Policy Research Working Paper 9606

Natural Capital and Sovereign Bonds

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WORLD BANK GROUP
Finance, Competitiveness and Innovation Global Practice
April 2021

Policy Research Working Paper 9606

Abstract

Natural capital is related to government bonds through the macroeconomy and credit risks. This paper estimates this relationship from the long-term, between-country view and the short-term, within-country view. The paper cautions against the former, as it is dominated by income differences. These are de facto ingrained, as they cannot be overcome by short-term policy efforts. The within-country view is unaffected by the *ingrained income bias* and leaves room for recent natural capital changes to affect bond yields. The paper finds that non-renewables (fossil fuels and mineral assets) raise bond yields, possibly due to the resource curse. Renewables (forests and agricultural wealth) lower borrowing costs because they are economically worthwhile investments. Protected areas are more likely to be luxury investments.

This paper is a product of the Finance, Competitiveness and Innovation Global Practice. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://www.worldbank.org/prwp. The author may be contacted at dwang5@worldbank.org.

Natural Capital and Sovereign Bonds

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JEL Codes: C33, C38, G12, N50, O13.

Keywords: Natural capital accounting, sovereign bond yields, ingrained income bias, interactive fixed-effects, latent common bond factors.

*This paper is prepared for the World Bank's Finance, Competitiveness and Innovation (FCI) Global Practice, Long-Term Finance Department as a part of the Global Program on Sustainability (GPS) under guidance of Ekaterina Gratcheva (Lead Financial Officer, FCI) and incorporates helpful feedback from Girum Dagnachew Abate, Kassia Antoine, Shinji Ayuha, Michael Andrew Brown, Maurice Bun, Raffaello Cervigni, James Cust, Harun Dogo, Teal Lincoln Emery, Erik Feyen, Bryan Gurhy, Timothy Grant Herzog, Aart C. Kraay, Glenn-Marie Lange, Samantha Power, Martijn Gert Jan Regelink, Henk Jan Reinders, Giovanni Ruta, Anderson Caputo Silva, Andrius Skarnulis, Fiona Elizabeth Stewart, Roy van der Weide. E-mail: dwang5@worldbank.org

1 Introduction

Environmental risks have become a key discussion point in the financial world. High-profile financial and political institutions have recognized the risks posed by climate change and the associated loss of natural capital. The Bank for International Settlements published a report on climate change and financial stability (Bolton et al., 2020), the Financial Stability Board's Task Force on Climate-related Financial Disclosures and the European Commission's EU Taxonomy provided regulatory frameworks to bring more transparency into reporting. Identifying the transmission channels between environmental risks and financial stability, and quantifying the exposure of financial institutions are the first and second items on the research priority list of the Network for Greening the Financial System (NGFS, 2020a, 2020b). In this context, it is surprising that fixed-income instruments have received comparatively little attention (Inderst et al., 2018), despite the colossal size of the global bond market of US$ 102.8 trillion in outstanding value (SIFMA, 2019). This paper studies the relationship between the environment and bonds through the lens of natural capital. It highlights the difficulties of comparing environmental performance between countries if said countries are at different stages of development.

Prior to looking at the data or specifying any models, let us take a step back and ask: Do markets even incorporate a natural capital into a sovereign bond prices? A direct connection may seem far-fetched to a bond trader, who is already keeping track of a catalogue of factors: monetary policies, central bank announcements, issuance policies, capital market depth, credit risk ratings, and macroeconomic fundamentals, global liquidity conditions, interest rate risk, currency fluctuations to name a few. Why should agricultural wealth or deforestation trends be added to this series? The following paragraphs argue that government debt already reflects the sovereign's natural capital. The more interesting question is whether this is reflected indirectly through the macroeconomy or directly through market perceptions. As we will see, this depends on whether we take the long-term or the short-term view.

