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Estimating debt limits for emerging countries

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A B S T R A C T

The relationship between sovereign risk and indebtedness level is an important guide for evaluating the probability of a debt default. The market discipline hypothesis establishes that the risk premium increases with debt-to-GDP ratio. According to this hypothesis' strong version, this relation is non-linear, and there is a threshold - here called debt limit - from which the credit access would be very difficult. This study provides debt limits for a panel of 18 emerging countries, using generalized method of moments for joint estimation of the thresholds. The countries studied were grouped by cluster analysis, and separately analyzed for each group. We find statistical evidence against the hypothesis of a common debt limit for all emerging countries. The main conclusion of the work is that those countries whose debt-to-GDP ratio exceeded their limits either had problems to get new loans to finance its debt and/or needed help from international institutes, as expected by the strong version of the market discipline hypothesis.

1. Introduction

The government debt of emerging economies has grown quickly since the 2008 crisis (IMF, 2016a). High and rising levels of debt reduce the fiscal space of an economy, limiting its capacity to react to adverse events. Concerning emerging countries, this situation is even worse, since they face lower credit tolerance because of their well-known difficulties in controlling fiscal variables.

There are different approaches in the literature to deal with the topic of public debt sustainability. The usual condition of sustainability establishes that the fiscal authority should ensure that the sum of primary surpluses (revenue minus expenses, excluding the payment of interest) expected for the future, discounted at present values, is enough to offset the current debt (Blanchard et al., 1991). As usual, both public debt and primary surpluses should be expressed as proportions of the country's GDP.

The problem with this definition is the uncertainty in relation to both the future surpluses and the discount factor applied, since future interest rates and product growth are unknown. Another approach, proposed by Bohn (1998), establishes that a fiscal policy is sustainable if it can produce primary surpluses that offset successive variations in the public debt-to-GDP ratio. Campos and Cysne (2019) applied this approach to Brazil, estimating a fiscal reaction function, reaching the conclusion that the country's public debt has been unsustainable since 2014.

A third possibility is to establish a theoretical relationship between risk premium and debt-to-GDP ratio. The sovereign risk premium, usually reflected by the EMBI+ (Emerging Markets Bond Index), aims to quantify the return required by investors to take a particular level of risk. The higher the probability of default (that is, of debt not being honored), the higher should be this indicator. Theoretically, the risk premium determines the cost of loans in the international market.

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The market discipline hypothesis (Bishop et al., 1989) establishes that, the higher the debt level, the higher the risk premium. The strong version of this hypothesis, formalized by Bayoumi et al. (1995) through a theoretical model,[1] consider that, from a particular value of the debt-to-GDP ratio, the risk premium would reach such a level that the country would be unable to get new loans, due to an accentuated increase in the probability of default. According to this approach, a fiscal policy becomes unsustainable if the indebtedness level exceeds the critical debt threshold, since, in this case, the government will face great difficulty in obtaining credit - that is, new loans to finance its debt - or would need some help from international institutions, as IMF.[2]

The practical implication of this threshold is that, as the debt level approaches the limit, it should be an alert for the fiscal authority to implement severe fiscal policy adjustment mechanisms.

As a preliminary descriptive analysis, Fig. 1 shows the scatterplot of quarterly time series of EMBI+ and debt-to-GDP ratio (2001–2016), considering four countries in the sample to illustrate: Argentina, Brazil, Hungary and Philippines.[3] It shows a positive relation between debt-to-GDP ratio and EMBI+. This result, although provided by a descriptive statistic (thus not incorporating effects of control variables, as it could be done through a statistical model) agrees with the market discipline hypothesis. Furthermore, it is possible to observe a non-linear relationship, with a limit for the debt-to-GDP limits from which the EMBI + grows quickly and suddenly (more evident in the case of Hungary).

Concerning the literature on emerging country debt thresholds, the following can be cited: Reinhart et al. (2003); Baldacci, Dobrescu, Petrova & Belhocine (2011); Siddique et al. (2016); Baharumshah et al. (2017) and Tran (2018). The latter is a panel analysis based on a linear approximation for the model proposed by Bayoumi et al. (1995).

Regarding modelling of the relationship between risk premium and level of indebtedness, it is also worth mentioning the work of Blanchard (2004), which related the probability of default with the real exchange rate, the real interest rate of dollar-denominated Brazilian government bonds, a measure of foreign investor risk aversion, net exports and external savings. This author, however, did not try to find debt thresholds from which the debt would become unsustainable.

The objective of this study is to estimate debt thresholds for 18 emerging countries, considering an adaptation of the Bayoumi model and quarterly general government debt-to-GDP ratio data, from 2001 to 2016. We chose these countries because they were going through economic changes in the transition to the 21st century, as will be discussed in section 3.

The estimation technique used was the generalized method of moments (Hansen, 1982), which, unlike the two-stage non-linear least squares method (2SNLLS, Amemiya, 1974) applied by Bayoumi et al. (1995), allows for joint-estimation of the parameters of the non-linear equations. Moreover, we show that the results provided by GMM are better than those provided by 2SNLLS.

The results' analysis, together with the countries' debt evolution and their access to credit over the study period, allows us to investigate the validity of the strong version of market discipline hypothesis. If it is true, we should find that countries whose public debts exceeded their estimated threshold had problems in financing their debt through new international loans. This analysis has not been done either by Bayoumi et al. (1995) nor by any other work in literature.

It is important to emphasize this work's contributions: while Bayoumi et al. (1995) restrict their work to study the relationship between yields and debt for a sample of American states, the present work: 1) finds specific debt limits for a sample of countries, thus providing relevant information for their fiscal policies; 2) uses a joint estimation method, which leads to better results than an individual equation method; 3) categorizes countries in groups with similar fiscal and economic characteristics, through cluster analysis; 4) investigates, using an appropriate statistical test, if it is reasonable to establish a common debt limit for all emerging countries, as argue some works; 5) discusses the validity of the strong version of the market discipline hypothesis.

Section 2 develops the theoretical framework. Section 3 describes the data used and sources, justifying the relevance of the sample selected. Section 4 presents the econometric methodology. Sections 5 and 6 report estimates and compares two estimation technique using a hypothesis test and other statistical arguments, showing the advantages of the method chosen for estimation. Section 7 presents a cluster analysis to group countries, according to relevant characteristics. Section 8 presents an historical analysis of some countries in the sample, showing that those ones whose indebtedness exceeded the limit in the study period were allocated in the same group. We further investigate whether these specific countries faced problems to acess credit, as expected. Section 9 applies a non-parametric test to investigate whether there is a common debt limit for all emerging countries. Section 10 discusses the validity of the strong version of the market discipline hypothesis, in view of the results found. Section 11 discuss some policy guides that could be implemented, based on the results of the work. Section 12 concludes.

2. Theoretical framework

The market discipline hypothesis establishes that, the higher the debt level, the higher the risk premium (Bishop et al., 1989). Flandreau et al. (1998) establishes three versions for the market discipline hypothesis, which differ from each other, mainly due to the theoretical functional form assumed for the relationship between the probability of default and its possible determinants:

$$r_{it}^{p} = \alpha b_{it} + \beta_0 + \beta_1 \frac{EX_{it}}{GDP_{it}} + \beta_2 \frac{GDP_{it}}{POP_{it}} \tag{1}$$

[1] Although it was Bayoumi et al. (1995) who formulated and formalized this version of the discipline market hypothesis, its denomination as "strong", in fact, follows the categorization proposed some years later by Flandreau et al. (1998).

[2] International Monetary Fund.

[3] Graphs for all other countries considered in this work are shown in annex A.

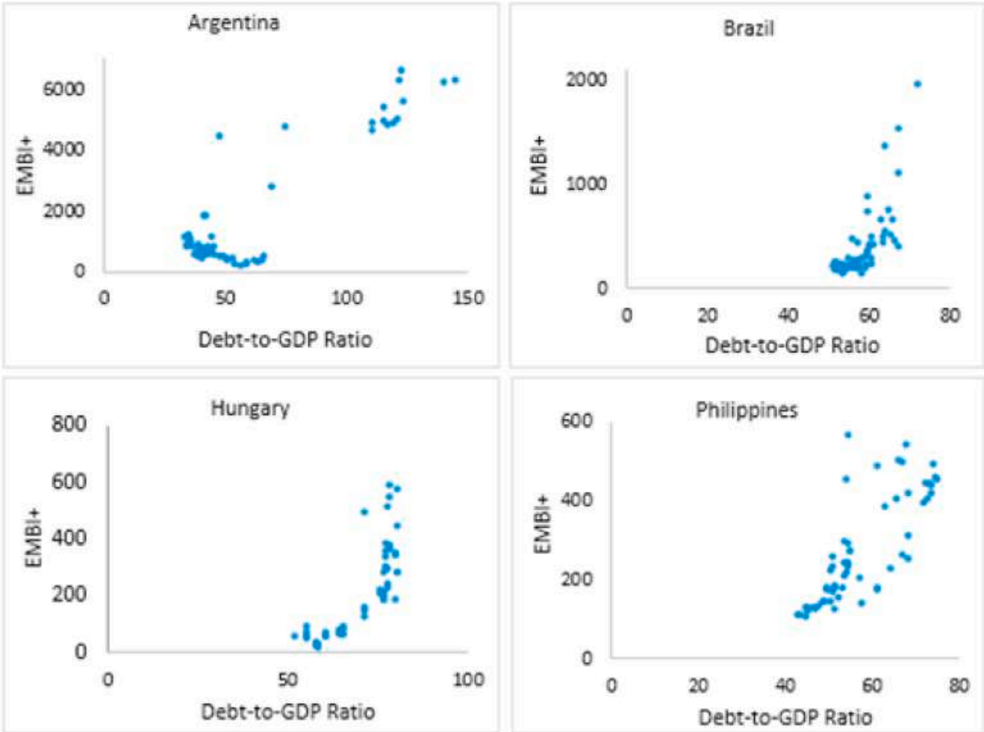

Fig. 1. EMBI + vs. debt-to-GDP ratio (2001–2016). Source: Author's elaboration based on World Bank and Oxford Economics database.

$$r^p_{it} = \exp\left(\alpha b_{it} + \beta_0 + \beta_1 \frac{EX_{it}}{GDP_{it}} + \beta_2 \frac{GDP_{it}}{POP_{it}}\right) \tag{2}$$

$$r^p_{it} = \left(\alpha b_{it} + \beta_0 + \beta_1 \frac{EX_{it}}{GDP_{it}} + \beta_2 \frac{GDP_{it}}{POP_{it}}\right) \frac{1}{1 - \delta_i b_{it}} \tag{3}$$

in which b_{it} is the debt-to-GDP ratio, EX_{it} is the value of the exports of country i and POP_{it} is its population size. Equations (1)–(3) represent, respectively, the weak, intermediate, and strong forms of market discipline. In the strong version, specifically, there is a debt limit $(1/\delta_i)$ so that the risk premium rises to such a level that potential creditors would not take the risk anymore.

