs and risk



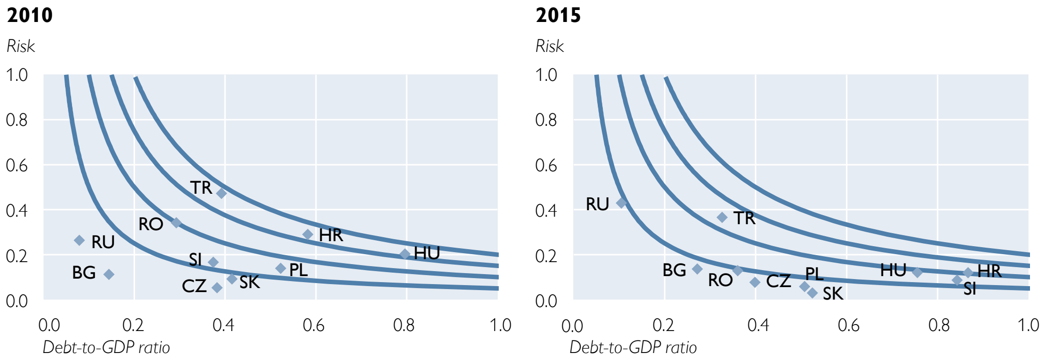
Source: Author's calculations.

the average interest rate are thus less likely today than they were shortly after the financial crisis. Chart 3 also shows that interest rate risk is largest in Turkey when averaging across the entire time span. Romania could reduce the degree of interest rate risk considerably, while Russia has moved up the risk ladder.

Chart 4 puts the interest rate risk into perspective with the overall level of debt, acknowledging that effective interest costs, as well as potential deviations from it, are the product of debt level and the interest rate. The blue lines indicate regions where the standard deviation of interest payments is 0.2%, 0.15%, 0.1% and 0.05% of GDP.[11] For normally distributed interest rates, the deviation from the expected rate thus remains below these limits in four out of five times. Chart 4 suggests a negative correlation between risk that emanates from the structure and

Chart 4

Size-adjusted risk



Source: Author's calculations.

Note: The blue lines indicate regions where the standard deviation of interest payments is 0.2%, 0.15%, 0.1% and 0.05% of GDP.

[11] *More specifically, the lines represent regions where* $d * \sqrt{r} = c$ *holds true for* $c = 0.2, 0.15, 0.1, 0.05$, *and* d *is the ratio of debt to GDP and* r *is risk (the one-step ahead variance).*

risk that emanates from the level of debt. Fiscal risk appears to be more dispersed when considering either the level or the structure of debt in isolation than when looking at those factors jointly. According to the figures presented in chart 4, Croatia, Hungary and Turkey exhibited the highest degree of uncertainty in 2015, with the theoretical standard deviation of interest payments amounting to roughly 0.1% of GDP.

3.2 The drivers of sovereign interest rate risk

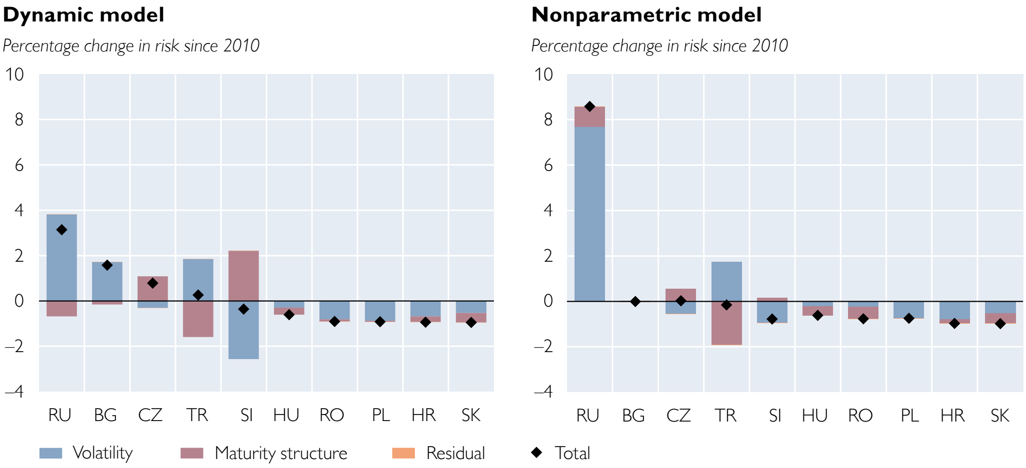
The maturity structure and the volatility of bond yields determine the degree of interest rate risk mechanically: the longer the average maturity, the less volatile are bond markets and the lower is the degree of interest rate risk.