Natural capital and the economy

The idea that natural resources are at the foundation of the economy is old. Around the time when the Bank of England issued the first sovereign bond, a group of French Enlightenment economists, the Physiocrats (Greek for "rule of nature"), asserted that all wealth of a nation is sourced from the land. In their view, every other economic activity finds its roots in agricultural surpluses, the prime mover of the economy. This body of thought has since lost its appeal and relevance, until policy discussions in recent years have revitalized the importance of nature to the world economy. In this context, natural capital is not restricted to only mean crop and livestock products, but also encompasses forests, minerals and fossil fuels. The World Economic Forum estimates that "$44 trillion of economic value generation – more than half of the world's total GDP – is moderately or highly dependent on nature and its services [...]" (WEF, 2020b). Dasgupta (2021) frames the loss of natural capital as part of a global asset management problem – one that humanity has been mismanaging.

When macroeconomic textbooks discuss economic growth, however, physical and human capital take center stage. If natural capital does make a guest appearance, the role it plays is more anecdotal or serves to explain phenomena not captured by the model. The seminal work of Mankiw et al. (1992), which empirically assesses the celebrated Solow (1956) long-run growth model, considers "resource endowments, climate, institutions, and so on" as part of the random technology intercept. The main attention is paid to capital, whose marginal productivity also determines the real interest rate, $r = F_K(K, L)$.[1]

Since the early days of macroeconomics, researchers have mended this gap with models that assign a more prominent role to nature (Dasgupta et al., 1974; Solow, 1974; Stiglitz, 1974). The key feature of these models is that exhaustible resources are *essential*. Solow (1974) expresses this idea as $Q = F(K, L)R$. In words, the aggregate economic output Q is a function of (physical) capital K and human labor L, but also requires an essential resource $R > 0$. Without it ($R = 0$), nothing can be produced ($Q = 0$). In this long-run growth setting, interest rates grow proportionally with the essential resources R.[2] This has clear consequences for bond yields. It is worth highlighting that this strand of literature is primarily concerned with the optimal extraction rate of *nonrenewables*, such as fossil fuels and minerals. While subsoil assets are part of the subsequent analysis, the main emphasis of this paper lies on *renewable* resources.

Why government bonds?

After we have seen how natural capital influences bond returns in the (very) long-run, we now examine their relationship in the short-run. The reader might wonder, why we are interested in bonds to begin with. The explanation is twofold. First, government bonds are issued with maturities several decades into the future. This horizon is necessary when thinking about costs of biodiversity loss or returns on sustainable farming practices. If environmental variables do influence yields, we will likely find them on the longer end of the yield curve.[3] Second, government bonds are publicly traded instruments. After bonds are issued, the secondary bond market shapes the prices as the securities find their ways into the balance sheets of pension funds, insurance firms or banks. Observed bond yields are therefore the result of a continuous price discovery process, moving according to the valuations and expectations of market participants. This feature differentiates bonds from forecasted growth figures published by central banks, government ministries or think thanks.

Explaining these bond yield dynamics is a main focus of the fixed-income literature. Different from equity markets, where an entire "zoo" of pricing factors help the investor understand stock returns, fixed-income attribution is a much more opaque subject. Bond yields can be decomposed into several factors and risk premia (Abrahams et al., 2016; Kim et al., 2005; Smets et al., 1997). We focus on expected inflation and the term premium. The former is conceptually in line with the previous discussion on growth models. An expanding economy fuels consumption growth which drives up prices of goods and services. The resulting expected inflation pressure will cause bond holders to

[1] $F(K, L)$ denotes the aggregate production function of an economy which takes capital and labor as arguments. The real interest rate or the return of capital is defined as the marginal productivity of capital $F_K(K, L) = \partial F/\partial K$. The Ramsey (1928) model introduces a consumer with time-preference ρ and intertemporal substitution elasticity θ. The equilibrium path implies that consumption growth $\dot{c}/c = \theta(r - \rho)$. Brand et al. (2018) consider this r as a way to define the natural rate of interest. For an excellent overview we refer the reader to Smulders et al. (2012).