Bayoumi et al. (1995), in a context different from the present work, propose a theoretical model to analyze the American states' indebtedness. Their model assumes that government debt securities are sold in competitive markets to risk-neutral creditors, maturing in one period. Therefore, the expected return on each bond must be equal to the return on a risk-free security, as follows:

$$\left(1 + r^f_t + r^p_{it}\right) P(H_{it}) + 0 \times (1 - P(H_{it})) = 1 + r^f_t \tag{4}$$

where r^f_t is the risk-free interest rate, r^p_{it} is the risk premium on the bond of country i in period t, $P(H_{it})$ is the probability of a default not occurring, and H_{it}, is a variable that determines whether country i can pay its debts in period t. The hypotheses are that $P^{'}(H_{it}) < 0$ and $P(0) = 1$.

The relationship between the risk premium and debt-to-GDP ratio will depend on the functional form of $P(H_{it})$ and on the determinants of H_{it}. Supposing that H_{it} is linear, the authors suggest describing it as follows:

$$H_{it} = \alpha B_{it} + \delta\left(r^f_t + r^p_{it}\right) B_{it} + \mathbf{x}^{'}_{it} \boldsymbol{\beta} \tag{5}$$

in which B_{it} is the stock of debt and $\mathbf{x}_{it}$ is a vector of exogenous variables.

In the present study, the following alternative specification is suggested for H_{it}:

$$H_{it} = \gamma + \alpha b_{it} + \delta_i \left(r^f_t + r^p_{it} - g_{it}\right) b_{it} + \mathbf{x}^{'}_{it} \boldsymbol{\beta} \tag{6}$$

where g_{it} is the GDP growth rate. The differences between equations (5) and (6) are because of differences between the works. While Bayoumi et al. (1995) work with a sample of American states, our study looks at countries. Thus, we use a more appropriate fiscal indicator, the debt-to-GDP ratio b_{it}, instead of the stock of debt B_{it}. Besides, we allow the δ coefficient to vary from country to country –

hence, its subscript i. Otherwise, a single debt limit for all countries would be imposed, hypothesis that, in this work, we will find to be unreal. Finally, a constant γ was also incorporated to the original model, in order to allow it to better fit the data.

Supposing that $P(H_{it}) = e^{-H_{it}}$ and applying ln on both sides of the equation, (4) becomes:

$$\ln\left(1 + r_t^f + r_{it}^p\right) - H_{it} = \ln\left(1 + r_t^f\right) \tag{7}$$

Using $\ln(1 + x) \approx x$ for a small x, the following is obtained: $r_{it}^p = H_{it}$. Substituting in (6):

$$r_{it}^p = \frac{\gamma + \alpha b_{it} + \delta_i\left(r_t^f - g_{it}\right)b_{it} + \mathbf{x}_{it}'\boldsymbol{\beta}}{1 - \delta_i b_{it}} \tag{8}$$

According to equation (8), the lower the value of b_{it}, the greater the impact over r_{it}^p, since, in this case, there is a low probability of default. However, as the debt level increases, the growth rate of the risk premium rises. As b_{it} approaches to $1/\delta_i$, r_{it}^p grows indefinitely (tending toward infinity).

This model supports the strong form of the market discipline hypothesis, as according to the categorization of Flandreau et al. (1998) (equation (3)). In addition, if $\delta_i = 0$, the relationship between r_{it}^p and b_{it} in (8) becomes linear, which would correspond to the weak. The parameters of equation (8) will be estimated by a joint-estimation econometric method, reported in section 4.

It is important to mention that, while Bayoumi et al. (1995) restrict their work to study the relationship between yields and debt for a sample of American states, this work considers a sample of countries, and estimated specific debt limits for each of them, through an appropriate econometric method. Besides, we analyze some other relevant aspects, like the use of a common limit for all countries and the validity of the strong version of the market discipline hypothesis.

3. Data

This work was based on quarterly data from 18 emerging countries at the beginning of the 21st century: Argentina, Brazil, Chile, China, Colombia, Dominican Republic, Ecuador, Hungary, Malaysia, Mexico, Peru, Philippines, Poland, Russia, South Africa, Turkey, Uruguay, and Venezuela. The study period is from the fourth quarter of 2001 to the second quarter of 2016.

The great motivation for choosing such countries, in addition to the availability of the necessary data, was the fact that their economies were going through a transition a little before the study period begins. The following are some examples. A further discussion will be made in section 8.

Poland experienced hyperinflation at the beginning of the 1990s and, from then on, it needed to restore a macroeconomic equilibrium, along with a transition to a market-based economy (Keller, 2008). Philippines and Malaysia, like other countries in Southeast Asia, despite having grown up a lot in the second half of the 20th century, felt because of the financial crisis in 1997 (IMF, 1998). Russia, in turn, was experiencing problems at the beginning of the 21st century, because it had totally reformulated its economy after the end of the Cold War, starting to adopt a market-based economy, and faced a crisis in 1998 that ended up resulting in a debt default (Fic & Saqib, 2006).

Turkey, as part of Europe and Western Asia, has an economy vulnerable to external shocks (Kilinc & Tunc, 2014). China is a case of "socialist market economy" that, in addition to having been growing significantly since the 1980s, completed its participation in the globalized economy by joining the WTO[4] in 2001 (Narayanan, 2005). The Hungarian economy was growing a lot since the 1990s, but started to be very vulnerable in the mid-2000s due to a large expensive fiscal policy, especially after the Financial Crisis of 2008 (Andor, 2009). South Africa was undergoing changes in the conduct of economic policy in the post-Apartheid period, as of 1994 (Bhorat et al., 2014).

Concerning Latin American countries, most of them were opening their economies after a period of intense indebtedness in the 1980s,[5] and some of them had experienced programs of monetary stabilization before the study period begins[6] (Fraga, 2004). The specific case of Venezuela is the most serious, since its economy deteriorated a lot throughout the study period, with hyperinflation and quite serious fiscal problems that would lead to a debt default in 2017 (Moatti & Muci, 2019).

Concerning the data, the fiscal variables considered were the gross debt and the surplus of the central government, both as a proportion of the GDP (or, as usually referred, as a GDP ratio). Graphs on Debt-to-GDP ratio for all countries in sample, over the study period, are in Annex B.

As a measure for sovereign debt securities, we considered the EMBI + spread risk premium. It consists in the difference between the mean return on the government bonds of an emerging economy, denominated in dollars, and the mean return on American government bonds of similar maturity, both weighted by the market share of each bond of the respective emerging economy. Scatterplots for EMBI + versus debt-to-GDP ratio, for all countries in the sample, are in Annex A.

As an exogenous variable, we considered the VIX, or CBOE volatility index, that measures the expected volatility of the American stock market implicit in call and put options of the S&P 500. As suggested by Gupta, Baldacci & Mati (2008) and Beirne and Fratzscher (2013), the VIX is a possible control variable for common external shocks to emerging markets. On the other side, Blanchard (2004) explains that variations in the EMBI + are not only because of the variations not only in the probability of default, but also in foreign

[4] World Trade Organization.
[5] The so called "lost decade".
[6] As an example, the Real Plan, in Brazil, in 1994.

investor risk aversion. Thus, including a proxy for risk propensity is necessary to avoid bias in the estimation of the α and δ_i in equation (8). For robustness analysis, another risk aversion measure was considered: the difference between the returns on BAA securities, with a 20-year maturity, and 10-year American government bonds, leading to similar results. Concerning the risk-free asset, we used the American government bond with a 5-year maturity. Again, for a robustness analysis, bonds with a 2 and 10-year maturity[7] were also used. The sources for all data used are showed in Table 1.

4. Econometric method

The technique adopted here to estimate the parameters in equation (8) was the generalized method of moments (Hansen, 1982), which allows for the joint-estimation of a system of non-linear equations. First, consider equation (8) in its estimable form:

$$r_{it}^{p} = \frac{\gamma + \alpha b_{it} + \delta_i \left(r_t^f - g_{it}\right) b_{it} + \boldsymbol{x}_{it}^{'} \boldsymbol{\beta}}{1 - \delta_i b_{it}} + \varepsilon_{it} \tag{9}$$

The estimation of equation (9) faces two classical econometric problems.

The first is the simultaneity: as indicated by Bayoumi et al. (1995), equation (9) is a credit supply equation, so that each country's demand for credit should be considered simultaneously.

The second problem is the endogeneity, since the debt-to-GDP ratio is calculated at the end of period *t*. Suppose, for example, that an idiosyncratic shock in country *i* increases the probability of a default ($\varepsilon_{\mathrm{it}} > 0$). From equation (9), international creditors will demand a higher risk premium on loans, which would lead to a higher basic interest rate for country *i*, thus configuring a recessive monetary policy. As a result, for the same level of debt, we would have a rise in $\mathrm{b_{it}}$, because of the reduction in both the GDP and $\mathrm{g_{it}}$. Thus, $\mathrm{Cov}(\mathrm{b_{it}}, \varepsilon_{\mathrm{it}}) \neq 0$, as well as $\mathrm{Cov}(\mathrm{g_{it}}, \varepsilon_{\mathrm{it}}) \neq 0$.