Chart 5 decomposes the percentage change in interest rate risk between 2010 and 2015 accordingly. The bars in red and blue depict the percentage point contribution of the maturity structure and the volatility of short- and long-term bond yields, respectively; the yellow bars show residual contributions. The black diamond represents the sum of these three components. Chart 5 highlights volatility in bond markets as being the main driver of the change in risk. Depending on the specification (dynamic versus nonparametric), interest rate risk increased by up to 800% in Russia, mainly owing to increased volatility in bond yields. Similarly, the positive dynamics observed in Croatia, Poland, Romania and Slovenia, where interest rate risk fell by up to 90%, were due largely to a decrease in volatility on the bond markets. Developments in Turkey and the Czech Republic are particularly worthy of note. While the Czech Republic is the only country where risk seems to have increased, largely owing to a reduction in the length of terms to maturity, Turkey has succeeded in curbing overall interest rate risk despite an increase in underlying volatility.

From a debt management perspective, the degree of bond market volatility is just one of the pieces of information feeding into decisions on a sensible borrowing strategy, rather than a separate and unrelated driver of risk. The slope of the yield curve and preferences are additional factors that determine the optimal maturity structure and, in turn, interest rate risk.

Chart 5

Change in risk since 2010



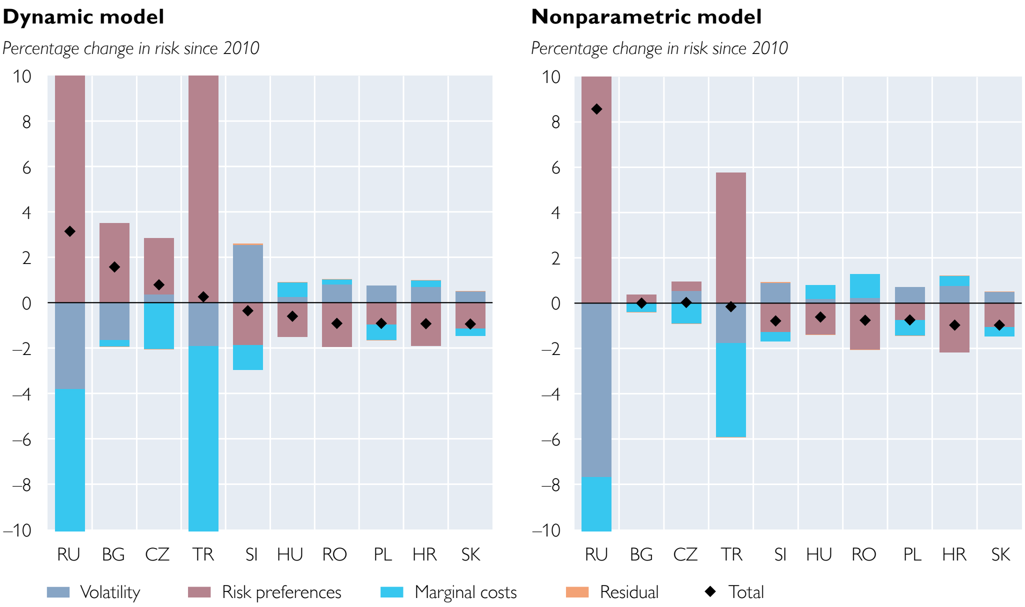
Source: Author's calculations.