[2] This statement becomes clear once we recall the relationship between the real interest rate and marginal productivity $r = \partial F(K, L)R/\partial K = F_K R$.

[3] The (government) yield curve traces out the bond returns over the maturities of all bonds outstanding. The curve has economic importance as is used as benchmark rates. See Figure 10, Appendix for a visual representation.

demand higher real returns on their investments. At the same time, an upward movement of bond yields can also be explained by the term premium.[4] This premium compensates the bond holder for giving up liquidity until the bond expires. Moreover, the creditor is exposed to the risk of not being paid back. The longer the maturity, the higher the cost of inaccessible liquidity, the higher the risk of a default occurring. Similar to inflation expectations, the eroding creditworthiness of a borrowing government constitutes another reason for bond holders to demand higher yields as compensation.

Thus, the same yield rise can be explained in (at least) two different ways. Disentangling concurrent explanations and identifying which aspect can be attributed to natural wealth will be the main challenge for this study. Let us illustrate this ambiguity with a concrete example. Suppose we find evidence that carbon wealth is indeed associated with higher long-term bond yields. From an inflation perspective, this is a positive indicator. Countries rich in fossil fuels can collect the rents from their resources, invest these into infrastructure, machinery and education programs, which lay the foundation for growth in the long-run (Romer, 1986). Norway is often cited as the example for this narrative. Its government ensured a gradual distribution of its oil rents over several generations to prevent the sudden windfall gains from disrupting the domestic economy (Gylfason, 2001). At the same time, high yields can also be a negative indicator. In fact, widening bond spreads are usually taken as a sign for higher credit risk. Rating agencies differentiate between investment grade bonds with low (or negative) yields and speculative grade bonds, also called high yield bonds or "junk bonds". But could abundance in natural resources lead to higher default risk?