The GMM estimation makes it possible to solve both problems. Define $\boldsymbol{w}_{it} = h$

$$f(\boldsymbol{w}_{it}, \varphi_i) = r_{it}^{p} - \frac{\gamma + \alpha b_{it} + \delta_i \left(r_t^f - g_{it}\right) b_{it} + \boldsymbol{x}_{it}^{'} \beta}{1 - \delta_i b_{it}} = \varepsilon_{it} \tag{10}$$

for $i = 1,\dots,N$. Then an appropriate set of instruments $z_{it} = [\delta ca_{it}\ g_{it-1}]$ is used, in which g_{it-1} is the lagged GDP growth rate in t-1 and δca_{it} is the variation in the current account balance.[8] Thus, it is ensured that:

$$E\left[\begin{bmatrix} \delta ca_{i2} & \cdots & \delta ca_{iT} \\ g_{i1} & \cdots & g_{iT-1} \end{bmatrix} \begin{bmatrix} f\left(\boldsymbol{w}_{i2}, \varphi_i^0\right) \\ \vdots \\ f\left(\boldsymbol{w}_{iT}, \varphi_i^0\right) \end{bmatrix}\right] = 0_{2\times 1}\ \forall\, i \in \{1, \dots, N\} \tag{11}$$

Then the second orthogonality condition is defined for the estimation:

$$\frac{1}{T-1} \sum_{t=2}^{T} \begin{bmatrix} \Delta ca_{1t} f\left(\boldsymbol{w}_{1t}, \varphi_1^0\right) \\ \vdots \\ \Delta ca_{Nt} f\left(\boldsymbol{w}_{Nt}, \varphi_N^0\right) \\ g_{1t-1} f\left(\boldsymbol{w}_{1t}, \varphi_1^0\right) \\ \vdots \\ g_{Nt-1} f\left(\boldsymbol{w}_{Nt}, \varphi_N^0\right) \end{bmatrix} = \boldsymbol{g}\left(\varphi^0, \boldsymbol{\omega}_{1T}, \dots, \boldsymbol{\omega}_{NT}\right) = 0_{2N\times 1} \tag{12}$$

in which $\boldsymbol{\omega}_{iT} = (\boldsymbol{w}_{i1}, \dots, \boldsymbol{w}_{iT})$. We thus obtain the orthogonality condition for the estimation. As $N = 13$ and $k = 1$, 26 orthogonality conditions are obtained to estimate 16 parameters. The $\widehat{\varphi}$ estimator is the one that minimizes $\boldsymbol{g}(\varphi, \boldsymbol{\omega}_{1T}, \dots, \boldsymbol{\omega}_{NT})^{'} \widehat{W}_T \boldsymbol{g}(\varphi, \boldsymbol{\omega}_{1T}, \dots, \boldsymbol{\omega}_{NT})$, where:

$$\widehat{W}_T = \widehat{\gamma}_{0,T} + \frac{1}{2}\left(\widehat{\gamma}_{1,T} + \widehat{\gamma}^{'}_{1,T}\right) \tag{13}$$

with:

[7] The EMBI + uses bonds with at least a 2.5-year maturity.

[8] The use of a GDP growth rate lagged by one period as an instrument was a way to work with endogeneity. This instrument was chosen in order to minimize the weak instrument bias, since it was the one that presented the highest correlation with the regressors. On the other hand, the variation in the current account balance, δca_t, was used to solve the simultaneity problem. δca_t approximates the variation in each country's net external liabilities, since a positive δca_t indicates an increase in external financing and, therefore, in the demand for credit of the country; inversely, a negative value of δca_t indicates a fall in the country's demand. Besides, this variable satisfies the stationarity condition.

Table 1
Sources of the data.

Variables	Source	Link
Debt-to-GDP ratio Surplus-to-GDP ratio	Oxford Economics(*)	https://www.oxfordeconomics.com/
GDP	World Development Indicator (World Bank)	https://databank.worldbank.org/source/world-development-indicators
EMBI + spread	Global Economic Monitor (World Bank)	https://databank.worldbank.org/source/global-economic-monitor-(gem)
American government bonds (20, 10 and 5-yer)	Federal Reserve Bank of St. Louis	https://fred.stlouisfed.org/series/DGS20 https://fred.stlouisfed.org/series/DGS10 https://fred.stlouisfed.org/series/DGS5
VIX	CBOE	http://www.cboe.com/products/vix-index-volatility/vix-options-and-futures/vix-index/vix-historical-data

(*)The Oxford Economics data were obtained from the Thomson Reuters Eikon platform.

$$\widehat{\gamma}_{v,T} = \frac{1}{T-1}\sum_{t=v+1}^{T}\begin{bmatrix}\delta ca_{1t}f(w_{1t},\varphi_1)\\ \vdots \\ \delta ca_{Nt}f(w_{Nt},\varphi_N)\\ g_{1t-1}f(w_{1t},\varphi_1)\\ \vdots \\ g_{Nt-1}f(w_{Nt},\varphi_N)\end{bmatrix}\begin{bmatrix}\delta ca_{1t}f(w_{1t},\varphi_1)\\ \vdots \\ \delta ca_{Nt}f(w_{Nt},\varphi_N)\\ g_{1t-1}f(w_{1t},\varphi_1)\\ \vdots \\ g_{Nt-1}f(w_{Nt},\varphi_N)\end{bmatrix}' \tag{14}$$

5. Estimates

This section presents the debt limits estimated for each country. The theoretical model considered was formalized in equation (8). At first, the δ coefficient of this model was estimated for each country by GMM (section 4). Based on these estimates, the corresponding debt limits (as a percentage of GDP) were calculated, given by the formula: $(1/\widehat{\delta})*100$. The results are in Table 2.

For a robustness analysis, an alternative method was also applied: the non-linear two-stage least squares method or 2SNLLS (Amemiya, 1974), described in Annex C, using the same set of instruments (see footnote 8). The reason for using two techniques is that, while GMM involves the joint estimation of all parameters, 2SNLLS, even though more usual for estimating non-linear equations, allows only to estimate each equation separately, as they were unrelated to each other.

The results for the 2SNLLS method are presented in Table 3.

6. Comparison between the methods

This section establishes a statistical comparison between the estimates in Tables 2 and 3 First, one can observe that, although the results for most countries were similar to each other, the methods led to quite discrepant results in four cases: Chile, Poland, Dominican Republic and Peru.

To reach a formal conclusion on the overall statistical significance of the differences between the results provided by the two methods, we applied the non-parametric Wilcoxon signed rank test.[9] This is a paired difference test, thus suitable for comparing the two observations for each country.

The Wilcoxon signed-rank test is conducted in the following way. Let d_i be the difference between estimates for country i. First, the modules $|d_i|$ are placed in ascendant order, and their original signals are registered ("original signals" means "+", if $d_i > 0$, and "-", if $d_i < 0$). The next step is to compute the rank of each $|d_i|$ (rank means ranking position, where 1 is assigned to the lowest value and 16 to the highest one). The third step is to obtain T^+, the sum of ranks of the $|d_i|$ whose original signs were positive, and T^-, the sum of ranks of the $|d_i|$ whose original signs were negative. Finally, the test statistic is calculated by: $T = \min(T^+, T^-)$. The hypotheses for the test are:

H_0: The results provided by the two methods are equal.

H_1: The results provided by the two methods are different and the decision rule is: H_0 is to be rejected, at the level α, if $T \le T_\alpha$, T_α being the critical value.

The results are showed in Table 4.

The table of critical values for each sample is in Annex D. In the present case, we get $T^+ = 33$ and $T^- = 103$. As the critical value for $\alpha = 0.05$ (the most usual significance level) is $T_{0.05} = 30$ and the test statistic values $T = \min(T^+, T^-) = 33$, it follows that the hypothesis is not rejected. Therefore, we can conclude that the results provided by the two methods are not different, at the 0.05 level.[10]

Despites the statistical similarity between the results, another point must be considered: in the four abovementioned cases where there was great discrepancy, the limits provided by GMM are economically more reasonable. To illustrate, it is expected that debt limits

[9] The use of the Wilcoxon test is because the parametric paired *t*-test supposes normally distributed data, what is not realistic in small samples, causing non-parametric tests to perform better. For details, see Conover (1999, p. 352–355).

[10] This conclusion, however, would not be valid if we used the 0.1 significance level, because $T_{0.1} = 36$.

Table 2
δ and Debt Limits (with 95% Confidence Interval) Estimated by GMM.

	$\widehat{\delta}$	Debt Limit (%)	95% CI (%)
Argentina	1.1459	87.27	[81.69; 92.85]
Brazil	1.0668	93.74	[87.60; 99.88]
Chile	1.8169	55.04	[46.76; 63.32]
China	0.5548[a]	–	–
Colombia	1.7281	57.87	[50.78; 64.96]
Ecuador	1.6388	61.02	[54.84; 67.20]
Hungary	1.2459	80.26	[74.35; 86.17]
Malaysia	0.1886[a]	–	–
Mexico	1.7883	55.92	[48.80; 63.04]
Peru	1.8182	55	[48.59; 61.41]
Philippines	1.5375	65.04	[58.26; 71.82]
Poland	1.3252	75.46	[70.14; 80.78]
Russia	1.7565	56.93	[51.28; 62.58]
Dominican Rep.	1.6611	60.2	[54.27; 66.13]
South Africa	1.6149	61.92	[56.36; 67.48]
Turkey	1.6119	62.04	[54.79; 69.29]
Uruguay	1.2895	77.55	[71.71; 83.39]
Venezuela	2.4667	40.54	[34.51; 46.57]

[a] Non-significant at the 5% level.

Table 3
δ and Debt Limits (with 95% Confidence Interval) Estimated by 2SNLLS.

	$\widehat{\delta}$	Debt Limit (%)	95% CI (%)
Argentina	1.1106	90.04	[78.45; 101.63]
Brazil	1.0818	92.44	[82.93; 101.95]
Chile	1.0156	98.46	[89.04; 107.88]
China	0.2397[a]	–	–
Colombia	1.6852	59.34	[48.72; 69.96]
Ecuador	1.7045	58.67	[48.76; 68.58]
Hungary	1.4196	70.44	[60.42; 80.46]
Malaysia	0.2914[a]	–	–
Mexico	1.6976	58.91	[49.76; 68.06]
Peru	1.3792	72.51	[63.08; 81.94]
Philippines	1.7215	58.09	[47.66; 68.52]
Poland	0.9434	105.99	[95.24; 116.74]
Russia	1.5851	63.09	[53.75; 72.43]
Dominican Rep.	1.2958	77.17	[67.64; 86.70]
South Africa	1.6547	60.43	[51.33; 69.53]
Turkey	1.6180	61.80	[52.72; 70.88]
Uruguay	1.1842	84.44	[74.80; 94.08]
Venezuela	1.9718	50.72	[40.45; 61.19]

[a] Non-significant at the 5% level.

Table 4
- Wilcoxon signed rank test.

Country	d_i	$\|d_i\|$	Rank	Original sign	Country	d_i	$\|d_i\|$	Rank	Original sign
Argentina	−2.77	2.77	6	(−)	Brazil	1.3	1.3	2	(+)
Chile	−43.42	43.42	16	(−)	Ecuador	2.35	2.35	5	(+)
Colombia	−1.47	1.47	3	(−)	Hungary	9.82	9.82	11	(+)
Dominican R.	−16.97	16.97	13	(−)	Philippines	6.95	6.95	10	(+)
Mexico	−2.99	2.99	7	(−)	South Africa	1.49	1.49	4	(+)
Peru	−17.51	17.51	14	(−)	Turkey	0.24	0.24	1	(+)
Poland	−30.53	30.53	15	(−)					
Russia	−6.16	6.16	8	(−)					
Uruguay	−6.89	6.89	9	(−)					
Venezuela	−10.18	10.18	12	(−)					

for Chile and Peru are close to those of Colombia and Ecuador, for example, since they are neighboring countries under similar conditions. Nevertheless, this expectancy is only confirmed by GMM results (and, in the case of Chile, the estimated limit was close to 100% by 2SNLLS, against 55.04% by GMM). As another example, the case of Poland also draws attention: there is no reason for this country to have a debt limit higher than 100% (2SNLLS provided 105.99%, against 75.46% by GMM).

