Improving the Estimates of Fiscal Space

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Abstract

We contribute to the fiscal space literature in both technical and empirical perspectives. First, we compute a time-varying fiscal space and show that complex fiscal space numbers resulting from solving the model provide crucial information in assessing fiscal sustainability, thus they should not be ignored. We propose three different scenarios to deal with complex numbers in an empirical framework. Second, we provide a new determinant for fiscal sustainability : sustainable development. Using data from 24 OECD countries from 1998-2015, we find that sustainable development, proxied by an Environmental, Social and Governance performance index, has a robust positive impact on fiscal space.

JEL classification: E61, E62, H62, H63, Q01.

Keywords: ESG performance, sustainability, debt limit, fiscal space, complex numbers.

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1 Introduction

The unexpected surge of sovereign debt in the aftermath of the great recession and the debt crisis that shook advanced economies prompted much thought about the nature and the level of a sustainable debt.

This paper constitutes an attempt at providing a better assessment of debt sustainability by computing a time-varying debt limit − the maximum debt-to-GDP ratio that a country can reach without defaulting − so far considered as a point estimate in existing frameworks. As a matter of fact, these frameworks make simplifying assumptions on the key determinants of the debt limit, in particular the growth rate of the output which is considered to be constant (Ghosh et al., 2013). Instead, we consider a more general formulation that allows the growth rate to vary over time, leading to a time-varying debt limit. The intuition behind our approach is straightforward: debt limit is subject to changes across years due to changes in the fundamentals, in particular during recession periods such as the global financial crisis. Moreover, investors may react to worsening fundamentals by revising risk premia on public debt, leading to a higher interest rate and therefore to a lower debt limit. The recent euro sovereign debt crisis is an illustration of this situation. For these reasons we argue that a time-varying debt limit would provide a more accurate measure of a country's debt sustainability.

Moreover, in standard literature, we notice that the debt limit is not always reported for some countries, in particular vulnerable ones. Methodologically, this is when the debt limit is not defined in the real domain ($\mathbb{R}$). This possibility is also present in our case. It appears mostly for vulnerable countries and in times of crisis. To deal with this situation we account for the debt limits that are defined in the complex domain ($\mathbb{C}$) when the real ones are not available. We argue that these complex numbers hold important information about debt sustainability especially during turmoil periods. Thus, they should not be ignored.

We find that, the debt limit varies within countries and this variation is more noticeable during recessions. Take Greece and Italy for instance, over our time period 1998-2015, the debt limit varies between 202% of GDP and 342% for Greece, and between 201% and 295% for Italy. Moreover, the average debt limit in our sample of OECD countries decreases from 295% of GDP in 2007 to 216% in 2010, and it jumped back to 299% in 2015.

As for complex debt limit values, first, we find that complex numbers appear the most in fragile countries such as Greece, Iceland, Ireland, Italy, Portugal and Spain. Together, they absorb more than half of the obtained complex debt limit values. Second, complex debt limit values appear in period of recessions and economic crisis. The year 2010 alone represents 28% of the total obtained debt limit values. Finally, we observe that complex debt limits, when they occur, are in general much lower than the debt limit defined only on the real domain ($\mathbb{R}$).

We also make an empirical contribution on the determinant of debt sustainability, namely the sustainable development. Using an Environmental, Social and Governance (ESG) performance index as a proxy for sustainable development, we find a positive impact on fiscal space which is defined as the difference between the debt limit and the actual debt. This result is robust to various sensitivity checks; It complements the existing studies which have so far focused on economic (Diaye et al., 2021) and financial (Capelle-Blancard et al., 2019) determinants of fiscal space.

The remainder of the paper is structured as follows: section 2 reviews the literature. Section 3 discuses fiscal space measures used in literature. Section 4 introduces the time-varying debt limit and complex debt limit values. Section 5 estimates the impact of sustainable development on fiscal space and Section 6 concludes.

2 Literature Review

Debt dynamic is abundantly discussed in macroeconomic literature. Fiscal space is driven by key variables that affect the public debt dynamic: real interest rates, real growth in the GDP and the primary balance. Bohn (1998) presented the concept of fiscal reaction function, describing the reaction of the primary balance towards an increasing level of debt. On US data, he showed that this is a sufficient condition for sustainability. While such method points out potential problems in fiscal policies, Ghosh et al. (2013) consider it as a weak sustainability criterion since it does not rule out a continuous rising of the debt-to-GDP ratio. That case would need a primary surplus that exceeds the GDP. To address this issue and to take into account the limits of primary surpluses, Ghosh et al. (2013) built a stricter sustainability criterion considering that debt is converging to a finite proportion of GDP: when the primary balance is greater than the growing debt-to-GDP at the interest rate - growth rate differential, then the primary adjustment will be offsetting the debt dynamics, leading the debt to a finite ratio. Along with Ostry and Abiad (2005), Mendoza and Ostry (2008), Medeiros et al. (2012) and Fournier and Fall (2015) their paper reports evidence of weakening reaction at higher debt level by contrast of Bohn (1998, 2008)'s results that suggest a sharpener response at high debt levels. Ghosh et al. (2013)'s paper comes along with the strand of literature investigating the non-linear fiscal behaviour of the fiscal reaction function towards an increasing level of debt.[1] In many papers, the fiscal fatigue phenomenon is tested in a polynomial form (quadratic or cubic) for the fiscal reaction toward debt ratio, where at a high level of this ratio, the fiscal effort needs to be so large that it becomes untenable. Stemming from such a behaviour of the primary balance, Ghosh et al. (2013) were able to identify a debt limit as a point of no return, where a sovereign borrower loses market access, thus, it will not be able to service its debt anymore with standard methods, leading it to default. They contributed in the debt sustainability literature[2] by proposing a method to assess the fiscal space defined by Heller (2005) as the room that can let governments provide resources without jeopardising their sustainability nor the stability of the economy.

Despite the different approaches used to assess defaults in the literature (Barro 1979; Blanchard et al. 1991; Bohn 1998, 2008; Bi 2012a; Bi and Leeper 2013; Ghosh et al. 2013; Fournier and Fall 2015 and Ganiko et al. 2016), there still is a missing piece of information in these models that should be added (Di Cesare et al. 2012; Beirne and Fratzscher 2013; Poghosyan 2014).

On a first scale, debt limits (therefore, fiscal space) depend on risk-free interest rates, the level of public debt and its trajectory, the reaction to the increasing debt,[3] the market perception, macroeconomic shocks, their size and the potential output growth. On a second scale, it depends on financing needs, fiscal track records and on the economic development (see Figure 1). Literature discussed as well other drivers related to sustainability, for instance, Reinhart et al. (2003) showed that default history should be considered, Kraay and Nehru (2006) stated that the effect of institutions is to take into account in external debt defaults, Fournier and Bétin (2018) shed the light on the importance of governance effectiveness, the export to GDP ratio, the expected recovery rate and investor's risk aversion, Arellano et al. (2017) discussed the importance of contagion and Catão and Kapur (2004) showed that external debt to export ratio matters. Moreover, in a simpler configuration, Botev et al. (2016) and Joumard et al. (2010) show that optimising health expenses can release spending pressures in the long run. Such containing of spending is crucial in a context were De la Maisonneuve and Martins (2015) are expecting a rise in health costs which in this case

[1]See Checherita-Westphal and Žďárek (2017) for a summary review on fiscal reaction function literature.

[2]See Botev et al. (2016) and Bouabdallah et al. (2017) for a summary review on debt sustainability literature.

[3]It relies on the assumption that government cannot indefinitely sustain public primary surpluses and will experience fiscal fatigue at some point.

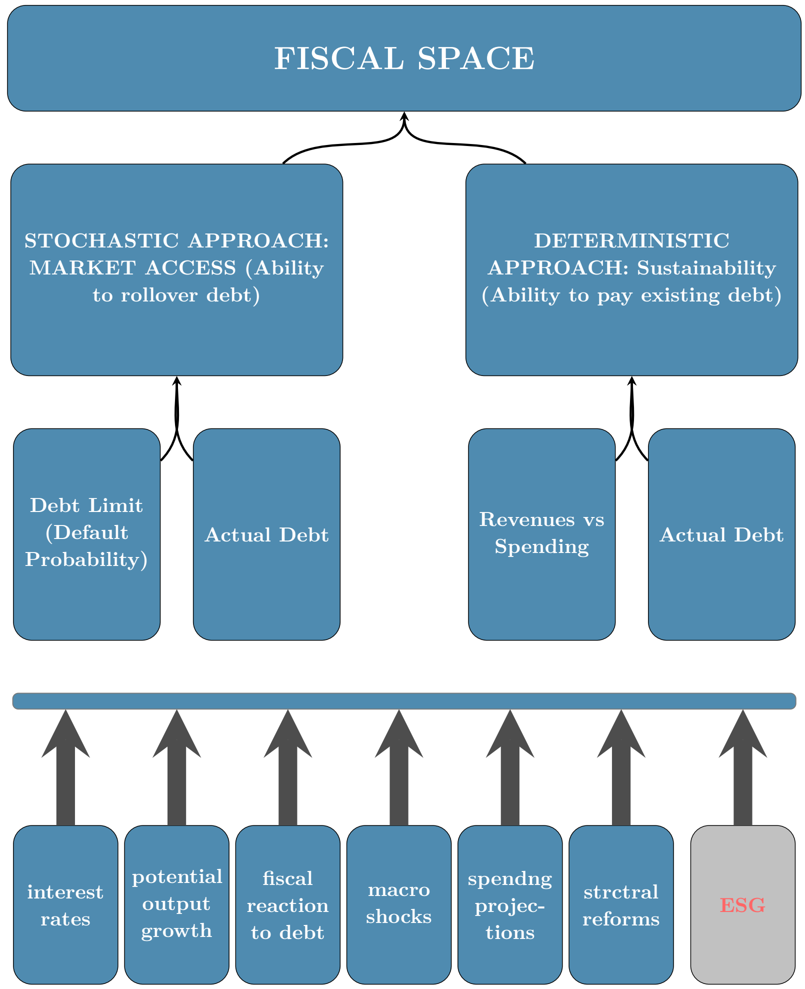

Figure 1: Determinants of fiscal space (adapted from Botev et al. (2016))

could require a rise in tax ratios and a fall in other spending in order to avoid sustainability risks.

In this paper, we take advantage from existent models and exploit the left out information by going beyond real solutions (R) of the model and explore the complex ones (C). Moreover, instead of relying on a one calibrated debt limit, we estimate a time-varying debt limit, taking into consideration market's reaction towards an increasing debt-to-GDP ratio. Also, by adding an Environmental, Social and Governance (ESG) extension to this literature, as presented in Figure 1, we aim to provide a better understanding for the drivers of default and see if these factors can provide an early warning for an upcoming fiscal fatigue phenomenon. This thought is in line with Papanikos (2014) who adopted the argument that markets take into consideration qualitative indicators when assessing debt sustainability.