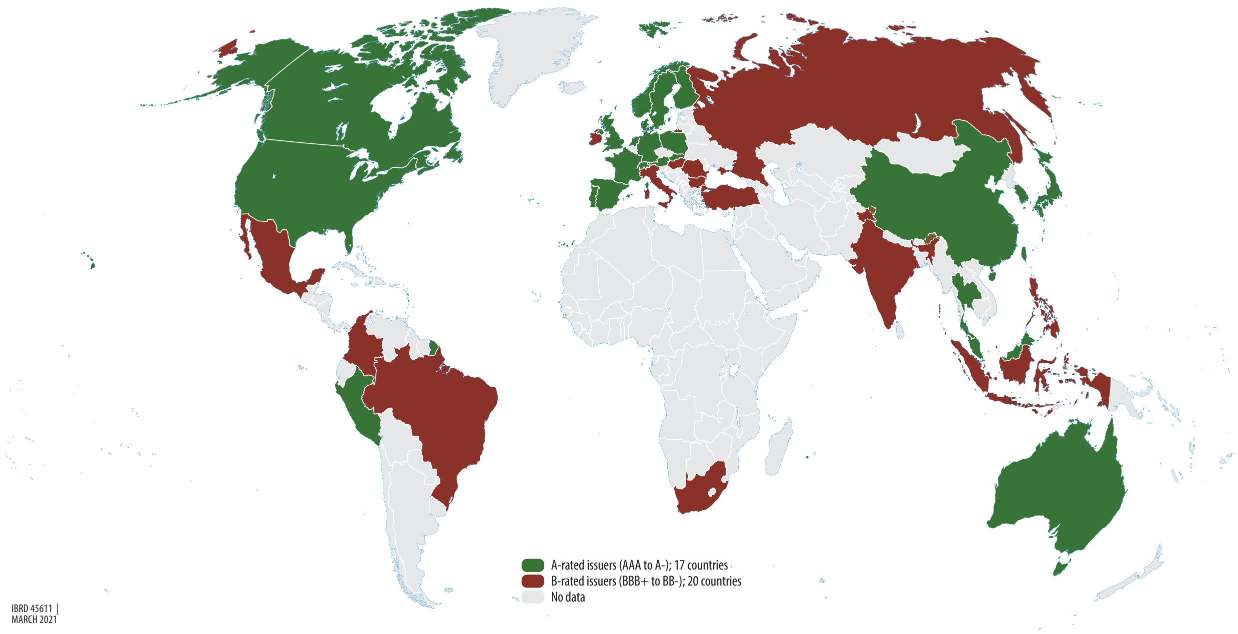
Natural resources bring risks

The development literature presents us with possible explanations. The natural resource curse, or the closely-related Dutch disease, describes the paradoxical phenomenon where resource-rich countries experience lower than expected growth (van der Ploeg, 2011; Venables, 2016). This runs entirely against the inflation channel rationale, where natural capital is supposed to give countries a leg up in climbing the development ladder. Whether a country is affected by the curse depends on the nation's government effectiveness, rule of law and level of corruption. If these are not strong enough, resource rents can be misappropriated and the country is diverted from a long-term sustainable growth path, raising the risk of default. The Netherlands' eponymous Dutch disease provides an alternative explanation, where newly discovered gas resources disrupted the country's export profile and exchange rate, leading to reduced economic growth.

Looking at the Norwegian and Dutch examples, the resource curse could also be labeled "non-renewable resource curse" as it is normally mentioned in the context of sudden discoveries of fossil fuels or mineral deposits. Could the same explanation also apply for renewable resources? The short-term rents from deforestation of the Amazon rainforest or the dwindling fish populations due to overfishing come to mind. It is not difficult to name other examples in the same, bleak flavor. In this paper, however, we are not primarily concerned with the dismal prospects of unsustainable resource exploitation. Nor are we concerned with the dire consequences of pollution and carbon

[4] In the spirit of Shiller et al. (1987) we use the word "term premium" synonymously with risk premium and liquidity premium.

Figure 1: Country coverage by rating groups



emissions. Instead, we are interested in the positive effects that renewable resources have on the economy. That is, instead of asking if countries are punished for deforestation through higher yields, we ask if countries are being rewarded for afforestation with lower borrowing costs.

The remainder of this paper is structured as follows. Section 2 introduces the reader to the wealth data, the rationale behind it and how it differs from other natural resource data, along with other data sets. Section 3 conveys the gist of this study graphically and discusses the confounding factors and the ingrained income bias. Section 4 revisits the problem in an econometrically more rigorous manner. Section 5 discusses limitations of the study and Section 6 concludes.

2 Data

Our sample comprises $N = 37$ countries, with 20 A-rated countries that have an average long-term debt rating between AAA and A- and 17 B-rated countries with ratings between BBB+ and BB- (see Table 1). We cover $T = 120$ months between January 2009 and December 2018. The countries were selected based on the availability of sovereign bond data, i.e. countries with established domestic capital markets. This limits our analysis to high and middle income countries.

2.1 Wealth data

Hamilton et al. (2006) argue that short-term economic variables alone are insufficient to measure a country's sustainable, long-term growth potential. Wealth accounting is necessary to have a complete picture.[5] The World Bank (Hamilton et al., 2006; Lange et al., 2021; Lange et al., 2018; Lange et al., 2011) has compiled data on the wealth of 141 nations, divided into three major categories: human capital (discounted lifetime earnings), produced capital (e.g. machinery, buildings, urban land) and natural capital (e.g. forests, cropland, protected areas, subsoil assets).

[5]Lange et al. (2018) draw the illustrative parallel between a country's GDP growth and its wealth, on the one side, and a company's income statement and balance sheet, on the other side.

Table 1: Sovereign ratings between Jan 2009–Dec 2018

We group the countries studied in this paper by their credit quality rating, based on Fitch Ratings' long-term credit ratings. The right-most columns indicate the highest, lowest and average alphabetic ratings observed in the sample. The rating groups used throughout this paper categorize AAA to A- ratings as "A-rated" and BBB+ to BB- as "B-rated".