Another important point to be highlighted is that GMM enables a joint estimation, so that all the information in the sample is taken into consideration, while 2SNLLS works with each equation in isolation, using only the information on each country to estimate the respective equation. On the other side, the comparison between the results on Tables 1 and 2 shows that, even though the Wilcoxon test indicated no evidence of different point estimates provided by the methods, the standard errors obtained with GMM are much smaller, which follow from the range of its confidence interval. Therefore, this method led to much more precise estimates than 2SNLLS.

This better precision reached by GMM, along with its more reasonable estimates, means that both the control of fixed effects (which are omitted when estimating each equation individually) and the correlation between the equations are important to increase the accuracy of the estimates, thus the joint inference seems to show substantial gains over the individual estimation of the equations.

Although this result should be expected, since this is a sample of emerging countries (and, therefore, should share characteristics), the 2SNLLS method does not consider these factors. It follows that is the better statistical treatment that may explain the better results provided by GMM.

It is important to mention that another way of considering the whole information in the sample would be to use models for panel data estimation, which also allows incorporating the effects of unobservable variables (such as each country's intrinsic institutional factors). Besides, using these models would require a new specification (or an approximation) of the system in a linear format.

Tran (2018) proceeds as in the previous paragraph. However, the transition parameter γ estimated by her does not have the same interpretation as the δ parameter in the model from Bayoumi et al. (1995). Instead, the method used in our work allows estimating the parameters of the correct non-linear model. Besides, the instruments considered (see footnote 8) allow to deal with endogeneity.

7. Clustering

One hypothesis in the literature is that there would be a common debt limit among groups of similar countries. In this work, we applied the cluster analysis technique in order to define groups of countries with similar relevant characteristics, considering debt-to-GDP ratios, estimated debt limits (by GMM), risk premiums (measured by EMBI+), GDP growth and two binary variables: one indicating if the country has received IMF assistance and the other indicating if the debt-to-GDP ratio has exceed the estimated limit, even if at some point, throughout the study period.

The clustering process was based on the non-hierarchical K-means method.[11] This algorithm consists in group the observations into k clusters (sets) $\{S_1, S_2, \ldots, S_k\}$, in order to minimize the within-cluster sum of squares. Formally, we define $S = \{S_1, S_2, \ldots, S_k\}$ such that:

$$\arg_S \min \sum_{i=1}^{k} \sum_{X \in S_i} |X - \mu_i|^2$$

where μ_i is the mean of points in S_i and $|X - \mu_i|$ is the Euclidean distance between X and μ_i. Further details about this non-hierarchical method can be found in Johnston and Wichern (2007), p. 696.

The resulting groups are the following:

Group 1:	Brazil, Chile, Colombia, Dominican Republic, Ecuador, Mexico, Peru, Poland, Russia and South Africa.
Group 2:	Argentina, Hungary, Philippines, Turkey and Uruguay.
Group 3:	China and Malaysia.
Group 4:	Venezuela.

Descriptive statistics for the non-binary variables used in the clustering are reported in Table 5.

8. Analysis

The estimated debt limits for group 1, with the 95% confidence interval, are reported in Table 6.

Concerning characteristics shared by group 1, all debt-to-GDP ratio trajectories kept below the estimated thresholds over the study period (see Annex B). Therefore, as expected, they did not lose access to credit at any time. Nevertheless, they have received IMF assistance at some point, either because of problems with balance of payments or due to impacts of the 2008 global crisis.

For example, Colombia, Mexico and Poland made use of the IMF "Flexible Line of Credit" in 2009 (for countries that, although had a solid record in economic policies, wanted to take preventive measures because of the 2008 crisis).

On the other hand, Brazil, Ecuador, Dominican Republic and Peru also signed agreements with IMF, as part of the so-called "high

[11] For an explanation of why this method is usually more efficient, see Johnson & Wichern, p. 701. Anyway, for robustness, the average linkage and the Ward's hierachical methods were also implemented, leading to the same results.

Table 5
Groups from the cluster analysis and their descriptive statistics.

GROUP	EMBI+					DEBT-TO-GDP RATIO (%)					GDP GROWTH RATE (%)				
	MEAN	MEDIAN	SD[a]	MIN	MAX	MEAN	MEDIAN	SD	MIN	MAX	MEAN	MEDIAN	SD	MIN	MAX
1	343.3	271.4	254.2	129.3	987.6	32.4	31.1	14.6	10.4	58.4	3.7	3.8	1.0	2.0	5.2
2	606.3	342.1	699.8	197.5	1852.3	61.1	61.3	11.3	44.2	72.5	3.7	3.1	1.5	2.1	5.4
3	135.8	135.8	21.1	120.9	150.7	31.4	31.4	20.4	17	45.8	7.2	7.2	3.3	4.8	9.5
4	1084.2	969.1	733.9	206.3	3144.2	23.3	20.4	9.7	11.2	55.8	1.2	2.4	8.9	17	18.3

[a] SD = Standard Deviation.

access precautionary arrangements". It is important to analyze the evolution of the trajectory of their debt-to-GDP ratio. The Brazilian example is showed in Fig. 2 (graphs of other countries in group 1 in Annex B).

Even though the Brazilian debt-to-GDP ratio did not reach the estimated threshold over the whole study period, we can see that it starts an increasing trajectory from 2014 to the end of the sample, suggesting that policy makers should consider making reforms. In the specific Brazilian case, tax and pension reforms are essential to keep the economy in a stable path and to promote long run growth. If these are not implemented, there is a risk that the country reaches its debt threshold, thus moving to group 2, and possibly losing credit access and/or needing external interventions.

The estimated debt limits for group 1, with the 95% confidence interval, are reported in Table 7.

Countries in group 2 they have in common debt-to-GDP ratios that reached or exceeded the estimated limits at some point, which led them to difficulties to access credit. For these countries, IMF recommended fiscal adjustments and made available specific assistance packages. These recommendations emphasized expenditure control, in order to reduce government deficits and the crowding out of investments, thus allowing the economy to establish a stable growth perspective.

Furthermore, we observed that all countries in group 2 followed strictly IMF recommendations, properly using the assistance obtained. Consequently, they could reduce their debt-to-GDP ratio to levels below the estimated debt limits. Next, we analyze the specific situation of each of them.

First, Fig. 3 illustrates the case of Argentina.

It is possible to observe that the Argentinian debt-to-GDP ratio crosses the upper limits of the estimated confidence interval between the first and fourth quarters of 2004. In fact, the country was in a recession since 1999, which led the government to declare a default at December 20, 01.[12] Only in 2005, when around 90% of its creditors accepted the renegotiation with the government, the debt-to-GDP ratio reduced to levels below the limit, remaining so until the end of the sample.

Although the graph indicates a recovery in credibility as early as 2005, due to the reduction in the debt, the country only exited the moratorium in 2016, when it would finally reach an agreement with the so-called "vulture funds", thus recovering its (temporary) access to international market.

The Uruguayan case is illustrated by Fig. 4.

We see that the Uruguayan debt/GDP ratio exceeded the upper limit in 2002, because of a severe banking crisis. In the same year, however, there was a negotiation with the American treasury, with the government obtained loans totaling US$ 1.5 billion,[13] divided between the IMF, World Bank, and IDB (Inter-American Development Bank), as well as an advance of the loan from the American government, while waiting for the loans from these three institutions to be formalized.

With the crisis already controlled, Uruguay restructured its debt in the first quarter of 2003, increasing the maturity of its bonds by five years, without any alteration in neither the principal nor the coupons. However, even though this country had been successful in gradually reducing its debt/GDP ratio since 2003, it only returned to a level below the lower debt limit in mid-2007.

Fig. 5 illustrates the Hungarian case.

The debt ratio was growing since the beginning of the sample, but crosses the lower limit of the 95% confidence interval for threshold only at the last quarter of 2008. In fact, the 2008 crisis affected severely the already unstable Hungarian fiscal scenario. Right after that crisis, the government, in order to try to avoid capital flight, increased the interest rate from 3% to 11.5%. This not being successful, the country made use of a rescue package financed by the IMF, the World Bank and the European Union, thus obtaining the amount needed to fund its 2009 budget.

Fig. 6 illustrates the case of Philippines.

As we can see from Fig. 6, the debt/GDP ratio for Philippines also crosses the limit in 2002, when uncertainties slowed down the economy in the early 2000s and the debt services payments reached alarming levels, with a fiscal crisis leading the country near to default at the beginning of 2005.

Finally, Fig. 7 illustrates the Turkish case.

As we can see in the above Figure, Turkey started the study period above the limit, due to the 2001 crisis, in which the economy faced the most severe recession since the Second World War. However, its fiscal situation started to recover in 2002, with a set of structural reforms and macroeconomic policies under the new Economic Program, with domestic demand as its main contributor.

[12] The recession worsens in 2001, when our study period begins, mainly because of the protests against unemployment, blocking the streets and not allowing goods to enter Buenos Aires, whether for local consumption or export.

[13] Current prices - based on 2002.

Table 6
Estimated debt thresholds for group 1.

	$\widehat{\delta}$	Debt Limit (%)	95% CI (%)
Brazil	1.0668	93.74	[87.6; 99.88]
Chile	1.0156	55.04	[46.76; 63.32]
Colombia	1.6852	57.87	[50.78; 64.96]
Dominican Republic	1.2958	60.20	[54.27; 66.13]
Ecuador	1.7045	61.02	[54.84; 67.2]
Mexico	1.6976	55.92	[48.8; 63.04]
Peru	1.3792	55.00	[48.59; 61.41]
Poland	0.9434	75.46	[70.14; 80.78]
Russia	1.5851	56.93	[51.28; 62.58]
South Africa	1.6547	61.92	[56.36; 67.48]

Group 3 contains China and Malaysia. These countries present a totally atypical debt/GDP ratio and EMBI+ (compared with the rest of the sample), which is reflected in the dispersion diagrams presented in Annex A. There was no positive relationship, i.e., it is not possible to see that a higher debt leads to a higher risk premium for these two countries. Both countries have become severely indebted over the past decades due to their growth models, typical of Asian countries. Nevertheless, it can be observed that the capital invested in these countries is well assured and protected, given the characteristic of these countries of having a strong regulation in the insurance sector, which manages to soften the risk of the agents, leading to a decrease in the risk premium.

These countries are exceptions in which the relationship between debt and risk premium does not follow the relationship proposed in this study. In both cases, the coefficients of the estimated models were not statistically significant, as showed in Tables 2 and 3.[14]

Venezuela (debt limit = 40.54%, see Table 2) was isolated in group 4. In fact, this is the only case of explosive growth in debt (and risk premium), at the end of sample, as showed by Fig. 8.

