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STOCHASTIC APPROACH TO DEBT SUSTAINABILITY ANALYSIS APPLIED TO SERBIA

ABSTRACT

This paper examines the public debt sustainability of Serbia, based on integration of financial gap analysis approach and stochastic modeling and forecasting of relevant macroeconomic and fiscal variables. Within this analytical framework, sustainability is interpreted as whether underlying policies can be sustained under plausible macroeconomic conditions without endangering solvency (Debrun, Celasun and Ostry, 2006).

Conventional debt sustainability analysis is conducted as a simple accounting exercise, based on deterministic forecasts of variables that are included into debt accumulation equation and arbitrary scheduled bound tests. However, because debt sustainability is a forward-looking concept, it cannot be assessed with certainty (Wyplosz, 2011). Stochastic approach to debt sustainability as an alternative to conventional debt analysis takes into account the high degree of uncertainty surrounding medium-term debt trajectories, which cannot be captured by simple bound tests as these are limited in number (ECB, 2012). The recent research in this area (Garcia and Rigobon, 2004; Debrun et al., 2006; Kawakami and Romeu, 2011) mainly uses a Vector Autoregression (VAR) modeling as a basic framework for econometric estimation of the relationships among interest and exchange rates, inflation and primary balance and their forecasting and simulation. In addition, impulse response analysis is based on calibrated shocks obtained by Cholesky decomposition of variance-covariance matrix of the regression residuals.

We apply stochastic approach to Serbian monthly data, run simulations of debt-to-GDP ratio and compare the results with IMF and Serbian Government mid-term projections. Our projections of debt-to-GDP ratio in two years ahead based on VAR approach gives the similar forecast relative to those given by IMF, while projections based on AR(1) approach seem to overestimate debt-to-GDP ratio with increase of forecast horizon. Yet, our forecasts strongly suggest that projection of Serbian government of debt-to-GDP ratio is too low and consequently misleading.

Keywords*: debt sustainability assessment, debt-to-GDP forecast, Vector Autoregression model, stochastic simulations, Serbia*

JEL classification*: H63, H68*

1. INTRODUCTION

The financial crisis and subsequent recession have led to rapid deterioration of government finances in many European countries, which has caused interest rates to rise strongly in some of them. Self-reinforcing effect on the deficits, the higher interest rates and declines in the creditworthiness of sovereign issuers have reduced the sustainability of future debt dynamics. The escalating yield spreads in the euro area in 2010 have underlined how suddenly these mechanisms can cut off a sovereign borrower from the capital markets. Threat of sovereign debt crisis in current worldwide economic circumstances clearly increases importance of proper debt management and debt sustainability analysis.

Conventional debt sustainability analysis is conducted as a simple accounting exercise, based on deterministic forecasts of variables that are included into debt accumulation equation and arbitrary scheduled bound tests. However, because debt sustainability is a forward-looking concept, it cannot be assessed with certainty (Wyplosz, 2011). Stochastic approach to debt sustainability as an alternative to conventional debt analysis takes into account the high degree of uncertainty surrounding medium-term debt trajectories, which cannot be captured by simple bound tests as these are limited in number (ECB, 2012). The recent research in this area (Garcia and Rigobon, 2004; Debrun et al., 2006; Kawakami and Romeu, 2011) mainly uses a Vector Autoregression (VAR) modeling as a basic framework for econometric estimation of the relationships among interest and exchange rates, inflation and primary balance and their forecasting and simulation. In addition, impulse response analysis is based on calibrated shocks obtained by Cholesky decomposition of variance-covariance matrix of the regression residuals.

In this work we analyze stochastic approach to debt sustainability assessment. Section 2 is dealing with framework of conventional debt analysis and its shortcomings. Section 3 introduces methodology of stochastic approach to public debt sustainability and provides empirical evidence on its application to forecasting of Serbian debt-to-GDP ratio.

2. CONVENTIONAL APPROACH TO PUBLIC DEBT SUSTAINABILITY ANALYSIS

Conventional debt sustainability analysis is a simple accounting exercise, based on the standard debt accumulation equation (ECB, 2012):

$$\Delta d_t = \frac{i_t - g_t}{1 + g_t} d_{t-1} + pb_t + dda_t \qquad (2.1)$$

where:

- $\frac{i_t - g_t}{1+g_t} d_{t-1}$ is the “interest-growth differential”, which captures the impact of the debt ratio-increasing interest rate as well as the impact of the debt ratio-reducing GDP growth rate
- pb_t is the primary deficit
- dda_t is the deficit-debt adjustment The deficit-debt adjustment relates to that part of the change in the debt-to-GDP ratio which is not reflected in the deficit.