3 Fiscal Space in standard literature

Synthetic indicators have been widely used in practice to assess the fiscal space. Among others, we cite the negative of the ratio of gross government debt to GDP from Romer and Romer (2019) (Figure A.1), the interest rate-growth rate differential (Figure A.2) and the years to repay public debt from Aizenman and Jinjarak (2010) (Figure A.3). These measures are known for their simplicity as they provide a straightforward signal, they are as well easy to communicate and each one of them reports a different message about sustainability. However, there is a trade-off between this simplicity and the ability to capture the different angles of fiscal space by using such indicators. Therefore, more elaborated frameworks exist. These frameworks consider losing market access (Ostry and Abiad 2005; Ghosh et al. 2013; Fournier and Fall 2015; Collard et al. 2015; Ganiko et al. 2016) or achieving long-term sustainability (Blanchard et al. 1991; Mendoza and Ostry 2008) or even both (Bi and Leeper 2013; Bi 2012b). In this paper we focus on the one proposed by Ghosh et al. (2013). The paper identifies a debt limit as a point of no return, where sovereign borrower loses market access, thus, it will not be able to service its debt anymore with standard methods, leading it to default.

They implemented their framework on a sample of 23 countries from 1985-2007. They identified 18 over 23 point estimates of debt limit (5 non-available estimates: Greece, Iceland, Italy, Japan and Portugal) when using the projected interest rate, and 21 over 23 point estimates (2 non-available estimates: Italy and Japan) when using the historical interest rate. This is because debt does not converge to a finite steady state debt ratio. Thus, for Ghosh et al. (2013), calculating a maximum debt level below which the convergence occurs is not fully meaningful. As for Fournier and Fall (2015),[4] an unavailable value suggests that a change in the behaviour is needed, these countries need to change their fiscal behaviour for their debt trajectory to become sustainable.

Such results depend on the dataset (countries with high/low debt), on the estimation approach (Fournier and Fall, 2015) and on the error specification terms (Medeiros et al., 2012). As pointed out in Ghosh et al. (2013), the model is also sensitive even to modest uncertainty in the estimates of the primary balance which can be translated into significant differences in debt limits. Therefore, a tiny change in these parameters can shift the debt limit from R to C leading to a non-available debt limit.

[4] Among 31 countries in their sample, when using model based interest rate they have 4 non-available solutions and 8 no solutions (no finite interest rate solution, if past fiscal behaviour prevails) and 4 non-available solutions and 2 no solutions situation when using the market based interest rate.

4 Adding new features to standard fiscal space definition

We provide two ways to improve the measure of fiscal space: time-dependent fiscal space (subsection 4.2) and complex fiscal space values (subsection 4.3).

4.1 Country-specific debt limits

We perform the calculation of the time-dependent fiscal space on a sample of 24 OECD countries[5] from 1998-2015. To do so, we proceed in three steps: (i) we estimate the fiscal reaction function (equation 1), (ii) we use the estimated function in the budget identity to obtain the debt limit for each country at each period (equation 2), and (iii) we compute the associated fiscal space (equation 3).

4.1.1 Fiscal Reaction Function

The fiscal reaction function is estimated following the model in equation 1:

$$s_{i,t} = \alpha_0 + \sum_{j=1}^{3} \alpha_j b_{i,t-1}^{j} + \boldsymbol{\beta}' X_{i,t} + \mu_{i,t}, \tag{1}$$

$$with\ \mu_{i,t} = \omega_i + \lambda_t + \varepsilon_{i,t},$$

where $s_{i,t}$ denotes the primary surplus of country i at a year t as a percent of GDP, $\sum_{j=1}^{3} b_{i,t-1}^{j}$ denotes the cubic form of the lagged debt (over GDP) to capture inflection points and to allow for fiscal fatigue, $X_{i,t}$ is a vector of controls widely used in previous literature[6] : at first we include output gap to control for business cycles.[7] Ghosh et al. (2013), Fournier and Fall (2015) and Zeng et al. (2014) find that higher output gap enhances the fiscal performance. Then we include expenditure gap[8] which controls for temporary outlays such as wars expenditures. A negative sign can be expected from the straight forward relationship between the primary balance and

[5] The country sample consists of Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Korea, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and United States

[6] Bohn (1998), Ostry and Abiad (2005), Woo (2006), Ghosh et al. (2013), Zeng et al. (2014), Fournier and Fall (2015).

[7] Real GDP growth can be considered as a determinant of primary balance. However, a causality issue can exist, we avoid any potential endogeneity problem by using output gap instead.

[8] Computed using the Hodrick-Prescott filter.

expenditure. We also include public debt stock as a share of GDP assessing the pressure on solvency. Bohn (1998) suggests a linear and positive link with the surplus unlike Ghosh et al. (2013) who suggest a nonlinear one, where authors show a weaker reaction of primary balance at higher debt level. Inflation is used to control for Patinkin effect on expenditure or the bracket creep effect on revenues. Also, a higher inflation releases the pressure on the debt which therefore lower the need to run primary surplus. Thus, the dominant sign of the coefficient in the regression is an empirical question. We also add oil prices to control the impact of price movements on the fiscal position for oil exporter countries, thus the higher the price is, the greater is the ability to generate surplus.

Moreover, we account for the existence of fiscal rule for expenditure, revenue, balance or debt. Such rules correct any shortcoming of the political process as some policies are tempted to overspend. As a result, the existence of fiscal rule removes a layer of uncertainty of fiscal policy but also enhance long-term growth and lowers recession risk as stated by Fournier and Fall (2015). Furthermore, we include an IMF programme dummy for whether there is an international influence on fiscal behaviour.

Our sample is homogeneous, it includes exclusively advanced economies which behave similarly when the level of debt increases. But still, there are unobserved countries and time specific characteristics of the primary balance that we capture by including a country fixed effects[9] ω_i and a time-specific effect λ_t. Therefore, the equation 1 is a two-way effect model estimated using a double-within estimator. Moreover, for a valid statistical inference, we control for heteroscedastic and autocorrelated disturbances by relaxing the assumption of independently distributed residuals. We do so by using robust standard errors.

Results are presented in Table 1. The table shows that the coefficients of the cubic form of the fiscal reaction function are statistically significant. The estimated coefficients of the other determinants show the expected sign and are statistically significant except for the inflation in our main specification (column 1). These results are similar when using only a country fixed effect (column 2) and when including an AR(1) error term (column 3).

Table 1: Fiscal reaction function

	Primary balance		
	Double within	Country FE	AR(1) error
Cubic debt			
Debt_t-1	−0.15	−0.15	−0.18
	(0.06)	(0.07)	(0.06)
Debt_t-1^2	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)
Debt_t-1^3	−0.00	−0.00	−0.00
	(0.00)	(0.00)	(0.00)
Controls			
Output gap	0.35	0.53	0.44
	(0.07)	(0.09)	(0.05)
Expenditure gap	−0.55	−0.77	−0.53
	(0.05)	(0.05)	(0.05)
Inflation	0.05	0.08	0.09
	(0.19)	(0.23)	(0.08)
Oil price	2.57	0.24	0.45
	(0.87)	(0.35)	(1.67)
IMF programme	−4.05	−4.11	−5.24
	(1.57)	(1.87)	(0.74)
Fiscal rule	1.48	1.62	−0.35
	(0.53)	(0.62)	(0.73)
Constant	0.00	2.51	3.85
	(0.08)	(2.14)	(0.81)
Number of obs	432	432	408
R2	0.50	0.58	.
Country FE	Yes	Yes	Yes
Year FE	Yes	No	No
aic	1701.82	1869.81	1654.25
bic	1742.51	1902.36	1694.37

Notes: Estimation with robust standard errors. Norway is the only oil exporter country in our sample. Standard errors in parentheses. Primary balance is in % of GDP. Column 1 displays estimation results using a double-within estimators, column 2 displays estimation results using country fixed effect, and column 3 displays estimation results taking into account and AR(1) error term. Sample of 24 countries from 1998-2015. The country sample consists of Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Korea, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and United States * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Source: Authors' estimates.

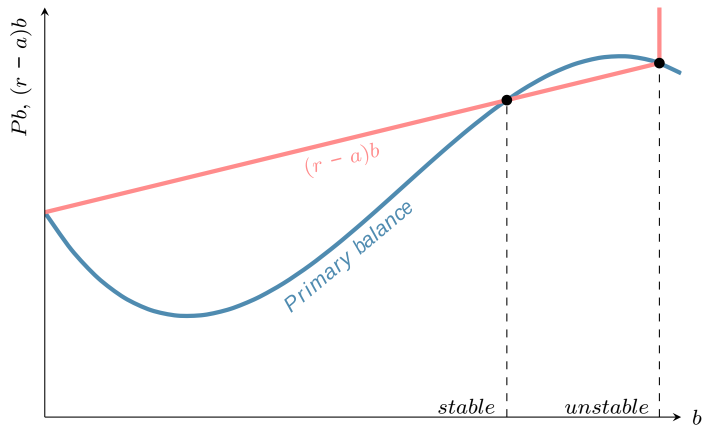

Figure 2: Debt limit – Equilibria

4.1.2 Debt limit and fiscal space estimates

We carry our calculations of the debt limit based on a market-based approach and we use the following elements: the fiscal reaction function (equation 1),[10] the real growth rate, and the real interest rate. For a given interest rate r that includes risk premium, the government reaches its limit for the highest debt stabilizing[11,12] the following equation:

$$\Delta b_{i,t} = (r_{i,t-1} - a_{i,t-1})b_{i,t-1} - \widehat{s_{i,t}} = 0, \tag{2}$$

where b is debt-to-GDP ratio, r the real interest rate,[13] a the real growth rate of GDP, and $\widehat{s}$ being the estimated primary surplus from equation 1. Debt limit, $b_{i,t}^{lim}$, can be obtained by solving the polynomial equation in 2. Several solutions exist, and the debt limit is the highest one. Graphically it is the highest intersection between $(r-a)b$ and pb in Figure 2. Such equilibrium is unstable and can be defined as a point of no return. The associated fiscal space, fs, is obtained from equation

[9] Haussman test reveals that a fixed effect is more suitable than a random effect model.

[10] We rely on the results in column 1 of Table 1.

[11] The elements of this equation are inter-dependent: a primary surplus decreases risk premium which decreases interest rates (Italy in 1990's) and a primary deficit increases risk premium that increases interest rates (Greece in 2009). According to the equation, solvency can be ensured as long as primary surpluses can be maintained permanently to honor debt commitments. However, there is a social acceptance limit to the raise of taxes or the decrease of expenses that result from an increasing debt without jeopardizing social and economic stability (Greece in 2010).