Venezuela is an atypical case of an emerging country that, although showing satisfactory growth rates in most of the sample, ended up losing control of its monetary policy, resulting in hyperinflation and economic collapse. Its debt-to-GDP ratio exceeded the limit in 2016 and, in 2017, the government declared default, exactly as expected from the strong version of the market discipline hypothesis. This case, therefore, reinforces the main conjecture under this work.

9. Test for common thresholds

The discrepancy between the estimated thresholds within groups 1 and 2 may be an indicative that common limits cannot be considered for all countries, but maybe within the subgroups, unlike argue some works in literature. For example, Reinhart et al. (2003) suggest a general threshold of 35% of GDP for emerging economies.[15] Tran (2018), considering (as here) the general government gross debt, finds limits close to that value, but only for the group of Latin American countries in her sample.[16] For the other group of countries considered, that is, those outside of Latin America,[17] the author finds limits between 40 and 55%.

In order to compare the groups, we used the Mann-Whitney non-parametric statistical test, which performs better than the (more usual) parametric *t*-test in small samples, as it not assumes normally distributed data with equal variances. The test procedure is summarized below. Further details can be found in Conover, 1999, p. 272–281.

The hypotheses of the Mann-Whitney test are:

H_0 : Debt limits of the groups are equal.

H_1 : Debt limits of the groups are different.

As for the data (limits, in our case), they are initially considered to constitute a single sample, with n_1 and n_2 observations, respectively. First, the observations must be ordered according to their estimated debt limits, from the smallest to the largest. Then, we sum the ranks of countries that originally appeared in the first and second samples, thus obtaining, respectively, R_1 and R_2.

The results are showed in Table 8:

The test statistic is: $U = \min(U_1, U_2)$, where:

$$U_1 = n_1 n_2 + \frac{n_1(n_1+1)}{2} - R_1 = 50 + 55 - 62 = 43$$

[14] Instead, Munir et al. (2016) find a statistically significant (at the level 0.01) debt threshold of 52.66% for Malaysia, and Sun (2019) finds, by two different methods, 77.27% and 93.43% as the maximum sustainable debt level for China.

[15] However, they consider only the external debt. Alper and Forni (2011) also analyzed debt limits for two groups of countries, defining groups of advanced and emerging economies, and estimating different thresholds for each of them, but they did not compare the emerging countries among them nor discuss the validity of a common limit for all of them.

[16] Argentina, Brazil, Chile, Colombia, Mexico, and Venezuela.

[17] China, the Philippines, Hungary, Poland, South Africa, Russia, and Turkey.

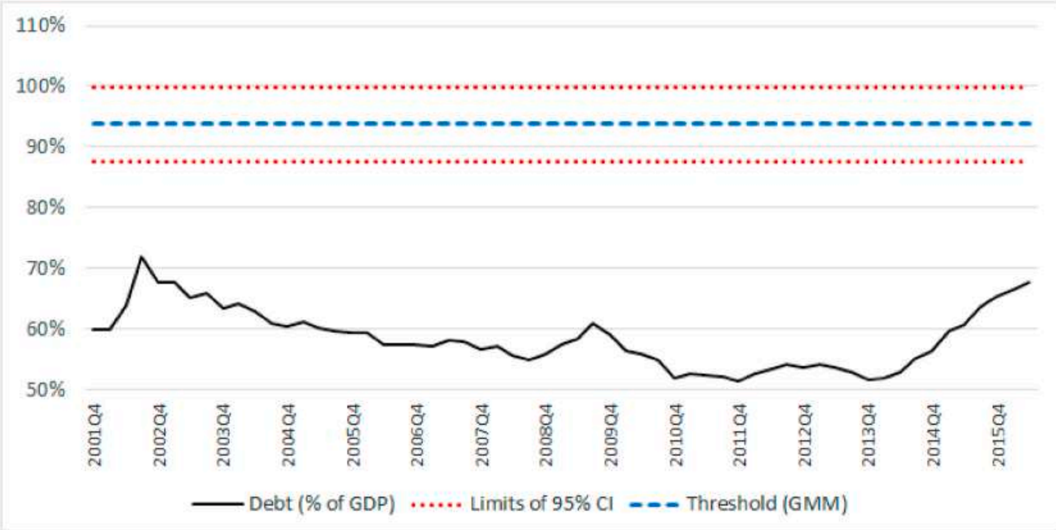

Fig. 2. Debt-to-GDP Ratio of Brazil and 95% Confidence Interval of the Estimated Debt Thresholds. Sources: author's calculations.

Table 7
Estimated debt thresholds for group 2.

	$\hat{\delta}$	Debt Limit (%)	95% CI (%)
Argentina	1.1106	87.27	[81.69; 92.85]
Hungary	1.2459	80.26	[74.35; 86.17]
Philippines	1.5375	65.04	[58.26; 71.82]
Turkey	1.5305	62.04	[54.79; 69.29]
Uruguay	1.2895	77.55	[71.71; 83.39]

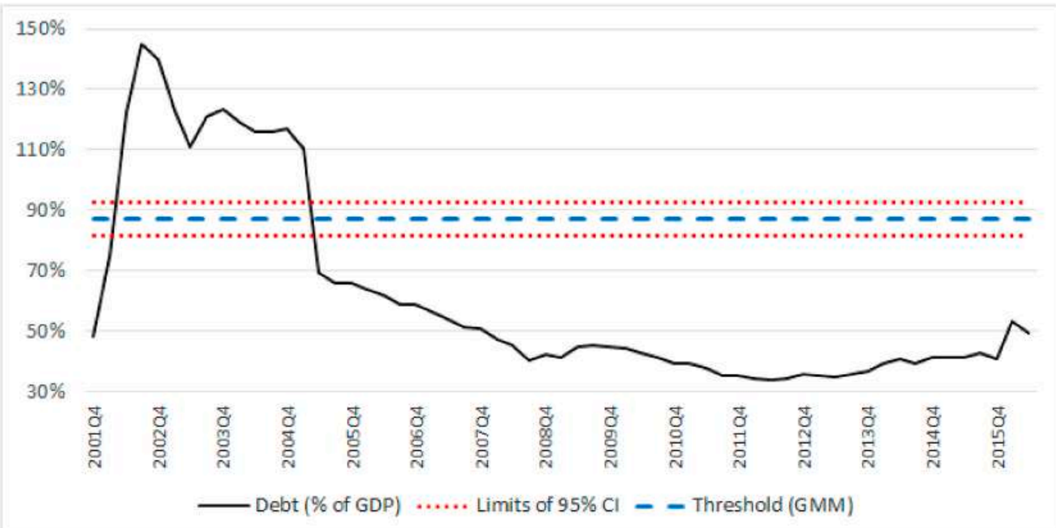

Fig. 3. Debt-to-GDP Ratio of Argentina and 95% Confidence Interval of the Estimated Debt Thresholds. Sources: author's calculations.

$$U_2 = n_1 n_2 + \frac{n_2(n_2+1)}{2} - R_2 = 50 + 15 - 58 = 7$$

Thus, the test statistic is: $U = \min(43, 7) = 7$. Therefore, H_0 is rejected, because $U \leq U_\alpha = 8$, where α is the 0.05 significance level for bilateral test (see Annex E). It follows that the debt limits for countries in group 1 and in group 2 are statistically different, at the

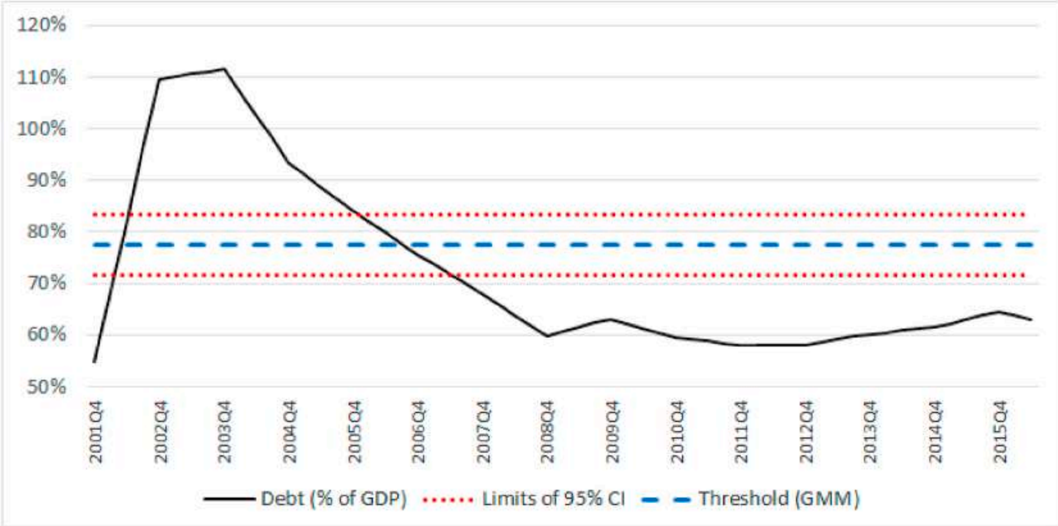

Fig. 4. Debt-to-GDP Ratio of Uruguay and 95% Confidence Interval of the Estimated Debt Thresholds. Sources: author's calculations.

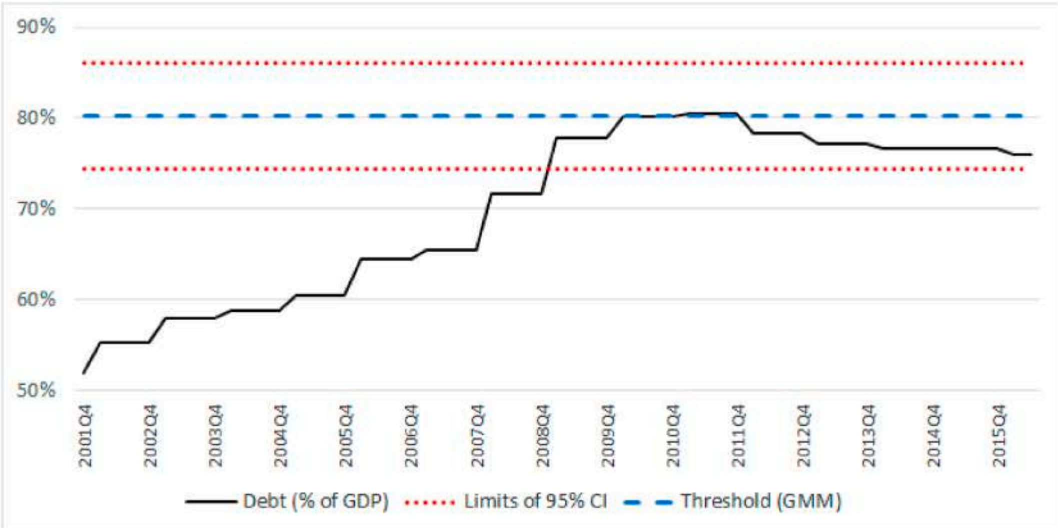

Fig. 5. Debt/GDP Ratio of Hungary and 95% Confidence Interval of the Estimated Debt Thresholds. Sources: author's calculations.

most usual level ($\alpha = 0.05$).