Probably the most used conventional approach in practice is IMF Debt Sustainability Assessment framework (DSA). Basically, DSA methodology imposes assessment of debt sustainability as the medium-term simulations of the debt-to-GDP ratio given specific macroeconomic forecasts and fiscal policy assumptions. Within this analytical framework, sustainability is interpreted as whether underlying policies can be sustained under plausible macroeconomic conditions without endangering solvency (Debrun, Celasun and Ostry, 2006). IMF country teams impose routinely this framework and publish the results as the part of report on “Article IV Consultations”[3].

According to the DSA, change in public debt could be decomposed into the regular part, comprised of identified debt-creating flows and irregular, comprised of unidentified residuals and change of asset. Identified part is further decomposed to automatic debt dynamics, i.e. contribution of interest rate, real GDP growth and change of exchange rate, then primary balance contribution and other identified flows, manly privatization receipts and recognition of contingent liabilities. Decomposition of public debt, according to this methodology allows sensitivity analysis of public debt under different scenarios of economic policies and macroeconomic development and stress testing of debt dynamic assuming some arbitrary market or fiscal shocks (so-called bound tests), as it is shown in Figure 1.

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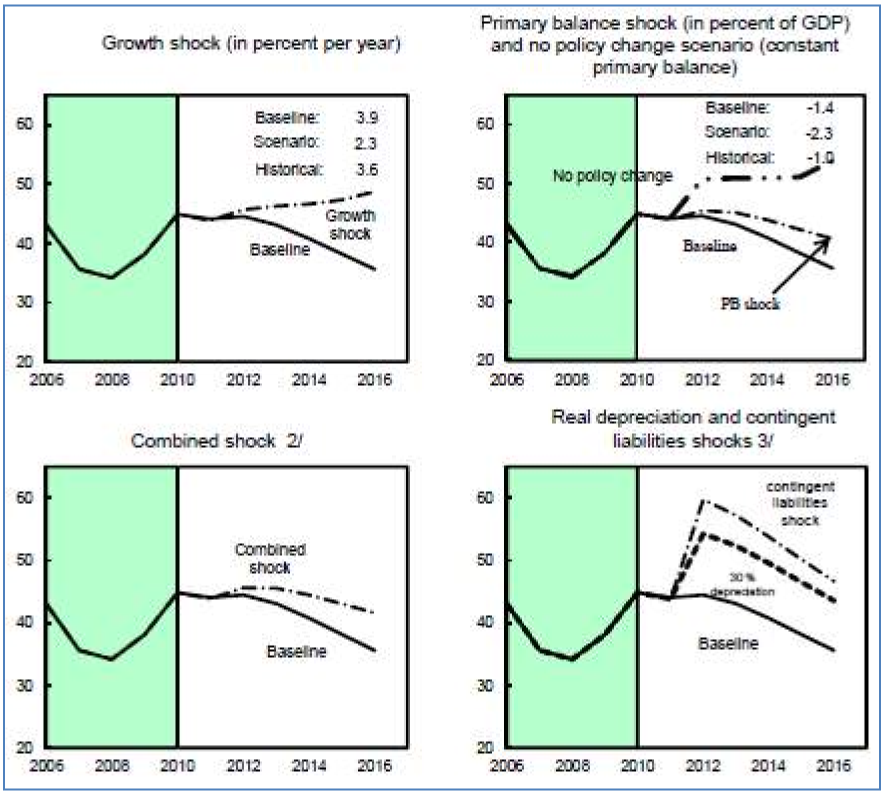
[3] The IMF consults annually with each member government. Through these contacts, known as “Article IV Consultations,” the IMF attempts to assess each country’s economic health and to forestall future financial problems.

Figure 1: Example of bound tests of Serbian government debt according to IMF DSA methodology



Source: IMF Country Report No. 11/311 (2011)

However, use of such conventional approach like DSA suffers from several shortcomings:

- it neglects country-specific correlation between main drivers of public debt and does not include these correlation patterns in forecasting (deterministic scenarios do not consider the effects of correlation);
- it neglects country specific shocks that affect the public debt drivers and does not use them to produce simulations; instead, it applies arbitrary selection of shocks that might not be supported by empirical facts at all;
- it produces single point forecast instead of giving distribution of possible forecasting outcomes.