[12] This identity shows that debt can be stabilized when inflation π_t is positive (with $r_{i,t} \approx i_{i,t} - \pi_{i,t}$) and when growth rate $a_{i,t}$ is higher than real interest rate r_{it} ($s_{i,t} = (i_{i,t} - \pi_{i,t} - a_{i,t})d_{i,t}$) even with a primary deficit. In all other cases, a primary surplus should be reached in order to stabilize debt.

[13] The real interest rate is the nominal interest rate minus the three years moving average inflation.

3 :

$$fs_{i,t} \stackrel{\text{def}}{=} b_{i,t}^{lim} - b_{i,t}. \tag{3}$$

4.2 Feature one : A time-varying debt limit

We consider a time-dependent debt limit. This concept does not exist in most models of sovereign default they rather consider a constant debt limit over time: $b_{i,t}^{\text{lim}} = b_i^{\text{lim}} \quad t$. This is due to the fact that these models make simplifying assumptions on the maximum primary surplus (as a fraction of output) and the growth rate of output, which are the main determinants of the debt limit. Precisely, these models assume that the maximum primary surplus is constant over time and that the growth rate is either independent and identically distributed (Collard et al., 2015) or constant (Ghosh et al., 2013).[14] However, a time-varying debt limit can be obtained by assuming a time-varying growth rate. Since there is no particular economic justification for the simplifying assumptions mentioned above, we do not impose them here. Instead, we consider a more general formulation that allows for time-varying growth rate $a_{i,t}$. Figure 3 displays the country-specific and time-varying debt limits.

4.3 Feature two : Adding complex debt limit values

Solving the equation 2 for each country and each year will lead to 18 × 24 values of debt limit. Among these values, 65 are complex ones detailed in Table 2. It clearly highlights years of crisis. Unlike the existing literature, we take advantage of the complex numbers as we consider that the existence of complex roots[15] is a signal for a temporary instability as the Figure 4 is showing : the countries that were in a vulnerable position due to the crisis are those who have the most complex debt limit values (for instance Greece, Ireland, Iceland and Italy). Overall, the figure shows that by not accounting for the complex numbers we overestimate the average debt limit (red versus green dots). It also shows that complex numbers are lower than the real ones highlighting therefore, the existence of an economic instability. This can also be proved by looking at the right hand side graph which points out that complex numbers exist the most in years of crisis. The complex

[14]One exception is Bi (2012a), who develops a framework that generates a time-varying maximum primary surplus from endogenous Laffer-curves.

[15]Complex numbers are obtained when the interest payments line does not meet the fiscal reaction function.

Figure 3: Debt limit - by country, by year

debt limit values show what standard frameworks were not able to do. By not accounting for the complex debt limit values we would not be able to visualize the magnitude of the instability.

5 Fiscal space and the Environmental, Social and Governance (ESG) performances

In this section we seek to assess the overall impact of the ESG performance on fiscal sustainability through the fiscal space. We seek to evaluate the impact of the ESG performance on fiscal space. So far, research showed that ESG performance has a negative impact on interest rate (Capelle-Blancard et al., 2019) and a positive impact on growth (Diaye et al., 2021). The interest rate and the growth of output are the main elements of the equation 2, they are considered as key

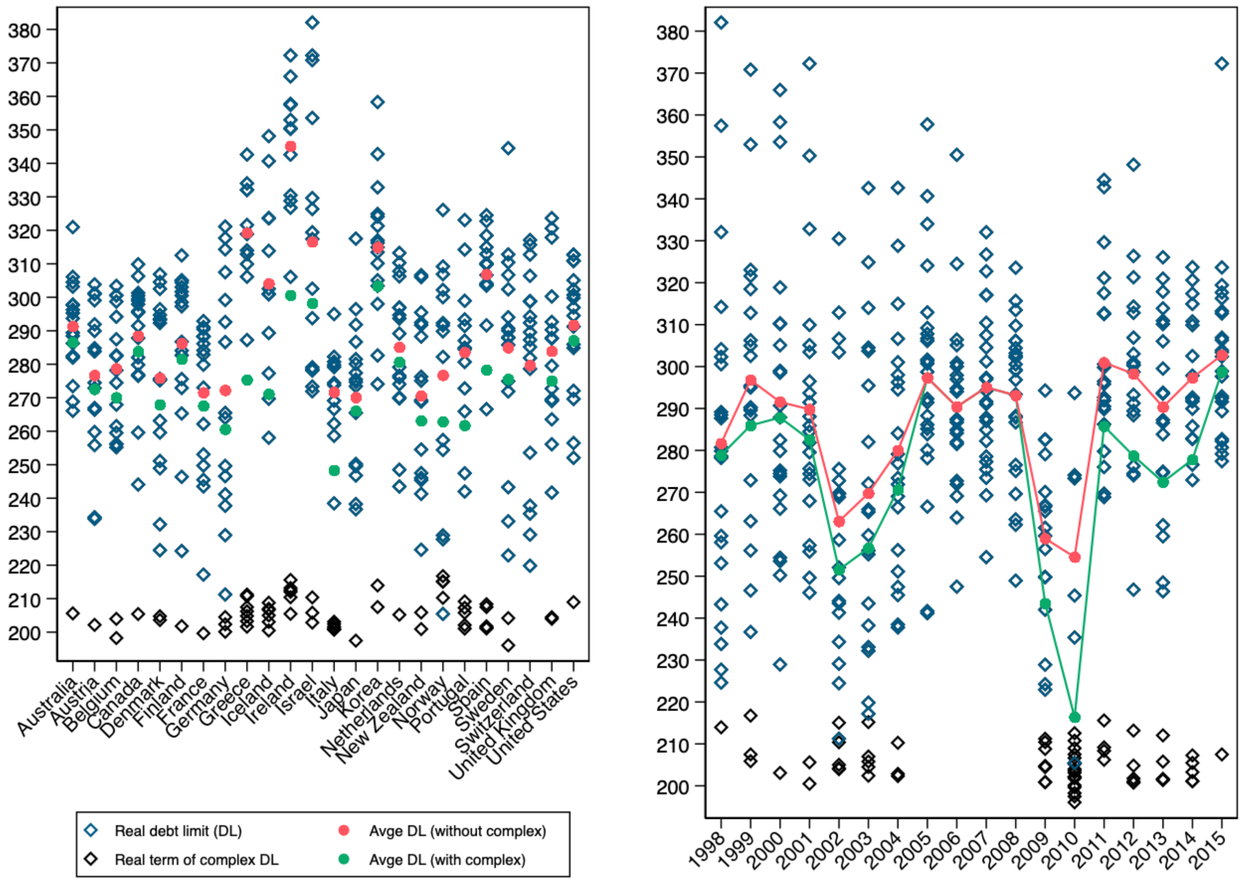

Figure 4: Debt limit (complex values included) - by country, by year

determinants of sustainability.

5.1 Data

Dependent variable

Our fiscal space estimates contain complex values. Dealing with such complex numbers in economic literature is not common. In order to take advantage of these values, we set three different strategies that can be accounted for. They are presented in Figure 5 . Either we take the module of the complex number computed as $\sqrt{a^2 + b^2}$, or we can consider only the real value, a,[16] of the complex number, or we can take the complex number in its complete form $a + ib$.

[16] This scenario is valid in our case because the complex part of the complex number is very small compared to the real part.

Table 2: Frequency of complex numbers in computing fiscal space

Country	N° of complex values	Years of complex values	% of total years
Greece	7	2009-2010-2011-2012-2013-2014-2015	39%
Iceland	6	2000-2001-2002-2003-2009-2010	33%
Ireland	6	2009-2010-2011-2012-2013-2014	33%
Italy	6	2003-2009-2010-2012-2013-2014	33%
Portugal	5	2010-2011-2012-2013-2014	22%
Spain	5	2010-2011-2012-2013-2014	28%
Norway	4	1999-2002-2003-2004	22%
Germany	3	2003-2004-2010	17%
Israel	3	2002-2003-2004	17%
Belgium	2	2002-2010	11%
Denmark	2	2009-2010	11%
Korea	2	1998-1999	11%
New Zealand	2	1999-2009	11%
Sweden	2	2002-2010	11%
United Kingdom	2	2009-2010	11%
Australia	1	2001	6%
Austria	1	2010	6%
Canada	1	2010	6%
Finland	1	2010	6%
France	1	2010	6%
Japan	1	2010	6%
Netherlands	1	2010	6%
United States	1	2010	6%
Switzerland	0		0%

Notes: countries sorted in descending order.

Independent variables

For this exercise, we construct an ESG performance index as a proxy for sustainable development. The index is constructed by applying a two-steps Principal Component Analysis on 18 imputs covering most of the sustainable development goals. It uses the World Development Indicators (WDI) to cover the environmental and social aspect of ESG and Kaufmann et al. (2005)'s World-wide Governance Indicators to cover the governance aspect. Details on the approach are available in appendix D. We use a limited number of controls in order to avoid the endogeneity bias that may occur due to reverse causality. Specifically, we avoid the usage of the variables included in equations 1 and 2. Instead, we use the ESG performance index in its lagged value, and we include

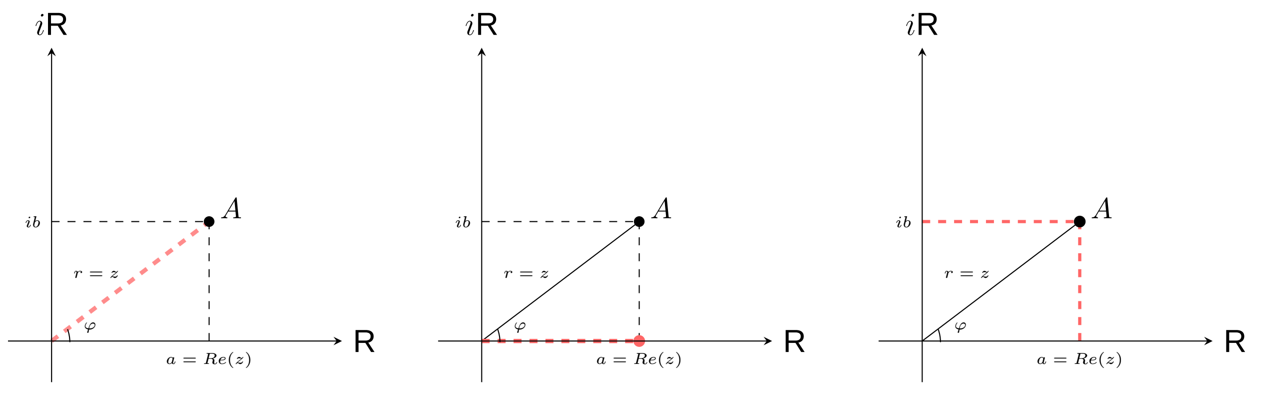

Figure 5: Fiscal Space - Possibilities of dealing with complex values

a vector of controls: the terms of trade as the ratio between export and import prices indices and the domestic credit provided to private sector by financial corporations. We also include the short-term interest rate to control for the position of monetary policy, the reserve in foreign currency and the current account balance. Finally we include the sovereign ratings which reflect a country's creditworthiness and control for fundamentals perception in the financial market.