However, there are other suggestions for grouping countries in the literature. Consequently, one question raises: if we have separated the countries into groups different from those reached by the cluster analysis, would the conclusion of different debts between groups limits remain?

As an example, we can follow Tran (2018) and use the groups "Latin America" and "Others". Table 9 reports the thresholds for each group:

Now, we have:

$$U_1 = n_1 n_2 + \frac{n_1(n_1+1)}{2} - R_1 = 60 + 55 - 75 = 40$$

$$U_2 = n_1 n_2 + \frac{n_2(n_2+1)}{2} - R_2 = 60 + 21 - 61 = 20$$

The test statistic values: $U = \min(40, 20) = 20$. Therefore, H_0 is not rejected at the level 0.05, as $U \geq U_{0.05} = 11$ (this value is different from that of the previous test because the sample sizes are different - see Annex E). It follows that we do not have evidence to support the conclusion that the debt limits for Latin and Non-Latin countries are statistically different, at the level $\alpha = 0.05$.

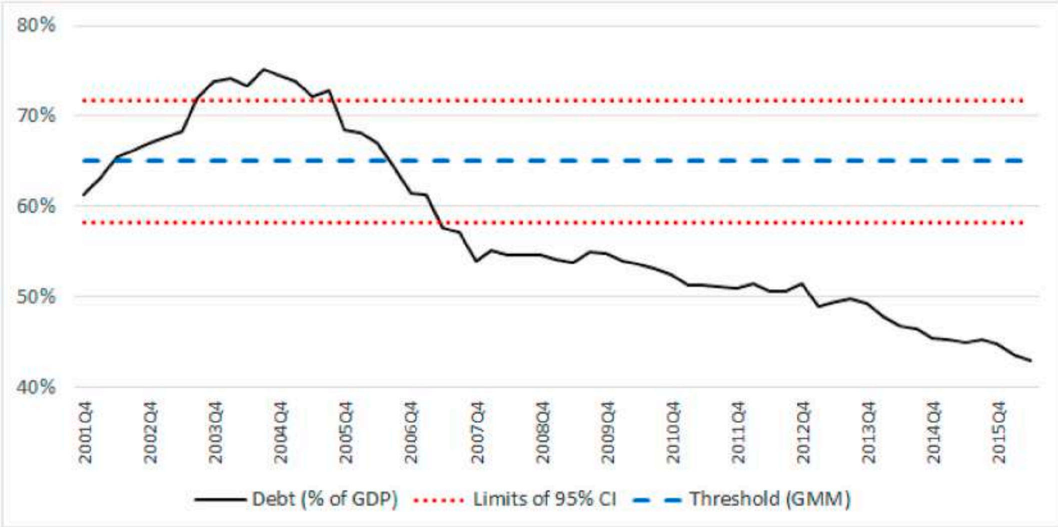

Fig. 6. Debt/GDP Ratio of Philippines and 95% Confidence Interval of the Estimated Debt Thresholds. Sources: author's calculations.

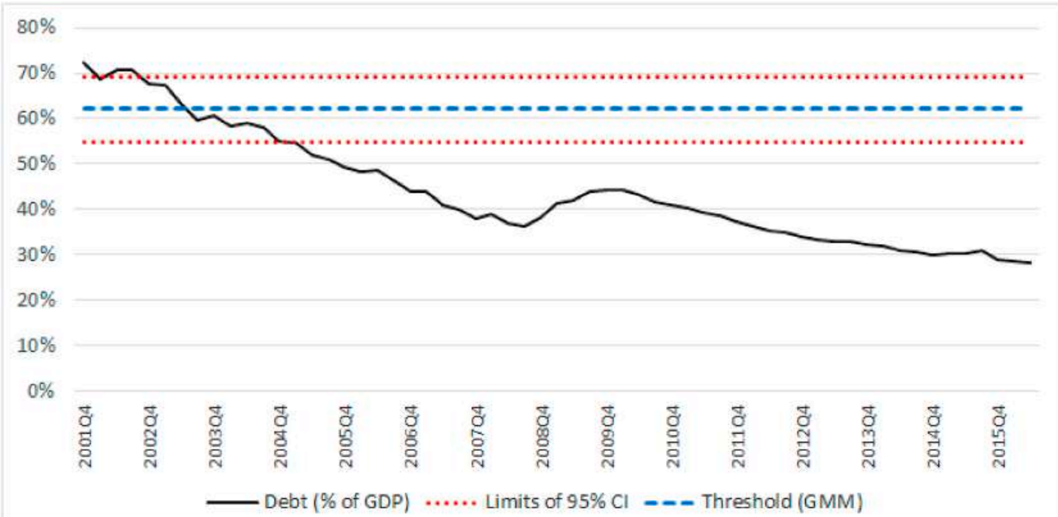

Fig. 7. Debt/GDP Ratio of Turkey and 95% Confidence Interval of the Estimated Debt Thresholds. Sources: author's calculations.

This conclusion goes against some works, for example, Tran (2018). Nevertheless, it is important to mention that this author founds debt thresholds that are not directly comparable to those reported in Table 2 of the present work, because she works with a linear approximation for the theoretical model, whereas we consider the exact nonlinear model, as described in section 2.

Other works provide arguments against establishing the same debt limit for all Latin countries. For example, according to Bizberg (2018), there are many differences among these countries, regarding the conduct of economic growth. To illustrate, in Brazil and Argentina we have a wage led growth, while the growth of Mexico and Chile are mainly attributed to the export sector. As another example, Lima (2018) argues that there is a clear heterogeneity in Latin American, both economically and politically. These arguments are reinforced by our conclusion that there is no difference between debt limits for the Latin group and the other emerging countries in the sample.

10. Is the market discipline hypothesis valid in its strong version?

Suppose that all the countries considered in the sample shared the characteristics of group 1, that is, despite not having debts above the threshold, they requested IMF assistance. Then, it might be an indication that a rise in the risk premium with the debt-to-GDP ratio would be enough for the country to ask for assistance and/or try to promote internal reforms. This situation corresponds to the

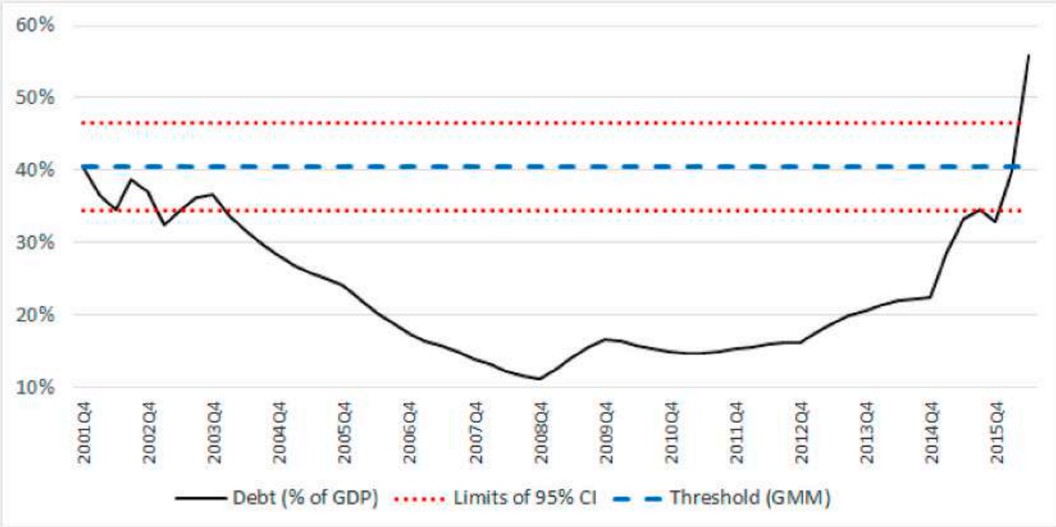

Fig. 8. Debt/GDP Ratio of Venezuela and 95% Confidence Interval of the Estimated Debt Thresholds. Sources: author's calculations.

Table 8
Ranks for the Mann-Whitney Test to compare countries in groups 1 and 2.

Group	Country	Debt Limit (%)	Rank	Group	Country	Debt Limit (%)	Rank
2	Argentina	87.27	14	1	Peru	55	1
1	Brazil	93.74	15	2	Philippines	65.04	10
1	Chile	55.04	2	1	Poland	75.46	11
1	Colombia	57.87	5	1	Russia	56.93	4
1	Dominican Rep.	60.2	6	1	South Africa	61.92	8
1	Ecuador	61.02	7	2	Turkey	62.04	9
2	Hungary	80.26	13	2	Uruguay	77.55	12
1	Mexico	55.92	3				

intermediate version of the market discipline hypothesis, with the debt kept under control.[18]

Taking that affirmation as valid, the increase in the risk premium would already be an incentive for the country to "discipline" its debt, and the threat of exclusion from the credit market would not be necessary. The most serious problem, in this case, is that most of these countries continue showing, at the end of the sample, a growing debt-to-GDP ratio, which raises an important question: what will occur if each of these countries reach the debt thresholds estimated in this study?

Group 2 contains the countries that had debts above the threshold over a period of the sample, and it is found that, precisely in that period, they had problems accessing the credit market. Therefore, this group provides statistical evidence[19] favoring the strong version of the market discipline hypothesis, that is, that the countries that reach the estimated debt threshold in fact ended up having credit problems in the international market and/or needed to undergo some external interference from the IMF, with assistance packages and a pressure for fiscal adjustments.

In the case of group 3, the estimated coefficients were not significant, which corresponds to the weak version of the market discipline hypothesis, that the relationship between the debt level and the risk premium is growing[20], but linear.

Finally, the isolated case of Venezuela can also be seen as one more evidence of the validity strong version of market discipline, since its debt-to-GDP ratio exceeded the estimated limit substantially and, as a result, the country ended up losing access to the international credit market.

Additional arguments are provided by the cluster analysis in section 7 and the tests in section 9.

First, one can see that an empirical evidence in favor of the strong version of the market discipline hypotheses is the difference,

[18] A possible conclusion is that creditors restrict credit for excessively indebted countries. It cannot be immediately affirmed, based on group 1, whether this reasoning is a sufficient incentive to avoid countries getting into excessive debt. For this, it would be necessary to observe what would occur when the countries crossed the threshold. As the countries in this group reduced their debts before reaching the limit, it is not possible to determine whether this occurred due to the threat of exclusion or because the intermediate version of market discipline is, in fact, valid, and the country adjusts its accounts only due to the internal losses derived from the gradual increase in the risk premium with the debt-to-GDP ratio.