Chart 6 illustrates the change in risk, decomposed from an optimal debt management perspective. Several differences come to light when contrasting this decomposition with the more mechanical view presented above. First, the volatility of bond yields plays a much smaller role and typically contributes in the opposite direction to that suggested by the first decomposition. This finding relates to the fact that volatility now affects the degree of interest rate risk both directly and indirectly: while escalated short-term dynamics increase the risk of future deviations mechanically, optimal debt management counterbalances this tendency by increasing the average maturity.[12] Second, the flattening of yield curves seems to have been a major reason behind the extension of average maturities, thus contributing significantly to the decrease in interest rate risk in many countries. Third, in most countries, changing risk preferences dampen the effect of other structural changes.

The behavioral decomposition highlights the cost-risk tradeoff involved in the management of public debt. With notable reductions in the marginal costs of long-term funding, as observed in the Czech Republic, Russia and Turkey, average maturities should have lengthened considerably. The fact that more maturity extensions are not imposed signals an increase in risk-taking preferences in those countries. By contrast, Croatia's debt agency extended the average maturity of public obligations slightly, despite the relative increase in the costs of long-term debt. This suggests that the degree of risk aversion has increased since 2010.

Chart 6

Change in risk since 2010



Source: Author's calculations.

[12] *The definition of risk and the optimal maturity structure implies that an increase in the volatility of short-term bond yields reduces total risk, while an increase in the volatility of long-term bond yields amplifies total risk when totaling the direct and indirect effects.*

4 Conclusion

This article draws on a new structural debt database to provide estimates of the risk and risk preferences associated with sovereign debt portfolios across CESEE. The empirical results suggest that the volatility of short- and long-term bond yields has decreased since 2010. At the same time, the average maturity of most debt portfolios has been extended, implying that the risk of sudden surges in sovereigns' composite interest rate is less likely today than it was shortly after the financial crisis. Notable exceptions from this general trend are Russia and Turkey, where interest rate risk remains prominent despite a lengthening of terms to maturity.

Combining the empirical results with a simple theoretical model facilitates the identification of the drivers of interest rate risk. The analysis suggests that both a reduction in the relative costs of long-term borrowing and a change in the weight debt managers place on cost minimization are key in understanding beneficial risk developments. As, in many countries, the yields on long-term borrowing (ten years) have dropped more sharply than the yields on short-term borrowing, the relative costs of long-term funding have decreased over time. Many debt management agencies have responded by increasing the share of long-term debt, thus reducing the composite interest rate's sensitivity to current market conditions. However, the ratio of marginal costs to marginal risk has increased over time. Risk minimization therefore seems to be of greater concern in many countries today than shortly after the financial crisis. In Bulgaria, the Czech Republic, Russia and Turkey, by contrast, debt managers' risk aversion seems to have decreased, hampering a further reduction in sovereign interest rate exposure over time.

The structural analysis provides valuable insights for optimal debt management. Most importantly, the model clarifies that a change in funding conditions requires a commensurate change in the structure of debt if costs and risk are to remain balanced at the margin. Yet in practice, debt management agencies tend to specify unconditional structural debt targets (or bands), with the result that interest payments are more volatile. Moreover, an increased responsiveness to prevailing conditions would imply the imposition of more extensions to average maturities. The current low interest rate environment would thus be locked in and boost fiscal space for the future.

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Annex

A.1 Drivers of sovereign bond yields in CESEE

Table A1 below summarizes the determinants of bond yields in a set of static regression specifications. Columns 1 and 2 show the estimated sensitivity of short-term financing costs, while columns 3 and 4 report estimates on the sensitivity of long-term financing costs. All specifications include country-specific time polynomials of the third order, as well as a set of year and quarter dummies to capture global trends in risk aversion. Columns 1 and 3 (labeled OLS – ordinary least squares) estimate the determinants of one- and ten-year bond yields in separate equations. In columns 2 and 4, a GLS approach increases the estimation efficiency by accounting for correlation between the equation's residuals.

Real interest rates and inflation impact significantly on the short and long end of sovereigns' yield curves. With an average short-run coefficient of around 0.36, short-term financing costs react more strongly to changes in the monetary variables. Ten-year bond yields increase by around 0.23 percentage points in response to a 1 percentage point increase in either inflation or the real interest rate. As expected, conventional monetary policy measures are thus more effective in steering the short end of the yield curve.