Consequently, these shortcomings could reflect in poor forecasting power of conventional debt analysis, as it is illustrated in case of Serbia, based on five IMF country reports, where DSA forecast of the debt-to-GDP (gross government debt) underestimates actual values for more than 8% on average.

Table 1: Comparison of DSA baseline projections and actual values of debt-to GDP for Serbia

Reporting year	2008	2009	2010	2011	2012	
February 2008	33.2	31.4	29.6	28.2		**Projections of debt-to-GDP in %**
May 2009		34.8	37.8	36.3	34.2	
April 2010		36.4	36.0	36.5	35.0	
July 2010			39.1	41.1	40.6	
October 2011			44.5	44.1	44.5	
Actual Values	33.39	38.06	46.48	50.02	63.65	
Forecast errors						**Average**
2006	-0.19	-6.66	-16.88	-21.82		-11.39
2007		-3.26	-8.68	-13.72	-29.45	-8.55
2008		-1.66	-10.48	-13.52	-28.65	-8.55
2010			-7.38	-8.92	-23.05	-8.15
2011			-1.98	-5.92	-19.15	-3.95
Average	-0.19	-3.86	-9.08	-12.78	-25.08	-8.12

Source: IMF country reports for Serbia and IMF World Outlook database

3. STOCHASTIC APPROACH TO PUBLIC DEBT SUSTAINABILITY ANALYSIS

Application of stochastic approach to public debt sustainability as a specific issue of cost-risk analysis of public debt emerged around 2003, trigged by the one of the shortcomings of traditional fiscal sustainability analysis which often does not take into account the effects of uncertainty (Burnside, 2004). In regard to the existing literature, stochastic approach to debt sustainability is mainly based on numerical approach and uses the common risk management tools (stochastic simulations, scenario analysis, stress testing); it is primarily subjected to stress testing and sensitivity analysis of public debt dynamics under the different scenarios of government economic policy or possible exogenous shocks. Ferruci and Penalver (2003) and Garcia and Rigobon (2004) works became the basis for the most persistent line in further research as they introduced stochastic modeling to the conventional Debt Sustainability Assessment framework. Related work in this field also includes Debrun, Celasun and Ostry (2006), Penalver and Thwaites (2005), Tanner and Samake (2006), Di Bella (2008), Gray et al. (2008), Giovanni and Gardner (2008) and Kawakami and Romeu (2011).

3.1. Methodology

Starting point of the methodology is debt accumulation equation which operates with real variables, under additional assumption that real interest rate on domestic and foreign debt is the same. Thus, debt accumulation equation in relative terms could be simply rewritten as:

$$d_t = (1 + r_t - g_t)d_{t-1} + pb_t, \tag{3.1}$$

where d_t is ratio of real [4] public debt to real GDP and pb_t is real primary deficit to real GDP, while r_t and g_t now represent real interest rate and real growth of GDP. In addition, as the left and right side of this equation in practice would never be equal due to debt-deficit adjustments, equation 3.1 could be further extended with new term which represents public debt skeletons, or simply said debt shocks, denoted as s_t .

$$d_t = (1 + r_t - g_t)d_{t-1} + pb_t + s_t . \tag{3.2}$$

It has to be emphasized that within the stochastic framework all variables in equation 3.2 apart from public debt are considered to be stochastic by nature and therefore they represent the possible sources of riskiness of public debt unexpected changes.

We considered to approaches in stochastic modeling of risk variables, one based on Vector Autoregression (VAR) estimation and one based on univariate autoregression (AR) estimation .