5.2 Model specification and estimation results

To estimate the impact of sustainable development on fiscal sustainability, we consider a standard fixed effects model that accounts for the ESG performance. Specifically, we estimate the following equation :

$$fs_{i,t} = \gamma_0 + \gamma_1 ESG_{i,t-1} + \mathbf{\Phi'} X_{i,t} + \nu_{i,t}, \tag{4}$$

$$\text{with } \nu_{i,t} = \kappa_i + \varepsilon_{i,t},$$

where $fs_{i,t}$ is the fiscal space computed for a country i at a time t. $X_{i,t}$ is a vector of controls. Fiscal space can be the object of country-specific unobservable characteristics that we capture by including a country fixed effects κ_i.[17] $\nu_{i,t}$ and $\varepsilon_{i,t}$ are the error terms. For a valid statistical inference, we control for heteroscedastic and autocorrelated disturbances by relaxing the assumption of independently distributed residuals. We do so by computing Rogers (1994) standard errors by

[17] Haussman test reveals that a fixed effect is more suitable than a random effect model.

clustering using the panel identifier.

Table 3: Fiscal space estimation − country fixed effect (FE)

	Fiscal Space		
	Only reals	Modules of complex	Reals of complex
ESG			
ESG_t-1	1.62	2.65	3.05
	(0.70)	(0.81)	(0.78)
Controls			
Current Account_t-1	1.55	1.74	1.81
	(0.77)	(0.68)	(0.75)
Terms of trade	0.85	1.03	1.04
	(0.38)	(0.41)	(0.45)
Domestic credit	−0.11	−0.39	−0.47
	(0.11)	(0.16)	(0.15)
Short-term interest	5.89	7.64	8.50
	(1.06)	(1.14)	(1.12)
Reserves in %GDP	21.65	55.69	63.80
	(20.35)	(20.23)	(26.66)
Financial rating	6.79	11.36	14.46
	(2.64)	(1.41)	(0.98)
Constant	−83.52	−213.03	−288.34
	(71.85)	(65.89)	(63.82)
Number of obs	362	427	427
R2	0.22	0.41	0.48
ρ	0.85	0.83	0.85
σ_e	23.68	32.89	34.64
σ_u	56.73	72.31	80.90
aic	3,300	4,177	4,221
bic	3,327	4,205	4,249

Notes: Estimation with robust standard errors. Standard errors in parentheses. Fiscal space is in % of GDP. Column 1 displays estimation results using only fiscal space values in the real domain, column 2 displays estimation results using the modules of complex fiscal space values when the ones in the real domain are not available, and column 3 displays estimation results taking into account the real part of the complex numbers when the real fiscal space values are not available. Sample of 24 countries from 1998-2015. The country sample consists of Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Korea, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and United States * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Source: Authors' estimates.

Table 3 presents estimation results; We notice a positive and significant coefficient of the ESG performance index on fiscal space. The coefficient is more significant and higher when taking into account complex fiscal space values (column 1 versus columns 2 and 3). Controls are also significant and have the correct sign except for the domestic credit provided to private sector and the reserves in column 1 where they are not significant. A higher current account, terms of trade and reserves in foreign currency will naturally increase fiscal space. Financial ratings show markets perception. A higher grade increases fiscal space. As for the short-term interest rate, it can be considered as a proxy for monetary policy. In this table we find a positive and a significant impact on fiscal space. One explanation of this finding is the anticipation mechanism. A central bank would increase interest rates when it sees a potential increase in the growth rate. Therefore, it will apply a restrictive monetary policy. Finally, the domestic credit provided to private sector shows a negative and significant impact on fiscal space in column 2 and 3.

Moreover, when excluding complex results (column 1), we obviously get fewer observations (362 compared to 427 in a complete set). In another words, by adding the 65 complex observations to our model (an increase 15.2% of observations) we double the R^2.

5.3 Sensitivity analysis

We evaluate the robustness of the results found in table 3 using alternative estimators, by removing potential outliers and by sub-sampling.

Alternative estimators

Equation 4 is estimated in a fixed effect framework which takes into account unobserved country characteristics of the fiscal space. Since our sample is a short panel (18 years for 24 countries), computing Rogers (1994) standard errors using cluster of countries will not only account for heteroscedasticity but also for autocorrelated disturbance. To the extent that there could be a persistence in the error term, making the model endogenous, we allow for a serial correlated error term modelled as an AR(1) process to address this potential bias. We therefore, estimate the following equation :

$$fs_{i,t} = \delta_0 + \delta_1 ESG_{i,t-1} + \mathbf{\Lambda'} X_{i,t} + \omega_i + \eta_{i,t}, \tag{5}$$

$$\text{with } \eta_{i,t} = \rho\eta_{i,t-1} + \varepsilon_{i,t},$$

and where $fs_{i,t}$ is the fiscal space computed for a country i at a time t. $X_{i,t}$ is the vector of controls used previously, ω_i is the country fixed effect and $\eta_{i,t}$ is the autocorrelated error term. Results are presented in the first 3 columns of Table 4. In order to take the autocorrelated process, the number of observations drops by 24. Results are similar to the ones in Table 3. The exception will be the coefficient of Reserves in foreign currency which not significant anymore. However, our ESG performance index remains positive and highly significant. Next, we argue that our dependent variable could be autocorrelated despite the fact that the panel is short. For the matter, we first perform the Levin-Lin-Chu unit root test[18] on the fiscal space with the module of complex numbers included. The test shows that the panels are stationary in three different specifications : (1) when the AR parameter is common and including panel means and time trend, (2) when the AR parameter is common and only panel means are included, and (3) when only the AR parameter is considered. We then perform the Wooldridge wald test for the serial correlation discussed in Wooldridge (2010). The null hypothesis of no first-order autocorrelation is rejected. For that matter we perform a linear dynamic panel-data estimation proposed in Arellano and Bond (1998) by considering the following equation :

$$fs_{i,t} = \phi_0 + \phi_1 fs_{i,t-1} + \phi_2 ESG_{i,t-1} + \mathbf{\Phi'} X_{i,t} + \omega_i + \epsilon_{i,t}, \tag{6}$$

where $fs_{i,t-1}$ is the past value of the fiscal space, ω_i are the panel-level effects (which may be correlated with the strictly exogenous covariates X or ESG), and $\epsilon_{i,t}$ are i.i.d. or come from a low-order moving-average process, with variance σ^2_ϵ. Estimation results are displayed in Table 4 columns 4, 5 and 6. Our results still hold. The ESG performance index is positive and highly significant. Controls remain with the expected sign and significant as well. The past value of fiscal space is highly significant and lower than 1.

Removing potential outliers and sub-sampling

Results are robust to several changes in the sample, and when removing potential outliers. In Table 5 we verify whether deleting subsets of the data would change our findings. We verify residuals, leverage and influence. Residuals reveal by how much fitted value differs from the observed one. Thus, we check for outliers that may have remarkable influence on our estimates. For the matter, in the first column, we only kept the observations that have the value of the studentized standard

[18] Null hypothesis: panels contain unit roots and the alternative hypothesis is that panels are stationary.

Table 4: Fiscal space estimation − alternative estimators

	Fiscal Space					
	Only reals AR(1)	Modules of complex AR(1)	Reals of complex AR(1)	Only reals A-B	Modules of complex A-B	Reals of complex A-B
ESG						
ESG_{t-1}	1.59	2.54	3.25	1.51	2.93	3.29
	(0.41)	(0.63)	(0.67)	(0.53)	(0.59)	(0.63)
Controls						
Crt $Account_{t-1}$	1.73	2.01	1.87	2.08	3.18	4.32
	(0.63)	(0.73)	(0.78)	(0.72)	(0.76)	(0.82)
Terms of trade	0.44	0.99	0.97	0.36	−0.30	−0.18
	(0.24)	(0.38)	(0.40)	(0.27)	(0.37)	(0.40)
Domestic credit	−0.11	−0.32	−0.42	−0.33	−0.38	−0.43
	(0.08)	(0.11)	(0.11)	(0.10)	(0.10)	(0.11)
Short-term i	5.82	8.56	9.58	5.91	8.00	8.86
	(1.05)	(1.36)	(1.44)	(1.05)	(1.29)	(1.37)
Frgn Reserves	−31.19	13.56	20.24	−54.71	6.57	41.13
	(25.99)	(36.28)	(38.40)	(24.25)	(34.38)	(37.66)
Financial rating	5.66	10.03	13.16	4.76	7.23	9.78
	(1.47)	(1.42)	(1.50)	(4.14)	(1.22)	(1.37)
Fiscal $Space_{t-1}$				0.21	0.30	0.32
				(0.06)	(0.05)	(0.05)
Constant	−14.05	−186.90	−273.01	8.41	−78.55	−163.54
	(12.26)	(34.02)	(35.97)	(83.01)	(52.61)	(56.98)
Number of obs	338	403	403	264	380	380
ρ	0.42	0.42	0.42			
σ_e	21.44	30.46	32.23			
σ_u	54.67	69.00	82.52			
aic	3,015	3,881	3,926			
bic	3,045	3,913	3,958			

Notes: Standard errors in parentheses. FS is the fiscal space in % of GDP. Column 1,2 and 3 use an AR(1) error term specification. Column 4,5 and 6 use an Arellano-Bond estimator. Column 1 and 4 display estimation results using only fiscal space values in the real domain, column 2 and 5 display estimation results using the modules of complex fiscal space values when the ones in the real domain are not available, and column 3 and 6 display estimation results taking into account the real part of the complex numbers when the real fiscal space values are not available. Sample of 24 countries from 1998-2015. The country sample consists of Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Korea, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and United States * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Source: Authors' estimates.

error lower than two in absolute value. Applying this method removes 24 observations (column 1). In column 2 and 3 of Table 5, we check for leverage which is an outlier that is measured by residuals but could have a potential effect on the estimates, that is if deleted, estimates will change significantly. We use Cooks distance influential statistics proposed by Cook (1977) and the DFITS of Welsch and Kuh (1977). DFITS is a scaled difference between predicted values for the i^{th} case when the regression is fit with and without the i^{th} observation. Following the $2\sqrt{k/n}$[19] cutoff usually used, 125 observations were removed. As for Cooks' distance, we follow the $(k-1)/n$ cutoff and removed only 15 observations. In the last column, we removed Norway from the sample since it is the only exporter country in the dataset. Our results hold across these changes. The coefficient of the ESG index stays negative and highly significant.