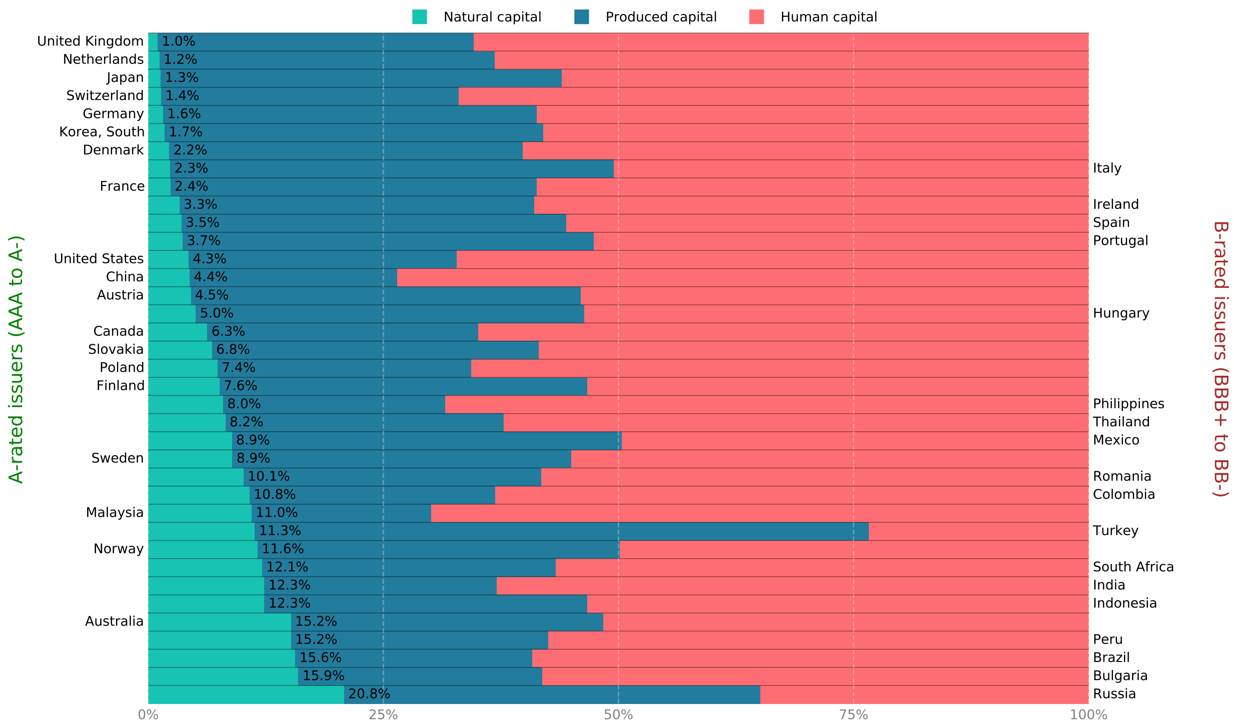
				Credit quality rating in sample		
Credit quality step	Country	Code	Eurozone	Highest	Lowest	Average
1	Australia	AUS	-	AAA	AAA	AAA
	Canada	CAN	-	AAA	AAA	AAA
	Denmark	DNK	-	AAA	AAA	AAA
	Germany	DEU	Yes	AAA	AAA	AAA
	Netherlands	NLD	Yes	AAA	AAA	AAA
	Norway	NOR	-	AAA	AAA	AAA
	Sweden	SWE	-	AAA	AAA	AAA
	Switzerland	CHE	-	AAA	AAA	AAA
	United States	USA	-	AAA	AAA	AAA
	Austria	AUT	Yes	AAA	AA+	AA+
	Finland	FIN	Yes	AAA	AA+	AA+
	France	FRA	Yes	AAA	AA	AA+
	United Kingdom	GBR	-	AAA	AA	AA+
	China	CHN	-	AA-	A+	AA-
	Korea, Rep.	KOR	-	AA	AA-	AA-
2	Slovak Republic	SVK	Yes	A+	A+	A+
	Ireland	IRL	Yes	A+	BBB+	A
	Japan	JPN	-	A+	A	A
	Malaysia	MYS	-	A	A-	A
	Poland	POL	-	A	A-	A
3	Italy	ITA	Yes	A-	BBB	BBB+
	Mexico	MEX	-	A-	BBB	BBB+
	Peru	PER	-	A-	BBB+	BBB+
	Spain	ESP	Yes	A-	BBB	BBB+
	Thailand	THA	-	A-	BBB+	BBB+
	Bulgaria	BGR	-	BBB	BBB-	BBB
	Colombia	COL	-	BBB+	BBB	BBB
	Russian Federation	RUS	-	BBB	BBB-	BBB
	South Africa	ZAF	-	A	BB+	BBB
	Hungary	HUN	-	BBB	BBB-	BBB-
	India	IND	-	BBB-	BBB-	BBB-
	Indonesia	IDN	-	BBB	BBB-	BBB-
	Philippines	PHL	-	BBB	BBB-	BBB-
	Portugal	PRT	Yes	BBB	BB+	BBB-
	Romania	ROU	-	BBB	BBB-	BBB-
4	Brazil	BRA	-	BBB	BB-	BB+
	Turkey	TUR	-	BBB	BB-	BB+