Furthermore, the results suggest that fiscal measures and contingent liabilities are important signals for the risk of default in the region. On average, the estimated impact of these variables is larger on long-term bond yields, likely reflecting the higher risk premium inherent in the costs of long-term funding. An increase of 1 percentage point in the ratio of debt to government revenue inflates ten-year bond yields instantaneously by 0.23 basis points. The response of one-year yields is not statistically significant. With estimated effects ranging between 0.01 basis points and 0.08 basis points, current deficits exert a similar, albeit much smaller, effect on the costs of short- and long-term funding. This result is in line with prior evidence, suggesting that the debt burden is a strong signal for the risk of default (Manasse et al., 2003), while the impact of fiscal deficits is less clear, potentially depending on the state of the economy (Jaramillo and Weber, 2013). Moreover, contingent liabilities affect sovereign borrowing costs across all estimated specifications. With an average response of 0.05 basis points, ten-year bond yields are more sensitive to changes in the share of nonperforming loans than one-year bonds (0.035 basis points).

The GLS approach suggests that lagged ten- and one-year bond yields are significant predictors of short-term yields, while the long end is only steered by the lagged effect of ten-year bond yields. The OLS estimations, by contrast, suggest that the lagged value of short-term bonds is negatively correlated with current long-term bonds.

Table A1

Drivers of short- and long-term bond yields, dynamic results

Dependent variable	One-year bond yields		Ten-year bond yields	
Estimation method	OLS	GLS	OLS	GLS
Explanatory variables	(1)	(2)	(3)	(4)
	Panel SUR regression, N=10, T=29			
Inflation	0.432***	0.380***	0.291***	0.238***
	(0.048)	(0.032)	(0.041)	(0.032)
Real interest rate	0.403***	0.356***	0.277***	0.235***
	(0.042)	(0.029)	(0.036)	(0.029)
Real effective exchange rate (REER)	–0.007***	–0.007***	0.008***	0.009***
	(0.002)	(0.001)	(0.001)	(0.001)
Debt-to-government revenue ratio	–0.008	0.006	0.291***	0.230***
	(0.074)	(0.057)	(0.071)	(0.057)
Deficit-to-government revenue ratio	0.036*	0.006	0.085***	0.012**
	(0.019)	(0.005)	(0.020)	(0.005)
Nonperforming loans (NPLs)	0.029***	0.043***	0.055***	0.055***
	(0.012)	(0.010)	(0.011)	(0.009)
Lag (one-year bond yield)	0.141*	0.259***	–0.153**	–0.065
	(0.076)	(0.046)	(0.068)	(0.046)
Lag (ten-year bond yield)	0.354***	0.264***	0.778***	0.736***
	(0.071)	(0.043)	(0.069)	(0.049)
Residual variation	0.241	0.280	0.223	0.183

Source: Author's calculations.

A.2 Portfolio rebalancing effects

The theoretical model abstracts from general equilibrium effects: debt managers' maturity choice does not affect the yield structure. In fact, standard economic theory predicts that arbitrage opportunities should equalize investors' riskless returns across all maturities (Modigliani and Sutch, 1966). Accordingly, the path of the central bank's policy rate determines both short- and long-term bond yields, while the relative supply of these bonds is irrelevant.

This view contrasts sharply with preferred habitat models, initially proposed by Culbertson (1957), where investors prefer specific time horizons. In its extreme form, the assumption of market segmentation implies that a shift in the composition of public debt toward longer maturities raises the yield on long-term debt and reduces the yield on short-term debt owing to supply effects. Vila and Vayanos (2009) and Greenwood and Vayanos (2014) extend the basic preferred habitat theory by incorporating arbitrage opportunities and thus introducing substitutability between debt maturities. Their model predicts that all yields increase in response to an increase in the debt portfolio's average maturity, reflecting the escalated aggregate risk associated with the larger supply of risky long-term debt.