3.1.1. VAR approach

In this work we extended out previous research (Zdravkovic, Bradic-Martinovic, 2012) based on Garcia and Rigobon (2004) with approach of Debrun, Celasun and Ostry (2006). Inflation rate π_t and real exchange rate depreciation e_t are added as the additional risk factors out of equation 3.2. By taking into the consideration that all of these risk variables are most probably correlated to certain degree, we could assume that they follow multinomial normal distribution with conditional mean $\boldsymbol{\mu}_\mathbf{t}$ and conditional variance-covariance matrix $\boldsymbol{\Sigma}_\mathbf{t}$

$$\{r_t, g_t, e_t, \pi_t, pb_t, s_t\} - N(\boldsymbol{\mu}_\mathbf{t}, \boldsymbol{\Sigma}_\mathbf{t}).$$

Under the assumption of joint distribution, dynamic of these variables could be modeled by the standard reduced-form VAR models. In this case, VAR model in vector terms is given as:

$$\mathbf{x_t} = \mathbf{c} + \sum_{i=1}^{p} \mathbf{A_i x_{t\text{-}i}} + \mathbf{v_t}, \quad \mathbf{x_t} = \{r_t, g_t, e_t, \pi_t, pb_t, s_t\} \tag{3.3}$$

[4] Terms real debt and primary balance here denote inflation-free value of debt and primary balance.

$$\mathbf{v_t} - N\left(\mathbf{0}, \mathbf{\Sigma_v}\right),$$

where $\{\mathbf{A_i}\}$ are matrices of lag coefficients up to p lags and $\mathbf{\Sigma_v}$ is variance-covariance matrix of reduced-form residuals. However, as the reduced-form residuals are linear combination of structural shocks, they are not suitable to perform impulse response analysis of innovations in risk variables dynamic which requires structural VAR models. Of course, the main problem with structural VAR models is identification of the model. As we do not impose some specific theory about the contemporaneous relations structure, we use recursive ordering approach by arbitrary proposed exogeneity of variables and set simple AB specification of structural VAR model:

$$\mathbf{Av_t} = \mathbf{Bu_t}, \tag{3.4}$$

where $\mathbf{A}$ is the matrix defining contemporaneous relations, $\mathbf{u_t}$ represent structural shocks and $\mathbf{B}$ is the matrix of structural form parameters.

Structural model is identified with orthogonalization of reduced-form residuals to obtain matrix $\mathbf{B}$ by Cholesky decomposition (Sims, 1981), $\mathbf{\Sigma_v} = \mathbf{BB'}$, while matrix $\mathbf{A}$ is assumed to be identity matrix. As matrix $\mathbf{B}$ is upper triangular matrix, the last variable will be the most exogenous and thus its innovation will have contemporaneous effects on all variables, while innovation in the first variable will affect only itself.

After the estimation, model's parameters can be used for deterministic projection of mutual path of all risk variables using the last known values of risk variables. In addition, using the variance-covariance matrix of estimated residuals it is possible to produce Monte Carlo simulations in order to obtain full stochastic forecast of these variables with simulated distribution of their probabilities. Forecasted values of relevant variables are plugged in debt accumulation equation in order to produce forecast of possible public debt paths.

Thus, methodology described could be summarized in the following steps.

- Based on historical data, parameters of reduced-form VAR(2) model[5] are estimated
  $$\mathbf{x_t} = \mathbf{c} + \sum_{i=1}^{p} \mathbf{A_i x_{t-i}} + \mathbf{v_t}, \quad \mathbf{x_t} = \{r_t, g_t, e_t, \pi_t, pb_t, s_t\};$$
- Matrix **B,** which represents mathematically how combination of **all** (structural) shocks of risk variables $\mathbf{u_t}$ affects particular values of risk variables, is estimated;
- Based on estimated coefficients from historical data, values of risk variables are forecasted ***k*** periods ahead, which is actually baseline (and deterministic) forecast
  $$\mathbf{x}_{\mathbf{t}+k} = \mathbf{c} + \sum_{i=1}^{p} \mathbf{A_i} \mathbf{x}_{\mathbf{t}+k\mathbf{-i}}, \quad \mathbf{x_t} = \{r_t, g_t, e_t, \pi_t, pb_t, s_t\}; \tag{3.5}$$

[5] Order of lag is restricted to 2 due to the limited number of observations in data sample and large number of parameters for estimation

- Based on estimated values of matrix B, simulations of reduced-form shocks (linear combination of structural shocks) are generated by running the simulations of structural shocks randomized from standardized normal distribution,

$$\tilde{\mathbf{v}}_{\mathbf{t}+k} = \mathbf{B}\tilde{\mathbf{u}}_{\mathbf{t}+k}, \quad \tilde{\mathbf{u}}_{\mathbf{t}} - N(0,1); \tag{3.6}$$

- Simulations of risk variables are produced by adding the simulated reduced-form shocks $\tilde{\mathbf{v}}_{\mathbf{t}+k}$ to deterministic projections of $\mathbf{x}_{\mathbf{t}+k}$;
- Simulated forecasts of risk variables are plugged into debt accumulation equation to simulate debt-to-GDP ratio paths.