Figure 2 shows the wealth composition of the countries studied. Natural capital, or natural wealth, is further divided into renewable and non-renewable resources. The term "renewables" refers to natural capital that can produce benefits in perpetuity under sustainable management. It stands in contrast to "non-renewables", which refer to extractable, subsoil assets. We do not use the term renewables in the sense of renewable energy sources.

Different from other data sets on natural resources, which account for stock or flows of a particular resource, the wealth data employs a forward-looking approach. Human capital, for instance, is calculated as the discounted expected lifetime earnings of an individual, which is either working age or still in school. A similar rationale applies to the valuation of natural resources. A country's fossil fuel wealth is calculated as the discounted value of future resource rents, until this non-renewable resource is depleted. Renewable resources distinguish themselves in that their discounting horizon depends on the rate of extraction versus replacement. For instance, forest

Figure 2: Wealth composition by natural capital

This graph shows the wealth composition of the 37 countries studied, ordered by the share of natural capital in the total wealth. The country names on the left (right) side belong to the A-rated (B-rated) category. We can see that countries with lower share of natural capital tend to belong to the A-rated category. Higher natural capital alone does not imply B-ratings or vice versa.



capital is a function of (inflation-adjusted) unit rents, production quantities and the difference between deforestation and re-/afforestation (World Bank, 2018).

