Linear and nonlinear panel regression models for fiscal policy evaluation

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Abstract: In this paper, we analyse the relationship between the primary surplus/deficit and debt for the group of eleven Central and Eastern European EU countries. Temporary spending and temporary output are also added to the regression equation as explanatory variables. We use annual data for the period between 1997 and 2020, obtained from Eurostat. The estimated panel regression model passes the employed specification and diagnostic tests. Our analysis reveals there is a significant positive response of the primary surplus to an increase in debt, providing empirical support for the sustainability of fiscal policy in the observed panel of countries during the observed period.

Keywords: FISCAL POLICY, NONLINEAR APPROACH, SMOOTH TRANSITION REGRESSION, PANEL MODELS, PRIMARY SURPLUS.

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1. Introduction

As explained in Kavkler (2021), the literature on the sustainability of fiscal policy encompasses various approaches, ranging from models based on the government’s intertemporal budget constraint (Bohn, 1998; Bohn, 2008) or cointegration in fiscal time series (Bartoletto, Chiarini & Marzano, 2012), to testing the stationarity of fiscal time series (Simo, 2021). However, most of these models largely ignore different possible fiscal regimes.

Piergallini and Postigliola (Piergallini & Postigliola, 2013; Piergallini & Postigliola, 2016; Piergallini and Postigliola, 2020) consider a nonlinear approach using the smooth transition regression (STR) model, which is a generalization of discrete switching models with a finite number of different regimes. The authors examine historical budget data for Italy for the period from 1861 to 2016 and draw two important conclusions. First, the nonlinear surplus-debt relationship performs better than the linear model. Second, the authors identify a threshold level of the debt-GDP ratio (around 105 %) above which there is a significant positive response of the primary surplus to an increase in debt.

Bohn (2008) studies the sustainability of fiscal policy in the United States for the period from 1792 to 2003. The author argues that the most credible evidence in favour of fiscal sustainability is the robust positive response of primary surplus to changes in debt-GDP ratio.

Mendoza and Ostry (2008) explain the “model-based sustainability approach” (MBS) based on the work of Bohn (1998, 2005). The proposed test examines whether an increase in public debt leads to an increase in the government’s primary fiscal balance. The test is based on the intuition that the fiscal authorities raise primary surplus as a consequence of increasing public debt. According to Mendoza and Ostry (2008), Bohn proved that if in the regression of primary surplus on public debt (augmented with the transitory government spending and the cyclical component of the real GDP), the regression coefficient of public debt is positive (and statistically significant), this is sufficient to establish empirical support for sustainability of fiscal policy.

This paper is structured as follows. First, we describe the methodological approach of smooth transition regression (STR) models and panel STR models. Using the data for the group of 11 Central and Eastern European EU countries, we study the sustainability of fiscal policy with a panel regression model. The results obtained are analysed and compared with empirical studies by other authors.

2. Methodology

2.1 Smooth transition regression models

The following description of the smooth transition regression modelling approach is taken from Kavkler and Böhm (2003) and Kavkler (2006), where it is summarized from Teräsvirta (1998) and Teräsvirta (1994).

Many elements of economic theory mention the idea that the economy behaves differently when the values of certain variables lie in one region than in another, or, in other words, follow different regimes. The first attempt to model such phenomena is represented by discrete switching models, where a finite number of different regimes is assumed. The central tool of this class of models is the so-called switching variable, which can be either observable or unobservable.

Since a smooth transition between regimes is often more convenient and realistic than just a sudden change, several scholars have proposed a generalization of discrete switching models in the following form:

\[ y_t = x_t'\phi + (x_t'\theta)G(\gamma; c, s) + u_t, \quad t = 1, 2, \ldots, T \]  \hspace{1cm} (1)

where \( \phi = (\phi_1, \ldots, \phi_p)' \) and \( \theta = (\theta_0, \theta_1, \ldots, \theta_p)' \) are the parameter vectors, \( x_t \) is the vector of explanatory variables containing the lags of the endogenous variable and the exogenous variables, i.e.

\[ x_t = (1, x_{t-1}, \ldots, x_{t-p}, z_{t-1}, \ldots, z_{t-p})' \]

whereas \( u_t \) denotes a sequence of independent identically distributed errors. \( G \) denotes a continuous transition function that is usually bounded between 0 and 1. Because of this property not only the two extreme states can be explained by the model, but also a continuum of states that lie between these two extremes. The parameter \( \gamma > 0 \) is an indicator of the speed of the transition between 0 and 1, while \( c \) indicates where the transition occurs.

The transition variable \( s_t \) is usually one of the explanatory variables or the time trend.

The most often used functional forms of the transition function are as follows:

- LSTR1 model: \( G_1(\gamma; c; s_t) = \frac{1}{1 + e^{-b(s_t-c)}} \)
LSTR2 model: 
$$G_2(y, c_1, c_2; s_i) = \frac{1}{1 + e^{-(G_1 - c_1 - c_2)}}$$
This is a non-monotonic transition function that is particularly useful in reswitching.

ESTR model: 
$$G_1(y, c_1; s_i) = 1 - e^{-(G_1 - c_1)^2}$$
The function is symmetric about c and very similar to the LSTR2 case with $c_1 = c_2$. Therefore it is sometimes difficult to distinguish between an ESTR and an LSTR2 model.