In Table 6 we split our sample to Euro and non-Euro countries from one side and to before and after 2009 from another side in order to check out for any changing of significance or any shifting of sign. Among the 432 observations in our sample, 234 are for euro countries (thus, 193 for non euro ones), 259 observations before 2009 and 168 after. Despite this split, the ESG performance index is still significant for Euro countries but less for non-Euro ones with a lower coefficient. As for column 3 of Table 6, The ESG performance index stays robust, positive and highly significant after the 2009 however its is not significant anymore when considering only before 2009 period (column 3). Furthermore, in the last two columns of the table we include Euro and Crisis interaction terms with our ESG index. The overall impact of ESG is still positive and significant and this is confirmed by a Wald test.[20]

[19]With k being the number of independent variables and n the total number of observation

[20]Test's result is available upon request.

Table 5: Fiscal space estimation − removing outliers

	Fiscal Space			
	Ex-Outliers obs	Ex-Cooks'd obs	Ex-dfit obs	Ex-Norway obs
ESG				
ESG_t-1	3.02	3.01	2.62	2.48
	(0.55)	(0.65)	(0.39)	(0.85)
Controls				
Current Account_t-1	1.58	1.49	1.42	2.06
	(0.72)	(0.78)	(0.56)	(0.65)
Terms of trade	1.21	1.26	1.11	0.72
	(0.40)	(0.41)	(0.23)	(0.39)
Domestic credit	−0.48	−0.51	−0.41	−0.37
	(0.10)	(0.12)	(0.07)	(0.16)
Short-term interest	8.30	8.11	7.01	7.92
	(0.86)	(0.95)	(0.69)	(1.15)
Reserves in %GDP	31.12	33.32	43.28	58.99
	(12.90)	(13.01)	(9.12)	(19.18)
Financial rating	13.54	13.15	11.62	11.43
	(1.13)	(1.31)	(0.98)	(1.48)
Constant	−277.86	−270.46	−215.46	−175.99
	(53.85)	(56.89)	(31.38)	(65.25)
Number of obs	403	412	302	409
R2	0.57	0.52	0.64	0.42
ρ	0.90	0.88	0.95	0.82
σ_e	26.03	28.56	16.22	32.74
σ_u	79.66	79.04	72.02	69.02
aic	3,752	3,913	2,521	3,997
bic	3,780	3,941	2,547	4,025

Notes: Fixed effect estimation with robust standard errors in parentheses. The fiscal space is in % of GDP. It consists of the values of fiscal space in the real domain and the module of complex numbers when real values are not available. Column 1 excludes the values of the studentized error term that are higher than 2 in absolute value. Column 3 excludes the observations that have a Cook's value $> 7/427$. Column 4 excludes observations that have a dfit $> 2 \times \sqrt{8/427}$. Column 5 excludes Norway since Norway is the only oil exporter country in our sample. Sample of 24 countries from 1998-2015. The country sample consists of Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Korea, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and United States * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Source: Authors' estimates.

Table 6: Fiscal space estimation − sub-sampling

	Fiscal Space					
	euro	non-euro	before09	after09	crisis interac	euro interac
ESG						
ESG_t-1	3.64	1.96	0.25	5.76	2.66	2.72
	(0.99)	(0.94)	(1.02)	(1.13)	(0.77)	(1.05)
Crisis					−30.92	
					(11.66)	
Crisis × ESG_t-1					0.03	
					(0.19)	
Euro × ESG_t-1						−0.13
						(1.26)
Controls						
Current Account_t-1	1.78	2.09	2.90	0.67	1.42	1.75
	(1.03)	(1.25)	(0.78)	(1.11)	(0.68)	(0.70)
Terms of trade	−0.22	0.92	0.23	0.71	0.99	1.02
	(0.81)	(0.45)	(0.43)	(0.78)	(0.40)	(0.41)
Domestic credit	−0.57	−0.07	0.08	−0.14	−0.29	−0.38
	(0.16)	(0.28)	(0.23)	(0.37)	(0.14)	(0.18)
Short-term interest	9.40	5.84	8.38	−0.27	7.53	7.64
	(1.47)	(1.96)	(2.58)	(4.82)	(1.08)	(1.15)
Reserves in %GDP	73.17	30.55	−66.51	−65.00	56.88	53.32
	(43.22)	(22.83)	(125.41)	(31.75)	(30.60)	(20.84)
Financial rating	11.90	6.03	21.74	6.87	12.38	11.29
	(2.00)	(2.15)	(5.30)	(2.77)	(1.56)	(1.59)
Constant	−124.28	−106.02	−282.92	−303.48	−241.45	−211.69
	(129.34)	(78.35)	(83.98)	(200.28)	(68.32)	(67.22)
Number of obs	234	193	259	168	427	427
R2	0.56	0.18	0.20	0.23	0.47	0.41
ρ	0.90	0.80	0.83	0.92	0.85	0.83
σ_e	31.57	33.54	27.72	32.07	31.22	32.93
σ_u	92.76	66.44	62.22	110.58	73.60	72.18
aic	2,273	1,899	2,437	1,622	4,134	4,179
bic	2,297	1,922	2,462	1,644	4,171	4,211

Notes: Fixed effect estimation with robust standard errors in parentheses. Fiscal space is in % of GDP. It consists of the values of fiscal space in the real domain and the module of complex numbers when real values are not available. Column 1 takes only euros countries, column 2 takes only non-euro countries, column 3 takes the years before 2009, column 4 takes the year 2009 and after, column 5 and 6 take the whole sample. They contain crisis interaction term and euro interaction term respectively. crisis is a time dummy that takes 1 for the years 2008,2009 and 2010. Sample of 24 countries from 1998-2015. The country sample consists of Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Korea, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and United States * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Source: Authors' estimates.

6 Conclusion

The paper is two-folded; It contributes to the fiscal space literature in both technical and empirical perspectives. The technical contribution consists of adding two features to the existent fiscal space measure. The first feature is considering a time-dependent debt limit obtained by considering a time-varying growth rate instead of the constant one assumed in literature. The second feature accounts for complex debt limit values (defined in $\mathbb{C}$) when real solutions (defined in $\mathbb{R}$) are not available. Among 432 values of debt limit, 65 are complex. We explore theses values and show that they are lower than the ones defined only in the real domain ($\mathbb{R}$). We also show that they appear the most in years of recessions and economic crises. We argue that complex debt limit adds crucial information to the analysis of public debt sustainability. By accounting for the imaginary part of a complex number ib we are able to measure the magnitude of an unstable economy and the degree of adjustment that has to be made in order to restore the public finances of a given country. Last but not least, we make an empirical contribution to the literature of the determinants of fiscal space by introducing a new determinant : sustainable development. Using data of 24 OECD countries from 1998-2015, we find a positive and significant impact of the ESG performance index − as a proxy for sustainable development − on the fiscal space. This result is robust to different types of estimators and different sensitivity checks.

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A Appendix

A.1 Synthetic indicators as a proxy for fiscal space

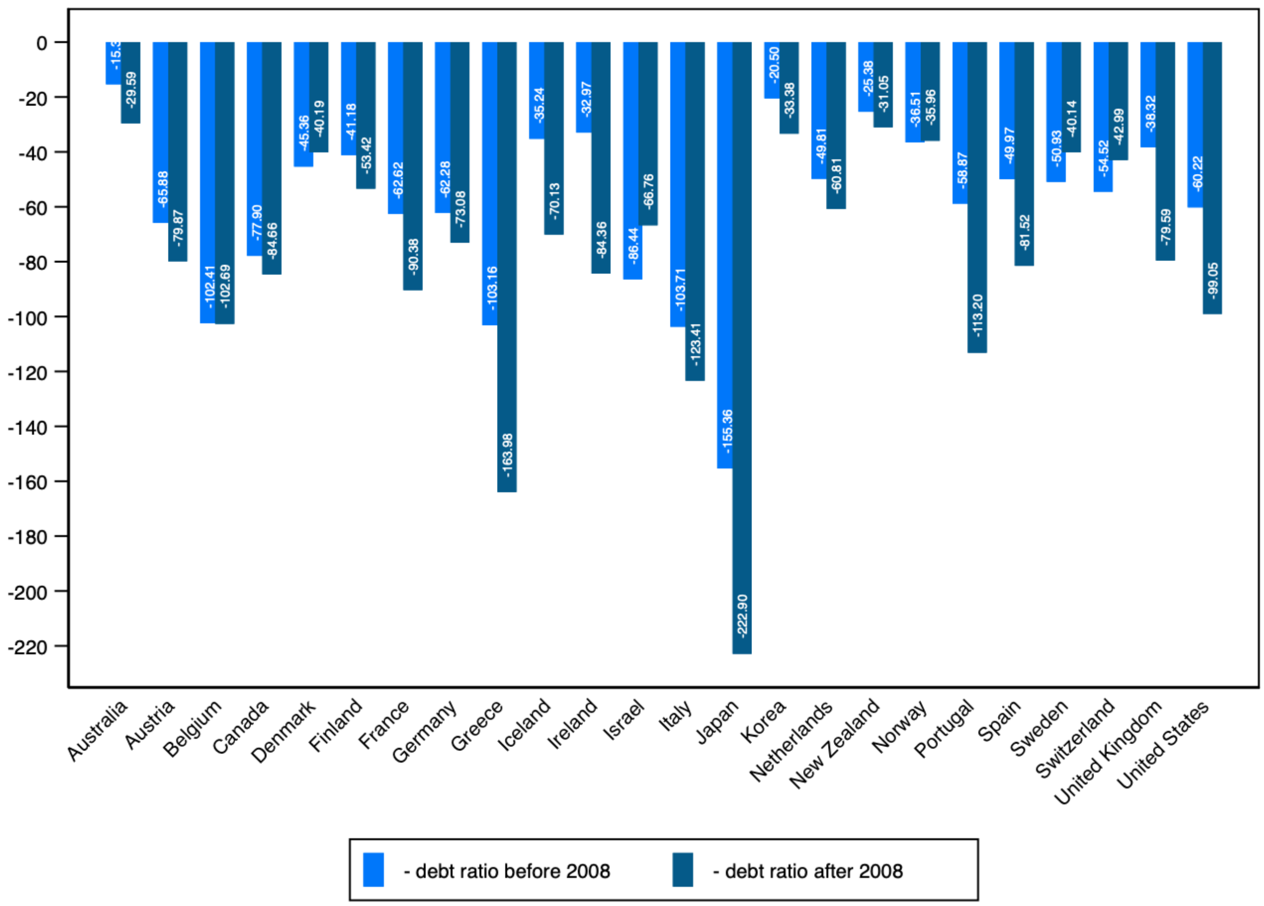

Figure A.1: the negative of debt ratio before and after 2008

While Figure A.1 shows how debt increased drastically after 2008, Figure A.2 reflects markets reaction and debt burden. It also shows the reaction of monetary policy during turmoil times. The figure also shows the changes in the real interest rate – growth rate differential before and after 2008 and it clearly points out relatively the critical situation for Greece, Spain, Portugal, Iceland but does not identify a threshold beyond which the situation becomes unbearable. As for Figure A.3, it is the de facto fiscal space before and after 2008 defined as the share of debt on the national revenue. It specifically shows in average how many years it takes for a country to repay its debt. As debt increased drastically after 2008 (Figure A.1), it is clear that it rose faster than the national revenue, so it will take more years to repay the existing debt.