[19] This is because all the coefficients of group 2 were statistically significant at the 0.05 level.

[20] The estimates of the α parameter were positive and significant at 0.05 level for all countries.

Table 9
Ranks for the Mann-Whitney Test to compare Latin (L) and non-Latin (N) countries.

Group	Country	Debt Limit (%)	Rank	Group	Country	Debt Limit (%)	Rank
L	Argentina	87.27	15	L	Peru	55	2
L	Brazil	93.74	16	N	Philippines	65.04	11
L	Chile	55.04	3	N	Poland	75.46	12
L	Colombia	57.87	6	N	Russia	56.93	5
L	Dominican Rep.	60.2	7	N	South Africa	61.92	9
L	Ecuador	61.02	8	N	Turkey	62.04	10
N	Hungary	80.26	14	L	Uruguay	77.55	13
L	Mexico	55.92	4	L	Venezuela	40.54	1

regarding risk premium and credit consequences, between countries that were or not successful in keep their debt-to-GDP ratio under the estimated limit. The cluster analysis led to grouping countries in sample exactly according to these characteristics.

Besides, the consequences for each group were those expected from the strong version of the market discipline hypothesis, as discussed in section 8. Finally, the Mann-Whitney test in section 9 showed that the difference between these two main groups is statistically significant.

Therefore, the statistical results of this work, combined with the discussion in section 8, in fact provide empirical support to theory under the strong version of the market discipline hypothesis.

It is important to mention that Bayoumi et al. (1995) didn't investigate the validity of the strong version of the market discipline hypothesis, since none state in their sample reached its debt limit.

11. Policy guides

Concerning policy guides, one can see that the estimated debt limit should be a kind of an alert indicator for policy makers. This is because, as the debt-to-GDP ratio approaches its estimated limit, the fiscal and monetary authorities must react, as soon as possible, by implementing fiscal adjustment mechanisms in order to avoid a great increase of the premium risk, a possible restriction on credit access (as expected by the market discipline hypothesis) and/or a debt default.

In the present work, it is important to emphasize the situation in group 2 countries. We observed that for all countries in this group, the estimated indebtedness limit was exceeded at some point. Nevertheless, they adopted measures that put their debt-to-GDP ratio on a decreasing path, thus returning below the limit. These measures were described in the analysis reported in section 8.

It is important to mention that, if these countries had been used their debt-to-GDP ratio as an alert sign, it would not be necessary to adopt emergency fiscal measures, but only preventive ones. For example, some countries in group 1, although did not exceed the estimated limit, should be careful about the tendency at the end of the sample. We can highlight the cases of Mexico and South Africa, illustrated in Fig. 9. The case of Venezuela (see Fig. 8), in group 4, also draws attention, since it is the only country in the sample whose debt-to-GDP ratio exceeds the estimated limit at the end of the sample, thus making large and immediate contractionary fiscal policy urgent for this specific emergency case.

Therefore, a general recommendation is that countries whose debt-to-GDP ratio either exceeded the limit or are about to reach it, must act by controlling government spending, increasing revenues, and reducing primary and nominal deficits, in order to control their debt-to-GDP ratios.

Among specific public policies to reduce public spending, we mention: (1) to establish fiscal surplus targets; (2) to keep interest rates low, since debt interest is part of total expenses; and (3) to reformulate social security programs, which, in some countries (e.g., Brazil), have a big and increasing deficit. On the other side, among public policies to increase public revenues, we can highlight privatizations and tax reforms to improve taxation efficiency. It is worth mentioning that some of these measures are under discussion about fiscal sustainability in emerging countries.

12. Conclusions

The relationship between sovereign risk and indebtedness level is an important guide for evaluating the probability of a debt default. The market discipline hypothesis establishes that the risk premium increases with the debt-to-GDP ratio. According to the strong version of this hypothesis, this relation is non-linear, and, from a particular level of indebtedness (here called debt limit), it would be very difficult for the government to get new loans, as a consequence of a quite high probability of a debt default.

This work estimated debt limits for a panel of 18 emerging countries, using a method that, unlike the usual 2SNLLS single-equation method, allows for joint-estimating the non-linear equations of the theoretical model, thus allowing to incorporate correlations between these equations and to control fixed effects, without the need to work with linear approximations of the original model.

Concerning results, we used the method of cluster analysis to separate the countries into four groups, based on values of relevant variables.

In group 1, all the countries kept the debt-to-GDP ratio trajectories below the estimated limits over the study period, thus not losing access to credit. On the other hand, for the countries in group 2, the debt-to-GDP ratios exceeded their estimated thresholds at some point of the study period. As a consequence, these countries had difficulties in accessing credit, having been forced either to implement

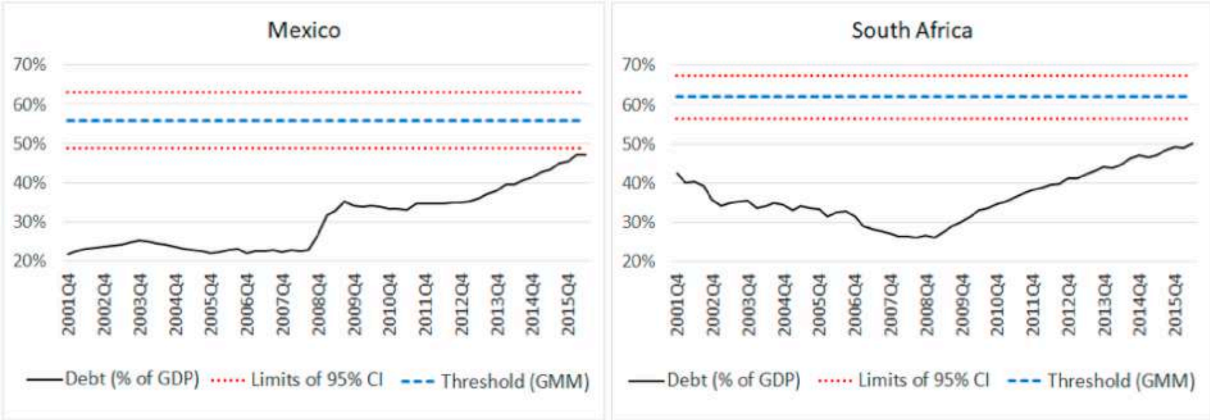

Fig. 9. Debt/GDP Ratio of Mexico and South Africa and their Estimated Debt Limits. Sources: author's calculations

severe fiscal adjustments or to ask for IMF assistance packages.

This could be seen as an empirical statement of the strong version of the market discipline hypothesis, since, whenever the debt limit was reached, the expected problems did occur. The Venezuelan case, even though atypical and thus classified separately, reinforced this conclusion.

Another objective of the paper was to test the hypothesis that, as argue some works, there would be a common debt limit among emerging countries. The Mann-Whitney test provided statistical evidence against this conjecture. Instead, countries in groups 2 and 4 have limits statistically different from those of group 1. However, when we consider other categorizations, like Latin and Non-Latin countries, the results did not lead to the rejection of the hypothesis of a common limit within the groups.

A policy recommendation based on this work is that the estimated debt limit should be a kind of an alert indicator. As the debt-to-GDP ratio approaches its limit, the policymakers must react by implementing fiscal adjustment mechanisms, thus avoiding a great increase of the premium risk and, as a consequence, much higher problems to acess credit.

Credit roles

The authors Eduardo Lima Campos and Rubens Penha Cysne were involved in all stages of this article, such as: Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Roles/Writing - original draft; Writing - review & editing.

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Declaration of interest

The authors hereby declare that there is no conflict of interest.

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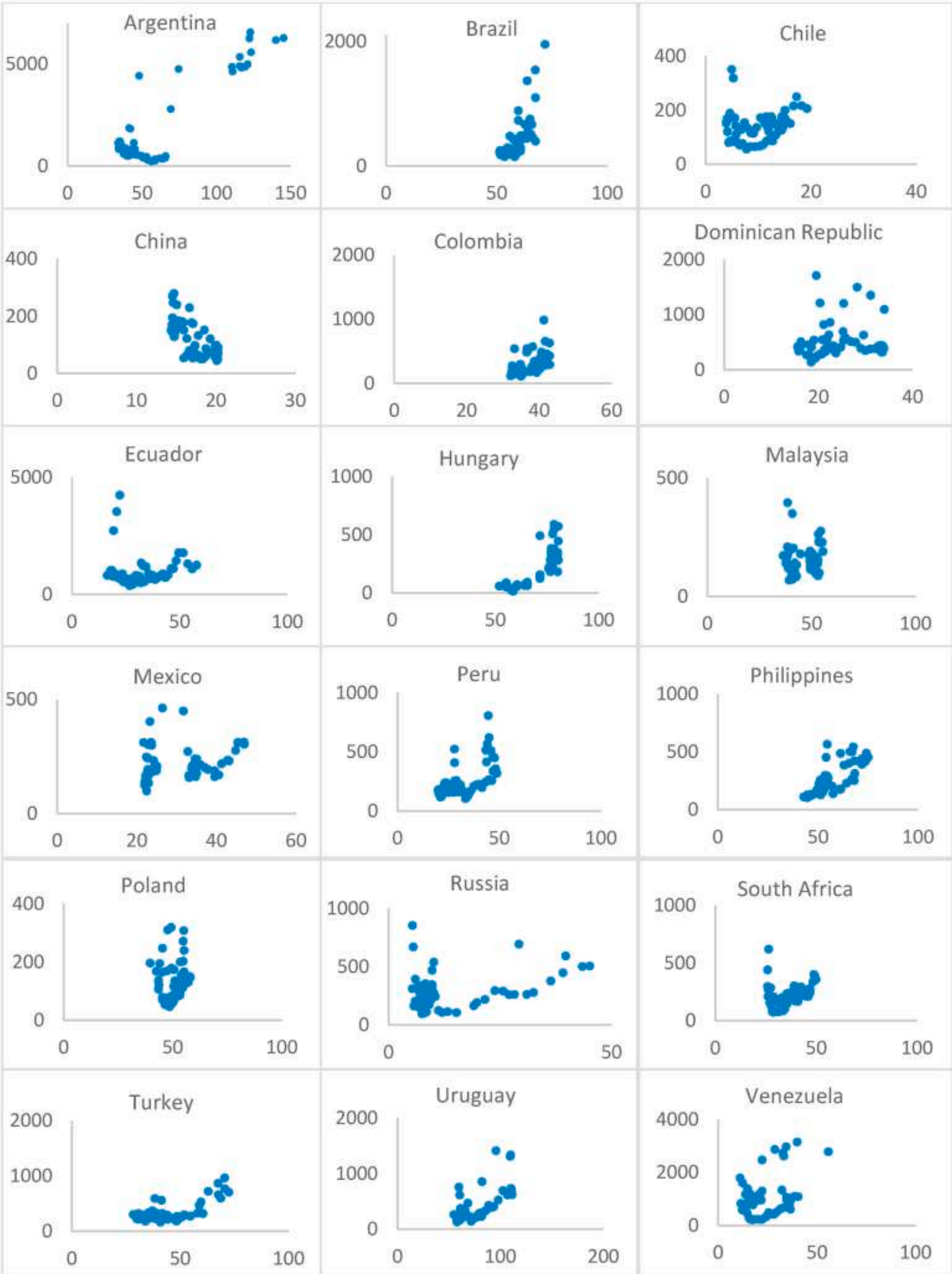
Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.iref.2021.07.014.