2.2 Panel STR models

Gonzales et al. (2005) develop the panel smooth transition regression (PSTR) models. The authors define the basic PSTR model with two extreme regimes as

$$y_{it} = \mu_{it} + \lambda_{et} + x_{it}'\phi + (x_{it}'\theta)(G(y_{it}; c_i, s_i)) + u_{it}$$

(2)

for $t = 1, 2, ..., T$ and $i = 1, 2, ..., N$, where $T$ and $N$ denote the time and cross-section dimensions of the panel model, respectively. $y_{it}$ is the dependent variable, $x_{it}$ is the $k$-dimensional vector of time-varying exogenous variables, $\mu_{it}$ and $\lambda_{et}$ stand for the fixed individual and time effects and $u_{it}$ denotes the errors. $G$ is the transition function, as already described in the previous subsection and $s_i$ is the transition variable.

The specification, estimation and evaluation of PSTR models is described extensively in Gonzales et al. (2005). The authors also study the small sample properties of the developed LM type tests and provide size and power simulations.

3. Data

Our empirical analysis is conducted for the 11 Central and Eastern European EU countries, namely Bulgaria, the Czech Republic, Croatia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia. The fiscal time series needed for our study are from the Eurostat Economics and Finance Database (2022). We used annual data for the period from 1997 to 2020, which is the widest range of data available on the Eurostat website for all the countries and all the time series needed. Following Piergallini and Postigliola (2020), the following time series were used in our analysis:

1. the surplus or deficit as a percentage of gross domestic product (GDP), called surplus in our analysis.
2. the debt as a percentage of gross domestic product, referred to in our analysis as debt.
3. the growth rate of real GDP (percentage change from the previous period). The temporary output variable (denoted temp_output in our analysis) was obtained by detrending the real GDP growth rate with the Hodrick-Prescott filter, as suggested by Piergallini and Postigliola (2020).
4. expenditure as a percentage of GDP. The temporary spending variable (denoted temp_spending in our analysis) was obtained by detrending the time series of spending relative to GDP using the Hodrick-Prescott filter, as suggested by Piergallini and Postigliola (2020).

Piergallini and Postigliola (2020) describe the rationale for constructing the last two time series using the Hodrick-Prescott filter and refer the reader to Bohn (2008) and Mendoza and Ostry (2008) for a more detailed explanation. Piergallini and Postigliola (2020) argue that therefore "temporary variations in output and spending are assumed to be generated by and ex post filtering". For the empirical analysis in the next section, the software package EViews was used.

4. Results and discussion

As the first step, we estimate the linear panel regression model with surplus as the dependent variable and the constant and the lagged variables debt, temp_output and temp_spending as the explanatory variables. The model is specified as the fixed effects model with cross-section and period fixed effects. White cross-section coefficient covariance method is applied. The estimation results are given in Table 1.

All explanatory variables are significant at the 5% significance level. The coefficient of the lagged debt variable (0.0149) conveys a significant positive response of the primary surplus to an increase in debt in the previous time period. Our results are thus consistent with those of Piergallini and Postigliola (2016, 2020) for Italy and with Bohn (2008) for the United States, and confirm the sustainability of fiscal policy in the observed panel of countries.

Table 1: Estimated fixed effects panel regression model

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<tr>
<td>c</td>
<td>-3.4637</td>
<td>0.2797</td>
<td>-12.383</td>
<td>0.000</td>
</tr>
<tr>
<td>debt(t-1)</td>
<td>0.0149</td>
<td>0.0075</td>
<td>1.9966</td>
<td>0.047</td>
</tr>
<tr>
<td>temp_output(t-1)</td>
<td>0.0848</td>
<td>0.0386</td>
<td>2.1965</td>
<td>0.029</td>
</tr>
<tr>
<td>temp_spending(t-1)</td>
<td>-0.1483</td>
<td>0.0477</td>
<td>-3.1110</td>
<td>0.002</td>
</tr>
</tbody>
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Root MSE 1.8569 R-squared 0.5956
Mean dependent var -2.8745 Adjusted R-squared 0.5312
S.D. dependent var 2.9256 S.E. of regression 2.0032

Similarly, Mendoza and Ostry (2008) analyse debt sustainability for a group of 22 industrialized countries over the period 1970 – 2005 and for 34 developing countries during the 1990 – 2005 period. The authors estimate a panel regression model with country-specific fixed effects and show that the coefficient of the debt variable is positive and statistically significant. The result holds true for the industrialized as well as emerging countries. Emerging economies exhibit a stronger response of the surplus variable. Several specifications are estimated as a robustness check.

5. Conclusion

In this paper, we analysed the relationship between primary surplus/deficit and debt for the panel of eleven Central and Eastern European EU countries. Our analysis revealed there is a significant positive response of the primary surplus to an increase in debt, providing empirical support for the sustainability of fiscal policy, according to the “model-based sustainability approach” developed by Bohn (1998, 2005). In the next step of our research,
we intend to estimate the nonlinear panel smooth transition regression model and compare the results with the linear modelling approach.

6. References