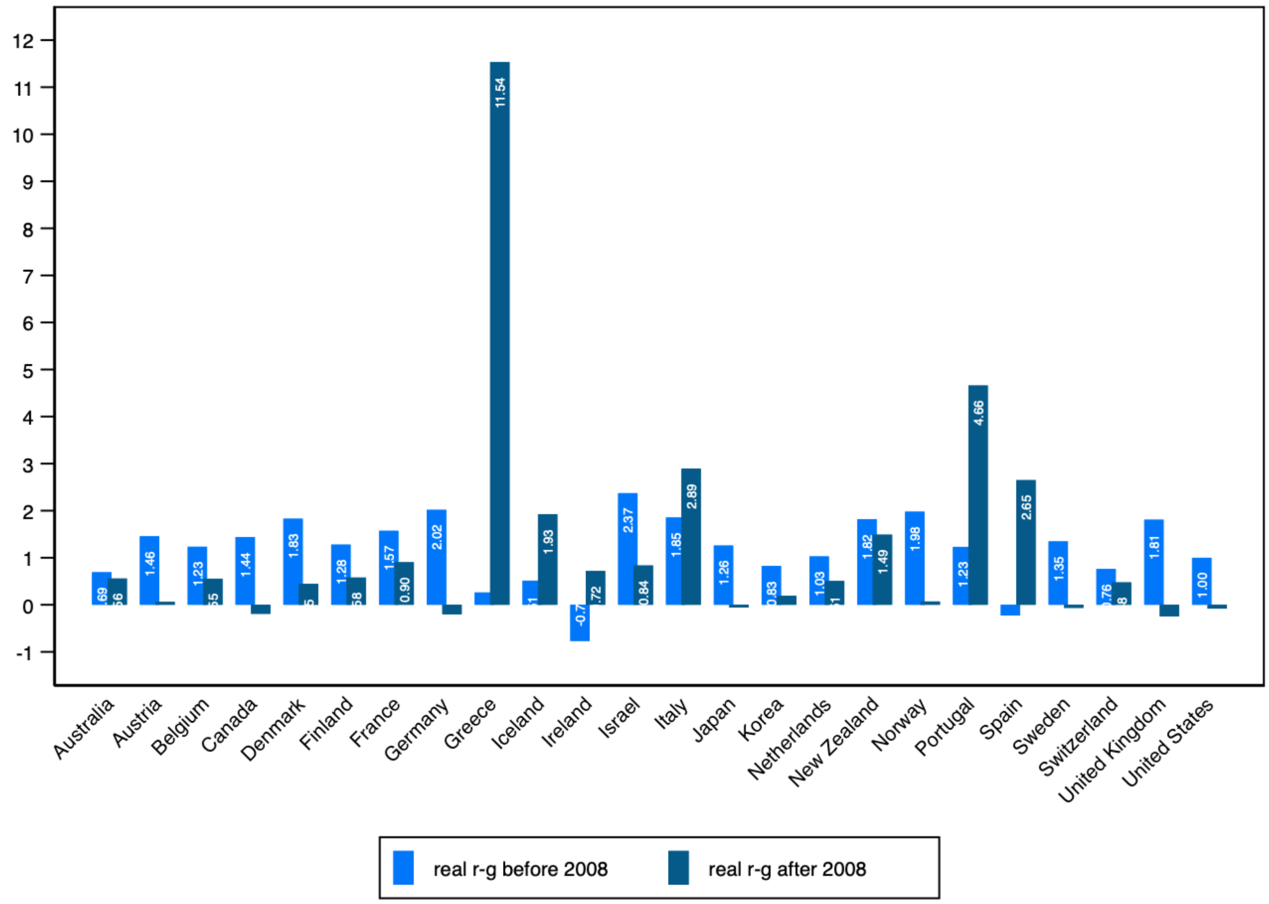

Figure A.2: real interest rate - growth rate differential, before and after 2008

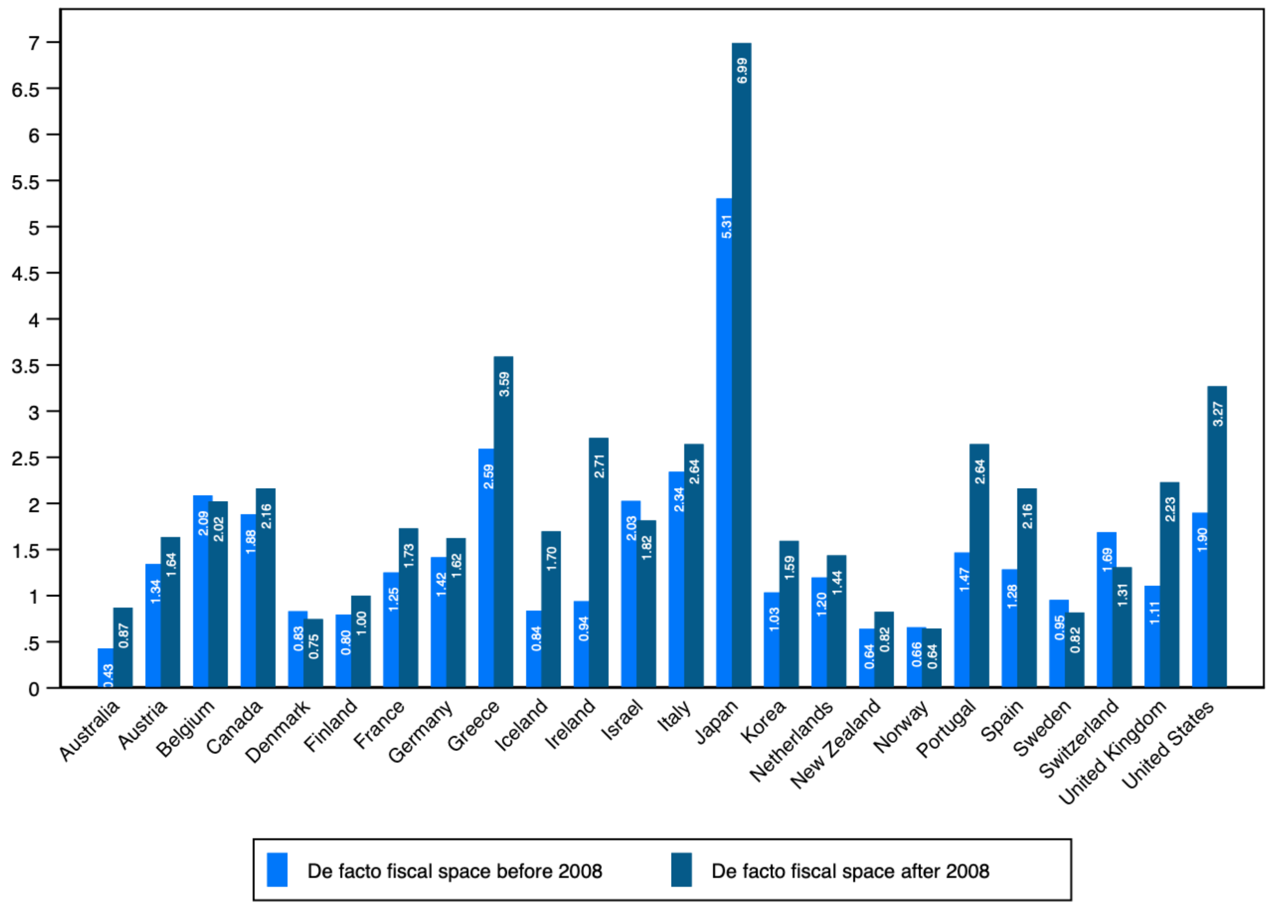

Figure A.3: De facto fiscal space before and after 2008

B Appendix : Complex numbers

B.1 Complex numbers definition

A is a complex number. By definition, it is then composed of two parts: a real and an imaginary one. One of the advantages of using complex numbers relies in the term ib or the red brace presented in Figure B.1. ib represents the distance of the point A from being a real number. That said, economically, ib represents the amount of adjustment that has to be made in order to get out of the crisis. Moreover, not all countries are affected by a crisis in the same way. Our approach is able to compare the size of the crisis relatively between countries and is able to tell a crisis duration but also in which year the crisis was at its worse.

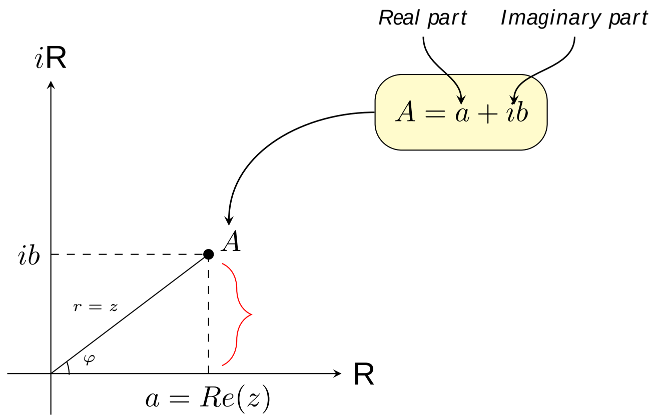

Figure B.1: Complex numbers

B.2 When complex numbers appears ?

Complex numbers appears when the interest schedule is high so there is no intersection between the curve and the line. Therefore, we suggest that complex numbers appears in times of economic instability.

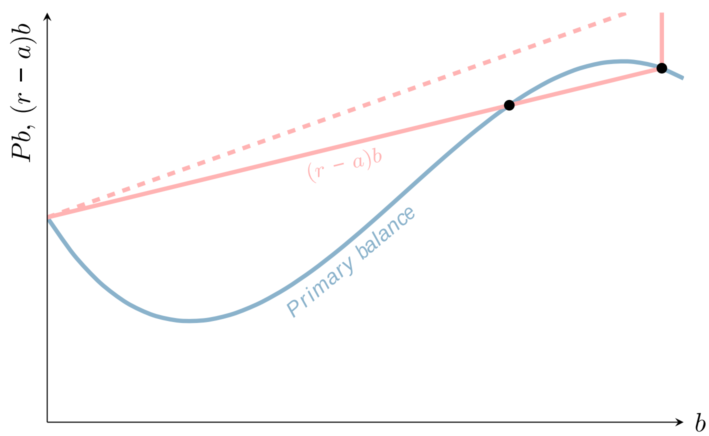

Figure B.2: Debt limit : The reason why complex numbers exist

C Appendix : Further Robustness checks

C.1 Removing 1 country from the sample

In Table C.1 we run the model in equation 4 while removing one country from the sample each time. Such exercise aims to check whether there is a country that has influence on the coefficient γ_1. The table shows a consistency of γ_1.