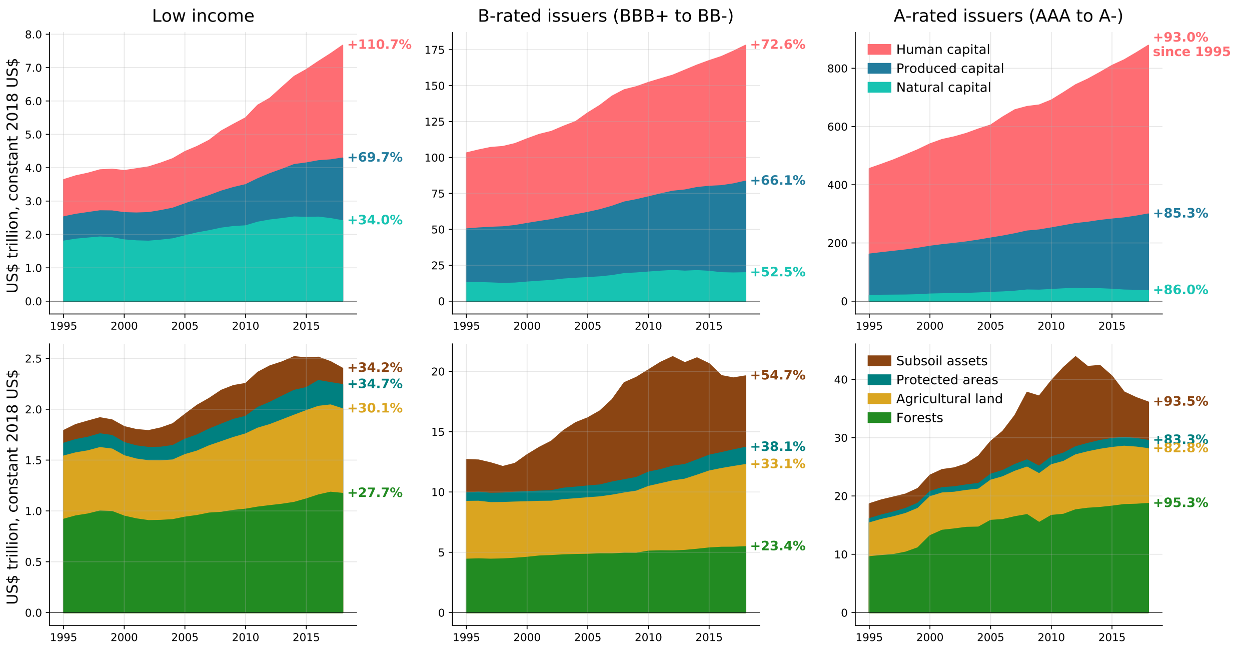
A main critique point of the wealth data is its low, annual frequency. While this characteristic may be undesirable for financial markets, where subsecond data can be used to arbitrage, the same property turns out to be an advantage in our case. Even if crop yield data would be available on a daily frequency, it would be conceptually meaningless, let alone the concerns about measurement errors and low signal-to-noise ratio.[6] In this study, the low frequency alleviates an econometric concern. Suppose bond yields and natural resources are related, which way does the effect go? With monthly, stationary bond series on the one side and annual, persistent wealth data on the other side, the estimated effect is more likely to originate from the latter. Moreover, the discounted resource rents are calculated with lagged, 5-year moving average rents (World Bank, 2018). This effectively makes the wealth variables predetermined. These technical arguments, however, do not preclude the existence of long-term trends in the bond data or the presence of other confounding and possibly unobserved variables that influence bond prices as well as natural resources.

The wealth accounting indicators used in this study were compiled on an annual frequency and will be made available together with the accompanying report (Lange et al., 2021). The values are comparable and qualitatively consistent with the publicly available 5-year frequency data until

[6]Monthly or quarterly data, on the other hand, might be more informative as they capture seasonal variations and are aggregated enough for higher signal-to-noise ratios to emerge.

Figure 3: Wealth and natural capital components over time

We compare how natural capital and its constituents developed throughout the sample period. The first row shows the breakdown of total wealth and the second row shows the components of natural capital. The percentages denote the growth of the respective component since 1995.



2014 from the World Bank's Open Data platform (Lange et al., 2018). See Figure 3 for a visual depiction of how individual wealth components evolved since 1995.[7] We then linearly interpolate the annual values to obtain monthly figures. Given the slow-moving and persistent process behind wealth, the linear interpolation is reasonable. Throughout this paper, wealth variables are transformed with the base-10 logarithm.