3.1.2. AR(1) approach

Our AR(1) approach to stochastic modeling is loosely related to Bergstrom et al. (2002) work, which is primarily concerned with Cost at Risk modeling of public debt. Their model consists of two building blocks, macroeconomic model based on AR(1) modeling of risk variables and strategies simulation part.

Methodology of AR(1) simulations is described by the following steps.

- It is assumed that each risk factor follows a univariate AR(1) process of the form:

$$\mathrm{x}_{\mathrm{t}} = \alpha + \rho x_{t-1} + \varepsilon_t, \quad \varepsilon_t - IIDN\left(0,\sigma^2\right) \tag{3.7}$$

- Based on historical data, the parameters of AR(1) process are estimated for each of the risk factors and estimate processes, as well as the error terms, using ordinary least squares or maximum likelihood estimator.
- Mean of each series $\overline{x} = \alpha/\left(1-\rho\right)$ and the (unconditional) variance of the error terms, $\sigma^2 = Var\left(\varepsilon_t\right)$ are calculated
- Different paths for x_t are simulated using the following dynamics implied by the AR(1) process:

$$\Delta\tilde{\mathrm{x}}_{\mathrm{t}+\Delta t} = \left(1-\rho\right)\left(\overline{x} - x_t\right)\Delta t + \sigma\sqrt{\Delta t} * \tilde{e}_{t+\Delta t} \tag{3.8}$$

  where Δt is the time step in the simulation, while $\tilde{e}_{t+\Delta t}$ is a random variable drawn from the standard normal distribution.
- Finally, we plugged simulations of risk variables into debt accumulation equation in order to produce stochastic simulations of debt paths.

3.2. Data

In regard to the political and economic changes that Serbia has passed during the recent decades, consistent series of monthly data do not exist for longer periods; therefore implementation of proposed methodology requires use of data with higher frequency for the empirical estimation of the model. We use the annualized monthly data to provide sufficient data set regarding the possible large number of parameters to be estimated by VAR model. This limits scope of data to period January 2008 – September 2012, for which exists consistent monthly data series of public debt and primary balance in nominal values. It is also important to emphasize that public debt in this analysis comprise only the debt of central government.

Additional problem to analysis is lack of monthly data on GDP, which is measured only on quarterly basis. In order to end up with approximated monthly data on GDP, we use methodology of Zaman and Markovic (2011) based on quarterly real GDP values weighted by weights obtained from index of industrial production, which is usually highly correlated with GDP dynamic. We used data on chain-linked values of GDP (in 2005 relative prices) as real GDP measure, as it is usual in statistical offices. Further, in order to obtain real values of public debt and primary balances, we used CPI base index as denominator. Data for public debt, primary balance and GDP are annualized as the rolling sum of monthly data for previous twelve months.

As the Serbian public debt portfolio is composed from loans and securities which very differ in maturities and currencies, we have to use some approximations of interest rates and exchange rate depreciation to meet the parsimonious data requirements of the model. Hence, we use the data on weighted average interest rate on government debt instruments which are provided by National Bank of Serbia as an approximation of aggregate interest rate. Real interest rate is obtained as a difference between nominal interest rates and inflation rates.

Aggregate exchange rate is approximated with EUR/RSD exchange rate, in regard to currency structure of debt portfolio were euro-indexed debt dominates, as well as strong correlation between EUR/RSD and exchange rates of other instruments indexed in foreign currency (mostly USD and CHF). Real depreciation is calculated as a difference between nominal depreciation and inflation rate. Debt shocks are calculated based on equation 3.2, as a difference between right and left side of the equation.

3.3. Results

At first, we estimated VAR model for the period January 2008 – September 2012. The estimation of the VAR parameters is of little interest and not shown here, instead the matrix B is presented in order to give insight how structural shocks in one risk variable influence other variables (positively or negatively).