Table C.1: Removing 1 country when estimating equation 4

Removed country	$\text{ESG}_{t-1}(\gamma_1)$	R^2	Observations
Australia	2.87	0.42	409
Austria	2.59	0.41	409
Belgium	2.40	0.42	409
Canada	2.64	0.41	409
Denmark	2.56	0.41	409
Finland	2.68	0.41	409
France	2.60	0.41	409
Germany	2.50	0.41	409
Greece	2.74	0.39	409
Iceland	2.84	0.45	409
Ireland	2.17	0.33	409
Israel	2.53	0.42	409
Italy	2.64	0.41	409
Japan	2.80	0.41	414
Korea	3.28	0.44	409
Netherlands	2.68	0.41	409
New Zealand	2.57	0.41	409
Norway	2.48	0.42	409
Portugal	2.73	0.38	409
Spain	2.71	0.39	409
Sweden	2.84	0.43	409
Switzerland	2.62	0.41	409
United Kingdom	2.59	0.41	409
United States	2.57	0.40	409

Notes: estimation with robust standard errors. Norway is the only oil exporter country in our sample. The short term interest rate in equation 4 has 5 missing values for Japan from 1998 to 2002. This is why when removing Japan, the number of observations becomes 414. *** p<0.01. Source: Authors' estimates.

C.2 Fixed versus random effect

Hausman test hypothesis that the country-level effects are adequately modeled by a random-effects model is rejected. Therefore, the fixed-effects model is more suitable for this specification. Table C.2 displays the results of the two models.

Table C.2: Fiscal space estimation − Fixed versus random effect

	Fiscal Space	
	Fixed effect	Random effect
ESG		
ESG_t-1	2.65	1.12
	(0.81)	(0.44)
Controls		
Current Account_t-1	1.74	1.50
	(0.68)	(0.65)
Terms of trade	1.03	0.82
	(0.41)	(0.44)
Domestic credit	−0.39	−0.24
	(0.16)	(0.12)
Short-term interest	7.64	5.97
	(1.14)	(0.90)
Reserves in %GDP	55.69	69.12
	(20.23)	(19.94)
Financial rating	11.36	10.09
	(1.41)	(1.32)
Constant	−213.03	−109.37
	(65.89)	(56.29)
Number of obs	427	427
R2	0.41	0.39
ρ	0.83	0.57
σ_e	32.89	32.89
σ_u	72.31	37.54

Notes: Fixed and Random effect estimations with robust standard errors. Norway is the only oil exporter country in our sample. Under the current specification, Hausman test indicates that the hypothesis that the individual-level effects are adequately modeled by a random-effects model is resoundingly rejected. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

C.3 ESG performance equally weighted dimensions

Table C.3: Fiscal space estimation − Alternative ESG weighting method

	Fiscal Space		
	Only reals	Modules of complex	Reals of complex
ESG			
ESG_t-1	2.05	3.07	3.58
	(0.76)	(0.86)	(0.84)
Controls			
Current Account_t-1	1.40	1.54	1.56
	(0.72)	(0.70)	(0.73)
Terms of trade	0.83	0.98	1.00
	(0.38)	(0.40)	(0.45)
Domestic credit	−0.16	−0.42	−0.51
	(0.11)	(0.17)	(0.16)
Short-term interest	6.21	7.78	8.73
	(1.06)	(1.05)	(0.99)
Reserves in %GDP	18.27	50.43	57.07
	(21.59)	(21.77)	(26.63)
Financial rating	6.55	10.22	13.14
	(2.60)	(1.52)	(0.96)
Constant	−91.80	−201.06	−277.23
	(70.74)	(60.34)	(58.47)
Number of obs	362	427	427
R2	0.23	0.41	0.49
ρ	0.88	0.86	0.88
σ_e	23.43	32.69	34.32
σ_u	63.66	81.02	92.36
aic	3,292	4,172	4,213
bic	3,320	4,200	4,242

Notes: Estimation with robust standard errors. Standard errors in parentheses. Fiscal space is in % of GDP. The three columns use an alternative ESG weighting method. Column 1 displays estimation results using only fiscal space values in the real domain, column 2 displays estimation results using the modules of complex fiscal space values when the ones in the real domain are not available, and column 3 displays estimation results taking into account the real part of the complex numbers when the real fiscal space values are not available. Sample of 24 countries from 1998-2015. The country sample consists of Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Korea, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and United States * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Source: Authors' estimates.

D Appendix : The creation of the ESG performance index

In this section we construct an Environmental Social and Governance performance index. Subsection D.1 describes the dataset, subsection D.2 motivates our choice of approach, and subsection D.3 details the way we proceed to construct our ESG index.

D.1 ESG dataset

In this paper we rely on public information in order to create the ESG composite index that cover most of sustainable development goals by relying on 18 inputs. We use the World Development Indicators (WDI) to cover the environmental and social aspect of ESG and Kaufmann et al. (2005)'s Worldwide Governance Indicators to cover the governance part of it.

WDI data covers two out of the three dimensions. The assessment of the environmental part is done by accounting for (1) the proportion of people that are not exposed to ambient air pollution by particulate matter 2.5 based on WHO air quality guideline, (2) the proportion that uses managed sanitation expressing a potential recovery of water and renewable energy,[21] (3) the proportion of forest area as a proxy for biodiversity, and (4) we account for three different measures reflecting the use of renewables showing how optimized is the use of energy resources and how improved the energy efficiency is.

For the social part, (1) we first look at health financing which is one of the targets of the sustainable development goals, and (2) at work stability, then (3) we look at education, precisely at a tertiary level that offers more specialized teaching after completing secondary education as a proxy for human capacity to the adaptation process (Smit and Pilifosova (2003)), (4) we look at the proportion of people using the internet, this indicates the development of infrastructure but also the social development and the access to information. (5) last but not least, we look at gender disparities at two different levels, (i) at work through the ratio of female to male labor force participation rate, and (ii) in decision making through the share of women in national parliaments because in strong democracies, parliaments are fully inclusive of the population they represents.

As for the governance dimension, Kaufmann et al. (2005)'s database uses perceptions-based in-

[21]Such variable can play a role at the social level as well since it can reduce health costs and premature death (WHO 2012)

dicators presenting six different clusters and providing a complete definition of governance by covering its three main areas: (1) the process by which government are selected, monitored and replaced (by using Voice and Accountability and Political Stability and Absence of Violence/Terrorism indicators), (2) the capacity of the government to effectively formulate and implement sound policies (by using Government Effectiveness and Regulatory Quality indicators) and (3) the respect of citizens and the state for the institutions that govern economic and social interactions among them (by using Rule of Law and Control of corruption indicators).

The database we are using is a panel data on the 18 inputs from 1997 to 2015 for 24 advanced economies. Namely, Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Korea, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and United States.

D.2 Strategy

We should consider two things when working on a multidimensional measure such as ESG: the comparability between the different dimensions and the weight of each one of them when constructing a composite indicator.

Most of extra-financial agencies use scoring techniques to solve the comparability issue between the three dimensions of ESG, however, they weight them equally when making a composite index. Albeit such weighting method simplifies things, Waddock and Graves (1997) and Ruf et al. (1998) proved that this way of doing is not efficient.[22] One can argue that by using the three dimensions separately we avoid the weighting issue. This is true, but in this case we fall for the Condorcet paradox.[23]

To get past these two challenges, we build up on the approach used in Capelle-Blancard et al. (2019) that uses factor analysis in order to construct our ESG composite index. Such method outstrip most of challenges stated above as (1) it provides only one interpretable index which is easier to deal with than a battery of separate indicators and visibly reduces the size of used variables without losing information and (2) it enables comparability within and between the different dimensions of the dataset.

[22]They reweighted KLD's (MSCI ESG Research now) dimensions based on CSR survey instead of equally weighting them. Their results show how by using the simple method (adding up the three dimensions) we under/over-estimate some dimensions to the detriment of others.

[23]See Capelle-Blancard and Petit (2017) for an explanation.

Capelle-Blancard et al. (2019) rely on a Principal Component Analysis (PCA thereafter) to weight their ESG index. They extract three components, one for each dimension : Environmental, Social and Governance components. Then they aggregate these components into a global index.

Our approach is different than the one they use. The main difference is that we construct our ESG performance index using a two-steps PCA instead of the one step one they use. The first step consists in applying a PCA separately on each of the predefined three domains.

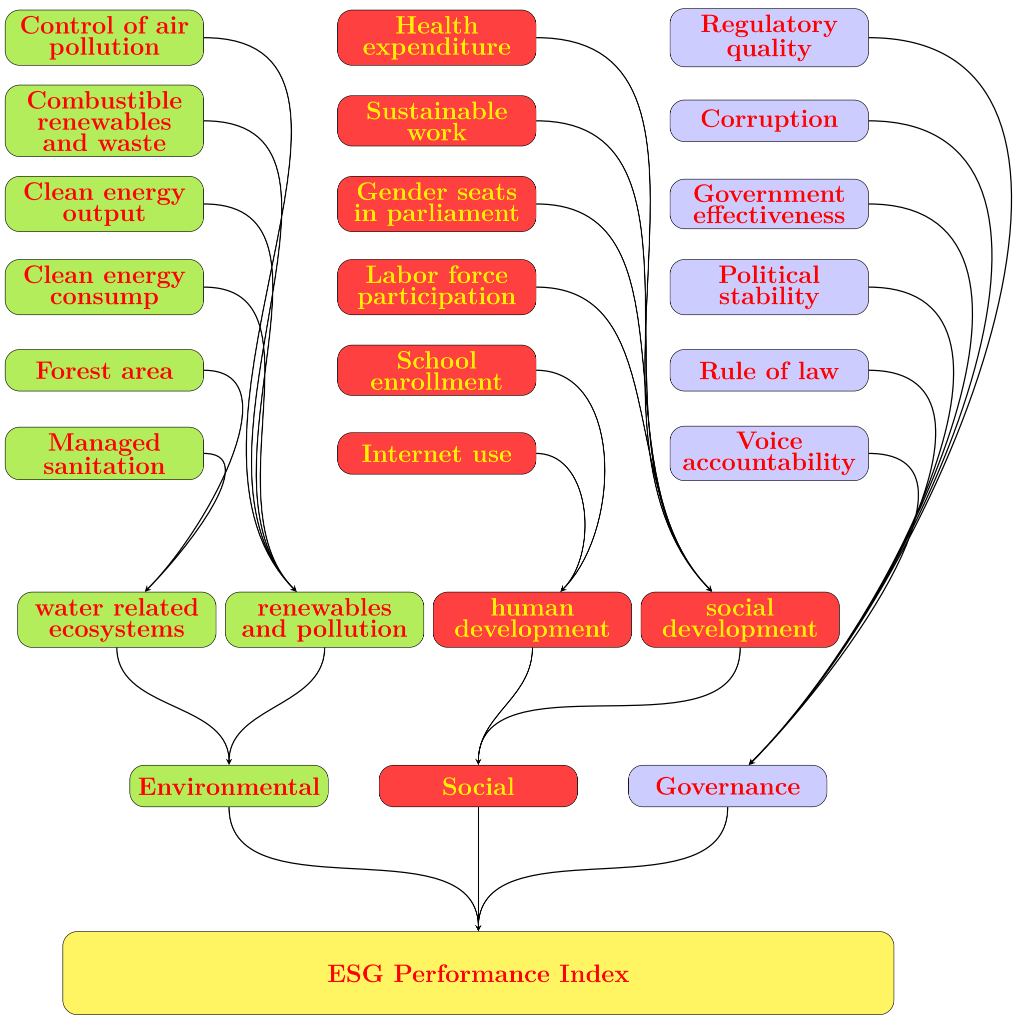

Figure D.1: ESG Performance Index

For instance, in the Figure D.1, the control of air pollution, combustible renewables and waste, clean energy output, clean energy consumption, forest area and managed sanitation are considered to be environmental variables. Applying PCA on these variables will reveal families that compose each dimension (for instance, water related ecosystems, and renewables and pollution are the two families that compose the environmental dimension). This first step will lead to three separate summary indicators : Environmental, Social and Governance indices. In the second step of PCA, we use these three indicators as an input to construct one ESG composite index. This step will evaluate the relative contribution of each dimension to the explanation of the overall variance of the unique index. These contributions are, therefore, used to assign weights in the aggregation process when creating the ESG composite index.