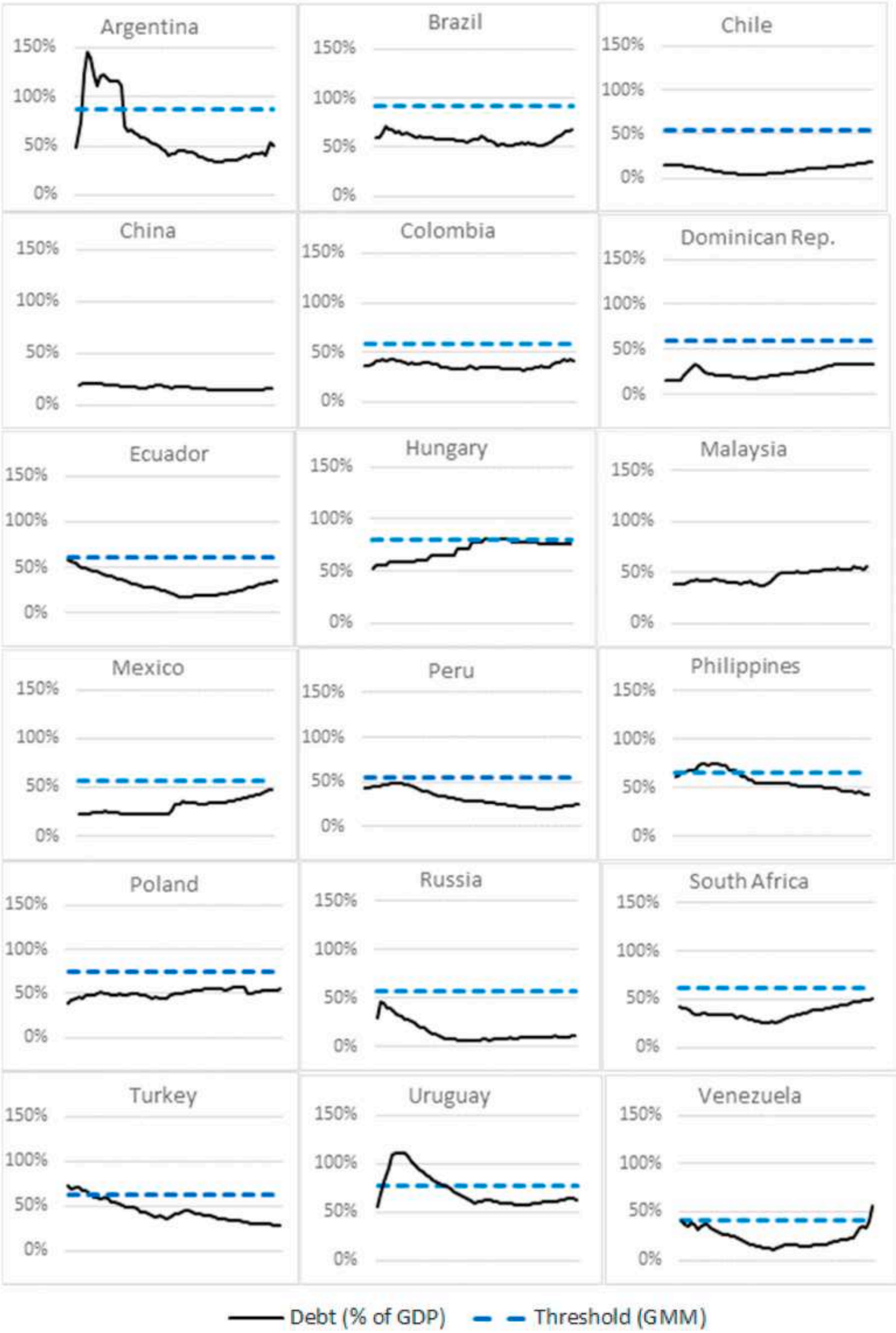
Annex A. Scatterplots – EMBI+ (ordinate) vs Debt-to-GDP Ratio (abscissa)

Annex A -Scatterplots – EMBI+ (ordinate) vs Debt-to-GDP Ratio (abscissa)



Annex B. Graphs of the Evolution of the Debt-to-GDP Ratio and Respective Limits

Annex B- Graphs of the Evolution of the Debt-to-GDP Ratio and Respective Limits



Annex C. Two-Stage Non-Linear Least Squares Method

The two-stage non-linear least squares method (Amemiya, 1974) estimate equations of a non-linear system separately. In order to apply the method to equation (9), the following are defined:

$$y_{it} = r^p_{it}, \mathbf{w}_{it} = \left(r^p_{it}, r^f_t, b_{it}, g_{it}, \mathbf{x}_{it}\right), \varphi_i = (\gamma, \alpha, \boldsymbol{\beta}', \delta_i), m(\mathbf{w}_{it}, \varphi_i) = \frac{\gamma + \alpha b_{it} + \delta_i\left(r^f_t - g_{it}\right)b_{it} + \mathbf{x}'_{it}\boldsymbol{\beta}}{1 - \delta_i b_{it}}, \mathbf{m}_i = \begin{bmatrix} n\dfrac{\gamma + \alpha b_{i2} + \delta_i\left(r^f_2 - g_{i2}\right)b_{i2} + \mathbf{x}'_{i2}\boldsymbol{\beta}}{1 - \delta_i b_{i2}} \\ n\vdots \\ n\dfrac{\gamma + \alpha b_{iT} + \delta_i\left(r^f_T - g_{iT}\right)b_{iT} + \mathbf{x}'_{iT}\boldsymbol{\beta}}{1 - \delta_i b_{iT}} \end{bmatrix}$$

$$\mathbf{Y}_i = \begin{bmatrix} nr^p_{i2} \\ n\vdots \\ nr^p_{iT} \end{bmatrix}, \text{ and } \mathbf{u}_i = \begin{bmatrix} nu_{i2} \\ n\vdots \\ nu_{iT} \end{bmatrix}.$$

The model to be estimated is: $\mathbf{Y}_i = \mathbf{m}_i + \mathbf{u}_i \forall\, i \in \{1, \ldots, N\}$

Now let $\mathbf{Z}$ be the vector of instruments: $\mathbf{Z}_i = \begin{bmatrix} ca_{i2} & g_{i1} \\ \vdots & \vdots \\ ca_{iT} & g_{iT-1} \end{bmatrix}$. Thus, we have:

$$\mathbf{Z}'_i(\mathbf{Y}_i - \mathbf{m}_i) = \sum_{t=2}^{T} \begin{bmatrix} n\left(r^p_{it} - \dfrac{\gamma + \alpha b_{it} + \delta_i\left(r^f_t - g_{it}\right)b_{it} + \mathbf{x}'_{it}\boldsymbol{\beta}}{1 - \delta_i b_{it}}\right)\Delta ca_{it} \\ n\left(r^p_{it} - \dfrac{\gamma + \alpha b_{it} + \delta_i\left(r^f_t - g_{it}\right)b_{it} + \mathbf{x}'_{it}\boldsymbol{\beta}}{1 - \delta_i b_{it}}\right)g_{it-1} \end{bmatrix}$$

$$\mathbf{Z}'_i\mathbf{Z}_i = \sum_{t=2}^{T} \begin{bmatrix} (ca_{it})^2 & g_{it-1}ca_{it} \\ g_{it-1}ca_{it} & g^2_{it-1} \end{bmatrix}$$

The 2SNLLS estimator $\widehat{\varphi}_i$ is the one that minimizes: $\Psi(\varphi_i) = (\mathbf{Y}_i - \mathbf{m}_i)'\mathbf{Z}_i(\mathbf{Z}'_i\mathbf{Z}_i)^{-1}\mathbf{Z}'_i(\mathbf{Y}_i - \mathbf{m}_i)$.

Annex D. Critical Values for Wilcoxon Signed Rank Test

n	0.005 one-tailed	0.01 one-tailed	0.025 one-tailed	0.05 one-tailed
	0.010 two-tailed	0.02 two-tailed	0.050 two-tailed	0.10 two-tailed
5	*	*	*	1
6	*	*	1	2
7	*	0	2	4
8	0	2	4	6
9	2	3	6	8
10	3	5	8	11
11	5	7	11	14
12	7	10	14	17
13	10	13	17	21
14	13	16	21	26
15	16	20	25	30
16	19	24	30	36
17	23	28	35	41
18	28	33	40	47
19	32	38	46	54
20	37	43	52	60
21	43	49	59	68
22	49	56	66	75
23	55	62	73	83
24	61	69	81	92
25	68	77	90	101

Annex E. Critical Values for Mann-Whitney Test (α = 0.05)

n_1	n_2											
	9	10	11	12	13	14	15	16	17	18	19	20
1												
2	0	0	0	1	1	1	1	1	2	2	2	2
3	2	3	3	4	4	5	5	6	6	7	7	8
4	4	5	6	7	8	9	10	11	11	12	13	13
5	7	8	9	11	12	13	14	15	17	18	19	20
6	10	11	13	14	16	17	19	21	22	24	25	27
7	12	14	16	18	20	22	24	26	28	30	32	34
8	15	17	19	22	24	26	29	31	34	36	38	41
9	17	20	23	26	28	31	34	37	39	42	45	48
10	20	23	26	29	33	36	39	42	45	48	52	55
11	23	26	30	33	37	40	44	47	51	55	58	62
12	26	29	33	37	41	45	49	53	57	61	65	69
13	28	33	37	41	45	50	54	59	63	67	72	76
14	31	36	40	45	50	55	59	64	67	74	78	83
15	34	39	44	49	54	59	64	70	75	80	85	90
16	37	42	47	53	59	64	70	75	81	86	92	98
17	39	45	51	57	63	67	75	81	87	93	99	105
18	42	48	55	61	67	74	80	86	93	99	106	112
19	45	52	58	65	72	78	85	92	99	106	113	119
20	48	55	62	69	76	83	90	98	105	112	119	127

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