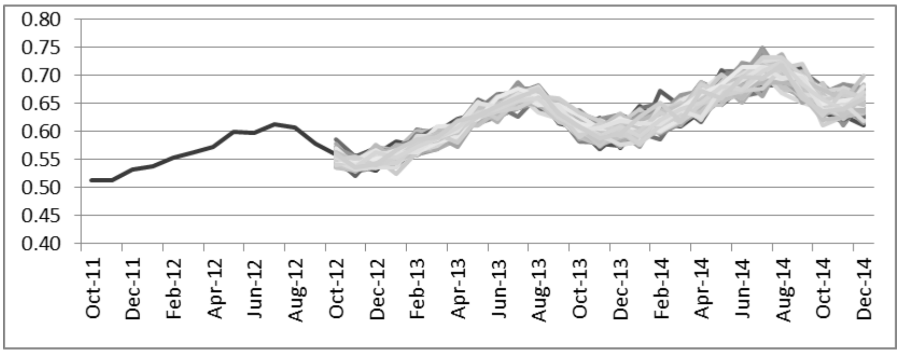
Table 2: Matrix B of estimated VAR model

	Real interest rate	Real GDP growth	Primary deficit	Debt shocks	Real exchange rate dep.	Inflation rate
Real interest rate	0.0074	-0.0013	-0.0019	-0.0015	0.0021	-0.0118
Real GDP growth		0.0037	-0.0012	0.0013	0	-0.0002
Primary deficit			0.0025	-0.0017	0.0004	-0.0001
Debt shocks				0.0119	0.0092	0.0038
Real exchange rate dep.					0.031	-0.0045
Inflation rate						0.0098

Source: author's calculations

Following chart present the dispersion of simulated debt paths over forecasting time (October 2012 – December 2014), based on 1000 simulations:

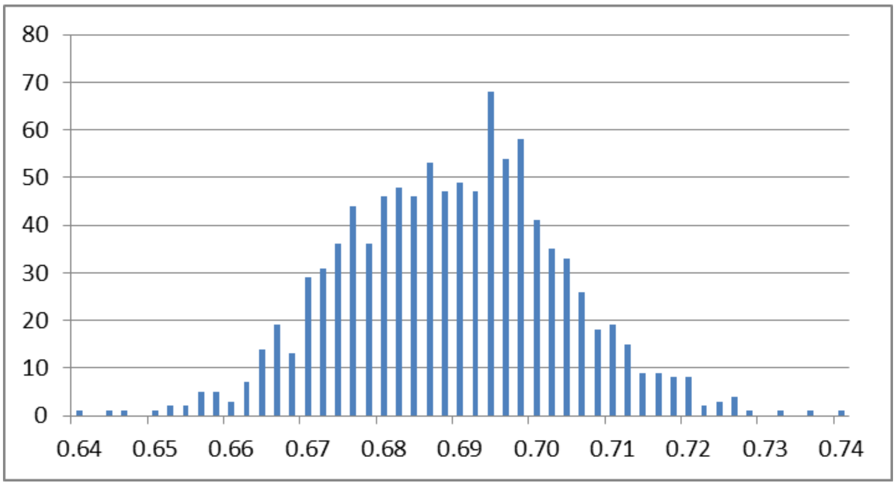
Figure 2: Simulated debt-to-GDP paths, VAR approach



Source: author's calculations

This chart demonstrates important advantage of stochastic approach in regard to conventional approach; instead of single point forecast of debt-to-GDP ratio over time, stochastic approach provides a range of possible debt-to-GDP ratios with assigned probabilities of their realization at any point in time. Following chart gives the range of possible values of debt-to-GDP ratio in June 2014 with probability distribution of their realization:

Figure 3: Probability distribution of forecasted debt-to-GDP ratio in June 2014

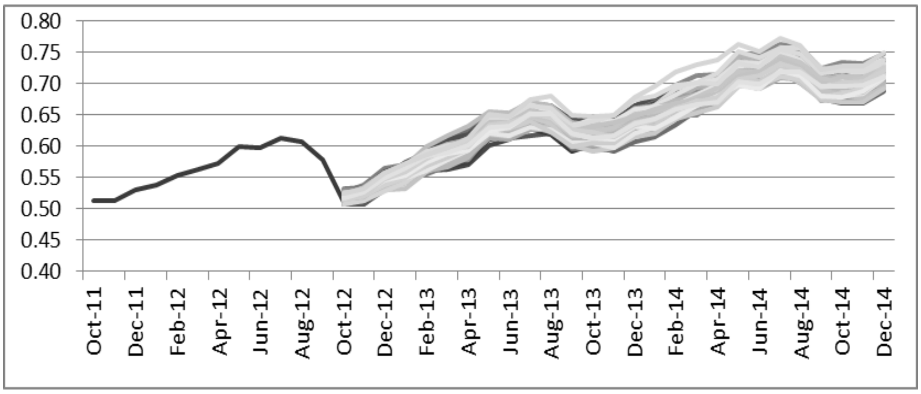


Source: author’s calculations

In addition, at any point in time it is possible to calculate probability that debt-to-GDP will exceed some threshold value. For example, if threshold value of debt-to-GDP ratio is set to 70%, by dividing number of simulations exceeding 70% with total number of simulations we end up with probability of 12.4% that debt-to-GDP will exceed 70%. This calculation could be done also in reverse manner - it is possible to determine critical value of debt-to-GDP that will be not exceeded for given probability, e.g. for probability level of 95%, critical value is 70.73%. It means that there is 95% chance that debt-to-GDP will not exceed value of 70.73%.

We also apply AR(1) approach as a benchmark and run separate regression to estimate parameters of the AR(1) process for real interest rate, GDP real growth and primary deficit. Following chart present the dispersion of simulated debt paths over forecasting time (October 2012 – December 2014), based on 1000 simulations:

Figure 4 Simulated debt-to-GDP paths, AR(1) approach



Source: author's calculations

Eventually, we compare four different types of projection: two obtained by conventional debt sustainability analysis (IMF recent projection and official projection of Serbian Government)[6] and two obtained by stochastic approach to debt sustainability analysis that we applied in this paper:

Table 3: Comparison of debt-to-GDP forecast

	2013	**2014**
VAR	61.27%	66.02%
AR(1)	61.43%	69.86%
IMF	64.68%	66.53%
Serbian Government	60.60%	53.30%

Source: author's calculations, IMF World Outlook Database, Strategy of Serbian Public Dent Management (2012)

Annual projections of debt-to-GDP for VAR and AR(1) approach are obtained by averaging simulations for given year. Our projections of debt-to-GDP ratio in two years ahead based on VAR approach gives the similar forecast relative to those given by IMF, while projections based on AR(1) approach seem to overestimate debt-to-GDP ratio with increase of forecast horizon. Yet, our forecasts strongly suggest that projection of Serbian government of debt-to-GDP ratio is too low and consequently misleading.

[6] IMF projection is related to level of gross government debt, thus it is not directly comparable to our projections which are related to debt of central government. However, historical data shows that central government debt participates with more than 95% in gross debt. Also, projection of Serbian Government is approximation of central government debt obtained by reducing gross government debt for debt of lower level of government.

4. CONCLUSIONS

There were several advances in recent years toward the improvements of the key shortcomings of conventional debt sustainability analysis, mainly lack of stochastic tools in application and lack of country specific calibration of shocks. In this work we analyze stochastic approach to debt sustainability assessment. Two approaches are proposed, first one based on mutual modelling of risk variables using the VAR estimation and second one based on separate estimation of autoregression process for each risk variable entering the debt accumulation equation.

We apply stochastic approach to Serbian monthly data, run simulations of debt-to-GDP ratio and compare the results with IMF and Serbian Government mid-term projections. Our projections of debt-to-GDP ratio in two years ahead based on VAR approach gives the similar forecast relative to those given by IMF, while projection based on AR(1) approach seems to overestimate debt-to-GDP ratio with increase of forecast horizon. Yet, our forecasts strongly suggest that projection of Serbian government of debt-to-GDP ratio is too low and consequently misleading in making policy decisions. Unfortunately, due to data unavailability for the longer period of time, it is not possible to conduct serious out-of-sample analysis.

Use of such parsimonious model for debt sustainability analysis like the one proposed in this research has its obvious advantages: lower data requirements (in sense of number of variables entering the model), ease of application, endogenous forecasting and capturing of country specific factors. Furthermore, we point important advantage of stochastic approach in regard to conventional approach; instead of single point forecast of debt-to-GDP ratio over time, stochastic approach provides a range of possible debt-to-GDP ratios with assigned probabilities of their realization at any point in time. In addition, application of stochastic approach allows calculating probability that debt-to-GDP will exceed some threshold value.

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