Portfolio rebalancing effects influence the optimal maturity structure of government debt. If the reaction of long-term rates to a change in the portfolio composition is more pronounced than the sensitivity of short-term rates, the term spread is an increasing function of the maturity structure. The implications of portfolio rebalancing effects can be seen in

$$c(\alpha) = i_s + \alpha b(\alpha),$$

where the term spread, *b(α)*, is now an increasing function of the maturity structure. With this cost objective, the first order condition can be rearranged to give

$$\alpha^{*,pr} = \frac{(1-\delta)e\sigma_s^2 - \frac{1}{2}\delta b}{(1-\delta)\left(e\sigma_s^2 + \frac{\sigma_l^2}{N^2}\right) + \frac{1}{2}\delta b'}.$$

Contrasting this expression with the one given in the main text shows that the optimal maturity is strictly shorter in the presence of portfolio-rebalancing effects, owing to the positive term in the denominator. The presence of portfolio-rebalancing effects could thus rationalize shorter optimal maturities. To examine whether the yield structure in effect responds to the sovereign's maturity choice, I re-estimated the dynamic regressions, including the ATR, as an additional explanatory variable.

Table A2 presents the results. According to the dynamic estimations, short-term and long-term bond yields increase instantaneously by 6 basis points and by 13 basis points, respectively, in response to a one-year increase in the ATR, controlling for lagged values of bond yields. Both estimated effects are significant at the 1% level. Combining the estimated persistence in the yield curve with these coefficients suggests a cumulative response of 20 basis points and 38 basis points in short- and long-term bond yields, respectively. Simple OLS estimations confirm the positive impact at the long end of the yield curve, but do not reject the null hypothesis for the sensitivity of short-term financing costs to changes in the portfolio structure.

Portfolio rebalancing effects are at odds with the assumption of perfect arbitrage across the yield curve and thus inconsistent with some of the fundamental assumptions of the widely used New Keynesian model (Chadha and Zampolli, 2013). However, they are in line with optimization behavior in preferred habitat models (Vila and Vayanos, 2009; Greenwood and Vayanos, 2010). The effect of government debt structures on bond yields has been examined before (Greenwood and Vayanos, 2014; D'Amico and King, 2013; Gagnon et al., 2010; Zhu and Meaning, 2012), but prior work was limited to U.S. and U.K. data.

Table A2

Drivers of short- and long-term bond yields, dynamic results

Dependent variable	One-year bond yields		Ten-year bond yields	
Estimation method	OLS	GLS	OLS	GLS
Explanatory variables	(2)	(4)	(6)	(8)
	Panel SUR regression, N=10, T=29			
ATR	0.003	0.057*	0.098***	0.127***
	(0.039)	(0.030)	(0.036)	(0.030)
Inflation	0.433***	0.398***	0.294***	0.269***
	(0.048)	(0.033)	(0.041)	(0.033)
Real interest rate	0.407***	0.377***	0.277***	0.266***
	(0.042)	(0.030)	(0.036)	(0.029)
Real effective exchange rate (REER)	–0.007***	–0.010***	0.004*	0.003
	(0.002)	(0.002)	(0.002)	(0.002)
Debt-to-government revenue ratio	0.022	0.056	0.259***	0.285***
	(0.070)	(0.059)	(0.066)	(0.059)
Deficit-to-government revenue ratio	0.051***	0.011*	0.050***	0.014*
	(0.013)	(0.006)	(0.012)	(0.008)
Nonperforming loans (NPLs)	0.028**	0.052***	0.060***	0.068***
	(0.012)	(0.011)	(0.011)	(0.010)
Lag (one-year bond yield)	0.156**	0.274***	–0.154**	–0.056
	(0.075)	(0.046)	(0.066)	(0.045)
Lag (ten-year bond yield)	0.339***	0.227***	0.779***	0.695***
	(0.070)	(0.044)	(0.067)	(0.049)
Implied long-run rebalancing effect	0.140	0.200	0.340	0.380
Residual variation	0.241	0.280	0.224	0.182

Source: Author's calculations.