The motivation behind our way of doing comes from the fact that PCA, just like any multivariate analysis, is a data-based approach that provides weights objectively, independently from the economic importance of the variable: the largest weights for the largest variation. Thus, such method is sensitive to any change in the data (for instance, when adding new observations such as new countries or larger time span): variables variations will be likely affected by data changes, affecting the contribution of each variable in each component, which can lead to the change of the components number. Therefore, if data changes, Capelle-Blancard et al. (2019)'s approach might reveal more than the three needed components (E,S and G). On one hand, the new components can be hard to interpret and on the other hand, if we choose to restrict subjectively our PCA to just three components (therefore ignoring the other new components) without following the Kaiser's selection criterion for the number of components, we face the risk of information loss. Instead, our two-steps procedure insure in getting three dimensions (E, S and G) even if observations change in the dataset.

D.3 Methodology

In a prior stage, we insure that a PCA is feasible. The correlation matrix for each dimension shows that most of the raw variables are not orthogonal so we will not get as many components as variables and Barlett's sphericity test shows as well that the observed correlation matrix diverges significantly from the identity matrix. Then, we use Kaiser-Meyer-Olkin measure of sampling adequacy to ensure that we can proceed with PCA. The measure compares the correlations and the partial correlation between inputs. In our case it is higher than 0.60 for the elements in Table D.1 which gives us the green light to proceed.

PCA is a linear transformation of the dataset that preserves original information coming from original inputs but partitioned over different orthogonal components. Such technique finds a unit length linear combinations of inputs with the largest variance. The first component shares the biggest variance (which decreases with every new component) and contain more information than the one that comes after. Since the variance is decreasing with every new component, we only extract the ones with eigenvalue equal or larger to the mean eigenvalue which is the same as the Kaiser's selection criterion (=1).[24]

However, dropping all the other components that do not fill the requirement will technically lead to a loss of information. Thanks to the orthogonality, by looking at the cumulative proportion in each panel of Table D.1 we are able to see how much information is preserved. For instance, 76.32% of the information is kept in the Environmental index, 72,10% in the Social Index and 80.74% in the Governance Index. Another way of saying, the first two components of Panel A in Table D.1 explain the sum of the variances of the individual components that said 76.32% of the overall variance, and so on.

The weight for every input in every component is assigned by normalizing squared loadings. In case of multiple components, as it is the case for the environmental and social index, weights of every component is assigned based on the explained variance by each component. For instance, in Social Index, 65,23% of the variance is explained by the first component $\left(\frac{2.82}{2.82+1.50}\right)$ and 34.76% by the second one.

Technically, let $x^D_{i,t,j}$ denote the standardized input variable j[25] of each dimension D belonging to a country i at a date t, where $D = \{E, S, G\}$. E, S and G stand for environmental, social and governance performances, respectively. Using PCA, we aim to find γ^D_j, ζ_k in the first step in order to compute $Z^D_{i,t}$ and $D_{i,t}$, and θ_w in the second step in order to compute $ESG_{i,t}$. The first step of our procedure is formulated as

$$Z^D_{i,t} = \sum_j \gamma^D_j x^D_{i,t,j}, \tag{D.1}$$

$$D_{i,t} = \sum_k \zeta^D_k Z^D_{i,t,k}, \tag{D.2}$$

where $Z^D_{i,t}$ is the component that represent the family where $x^D_{i,t}$ belongs. γ^D_j is the weight attributed for the input variable $x_{i,t,j}$ of a dimension D which is determined by normalizing squared

[24] The selection process for the number of components can be done also by looking at the scree plots (elbow method) as we retain the components associated with the high part of the scree plot and drop components associated with the lower flat part of it. these plots are available upon request

[25] $j = 1 \cdots 6$

loadings. Each dimension D has k[26] family. ζ_k^D is the weight attributed to the family $Z_{i,t}^D$ of dimension D. ζ_k^D is the variance proportion of the family $Z_{i,t}^D$ that is computed as

$$\zeta_k^D = \frac{1}{\sigma^2_{total^D}} \sum \sigma^2_{Z^D}, \tag{D.3}$$

where σ_Z^2 is the variance of component Z in dimension D, and σ^2_{total} is the sum of components' variance in dimension D.

The second stage PCA consists on performing a PCA on D, thus, $ESG_{i,t}$ is obtained as follows:

$$ESG_{i,t} = \sum_w \theta_w D_{i,t,w}, \tag{D.4}$$

where $ESG_{i,t}$ denotes our ESG performance index, and θ_w is the weight attributed to each dimension D.[27] Table D.1 displays the value of our parameters in 4 panels.

[26] $k = 1, 2$ for E and S and $k = 1$ in dimension G.
[27] $w = 1, 2, 3$.

Table D.1: Environment, Social and Governance Indices formation

Variables, $x_{i,t,j}^{D=E,S,G}$	Component 1, $Z_{i,t,k=1}^{D}$		Component 2, $Z_{i,t,k=2}^{D}$	
	Loadings	Weights, γ_j^D	Loadings	Weights, γ_j^D
Panel A: Environmental Index	**Renewables & pollution**		**Water ecosystems**	
E_1_Control of Air pollution	0.24	0.26	0	0
E_2_Managed sanitation services	0	0	0.33	0.44
E_3_Forest area	0	0	0.42	0.56
E_4_Combustible renewables and waste	0.12	0.14	0	0
E_5_Renewable electricity output	0.26	0.28	0	0
E_6_Renewable energy consumption	0.30	0.32	0	0
Variance, $\sigma_{Z^E}^2$		2.82		1.76
Proportion, $\zeta_{k=1,2}^{E}$		0.62		0.38
Cumulative Proportion		0.47		0.76
Panel B: Social Index	**Social dev**		**Human dev**	
S_1_Female to male labor force	0.27	0.34	0	0
S_2_Employment Stability	0.17	0.22	0	0
S_3_Health expenditure	0.11	0.13	0	0
S_4_School enrollment	0	0	0.55	0.81
S_5_Individuals Using the Internet	0	0	0.13	0.19
S_6_Women in National Parliaments	0.24	0.31	0	0
Variance, $\sigma_{Z^S}^2$		2.82		1.50
Proportion, $\zeta_{k=1,2}^{S}$		0.65		0.35
Cumulative Proportion		0.47		0.72
Panel C: Governance Index	**Governance**			
G_1_Voice and Accountability	0.41	0.17		
G_2_Rule of Law	0.44	0.19		
G_3_Regulatory Quality	0.40	0.16		
G_4_Polit Stab and Abs Violce/Trrism	0.33	0.11		
G_5_Government Effectiveness	0.42	0.18		
G_6_Control of Corruption	0.44	0.19		
Variance, $\sigma_{Z^G}^2$		4.84		
Proportion, $\zeta_{k=1}^{G}$		1		
Cumulative Proportion		0.81		
Panel D: ESG Index	**ESG**			
Environmental index	0.56	0.31		
Social index	0.60	0.37		
Governance index	0.56	0.31		
Variance		2.03		
Proportion		1		
Cumulative Proportion		0.68		

E Appendix : Data definition and sources

Table E.1: Economic data sources

Variable	Source
Primary balance (%GDP)	Cross-Country database of fiscal space (World bank)
Debt (%GDP)	Cross-Country database of fiscal space (World bank)
Sovreign ratings	Cross-Country database of fiscal space (World bank)
Growth (% change) and Output gap (calculated using the Hodrick-Prescott filter)	World Economic Outlook (IMF)
Expenditure (% GDP) and Expenditure gap (calculated using the Hodrick-Prescott filter)	World bank
Inflation (CPI, average of period change Y/Y)	World Economic Outlook (IMF)
Trade Openness (sum of exports and imports of goods and services (% GDP))	World bank
IMF programme	IMF Monitoring of Fund Arrangements database
Fiscal rule	IMF Fiscal rule database
Oil price	IMF Primary Commodity prices
Interest rates (short and long terms)	OECD
Current account balance	World bank
Reserves (includes gold)	World bank
Domestic credit provided to private sector	World bank
Terms of trade ratio	OECD

Table E.2: ESG data source

Variable	Source
PM2,5 Air Pollution, Population **not** Exposed to Levels Exceeding Who Guideline Value (% of Population)	World bank
Managed Sanitation Services (% of Population)	World bank
Forest Area (% of land area)	World bank
Combustible renewables and waste (% of Total energy)	World bank
Renewable electricity output (% of total electricity output)	World bank
Renewable energy consumption (% of total final energy consumption)	World bank
Domestic general government health expenditure (% of current health expenditure)	World bank
Non-vulnerable employment, total (% of total employment) (modeled ILO estimate)	World bank
Ratio of female to male labor force participation rate (%) (modeled ILO estimate)	World bank
School Enrollment, Tertiary, (% Gross)	World bank
Proportion of Seats Held by Women in National Parliaments	World bank
Individuals Using the Internet (% of Population)	World bank
Control of Corruption: Estimate	World bank
Government Effectiveness: Estimate	World bank
Political Stability and Absence of Violence/Terrorism: Estimate	World bank
Regulatory Quality: Estimate	World bank
Rule of Law: Estimate	World bank
Voice and Accountability: Estimate	World bank

Notes: Managed Sanitation Services, Domestic general government health expenditure and School Enrollment have 78, 72 and 8 missing variables, respectively. We used interpolation to fill the missing data.