2.2 Bond data

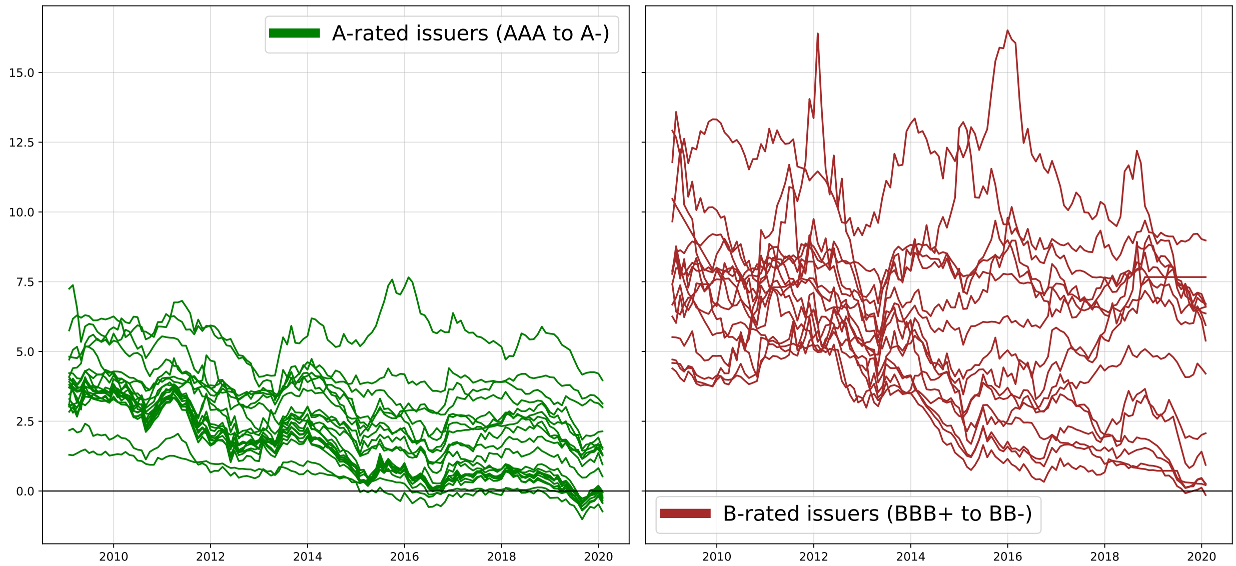
Sovereign bonds of developing markets and middle income countries are sometimes issued in both foreign and local currencies. This study focuses on local currency bonds. This choice is primarily motivated by the larger size of sovereign bond markets in local versus foreign currencies. According to the debt securities statistics of the Bank for International Settlements, the average amount outstanding between 2009–2018 for central government debt is US$ 19.7 trillion for domestic currencies and US$ 78.3 billion for foreign currencies. If we exclude the United States and Eurozone countries, the numbers reduce to US$ 6.6 trillion for domestic and US$ 49.0 billion for foreign currencies. This is also reflected by the broader bond data coverage across countries and time for local currencies.

One concern for this choice might be the "original sin" (Eichengreen et al., 1999; Eichengreen et al., 2002), describing the inability of developing countries to adequately borrow domestically or internationally when issuing debt in their own currency. Instead, countries issue debt denominated in USD or EUR, which insulates the creditor from domestic inflation, liquidity or solvency concerns of the issuing country. However, Hausmann et al. (2003) do not find evidence that these concerns

[7]The data used in this paper was obtained from the World Bank's wealth team and is subject to change prior to the release of the new wealth data described in Lange et al. (2021).

Figure 4: 10-year monthly bond yields for A- and B-rated issuers

We present the end-of-month bond yield data. Although all bonds studied are investment grade, we can discern a clear co-movement in the yields of A-rated issuers, which is much less pronounced in B-rated issuers.



explain the original sin. Instead, only the total size of the economy matters. Further, Claessens et al. (2007) find that the depth of the domestic financial system, exchange rate regimes and the composition of the investor base matter for how much a country decides to issue in foreign currencies. Regarding the sovereign credit risk, Amstad et al. (2020) do not find evidence for differences in credit ratings due to higher inflation risks. They also find that the gap in credit ratings between currencies has narrowed within the past two decades due to favorable global reserve conditions.

We use Bloomberg's end-of-month generic government bond indices for the 10-year and 2-year tenors (Figure 4, Appendix). We treat the former as the long-term yields in this study and proxy the slope of the yield curve through the difference between the 10- and 2-year rates. Missing data points are imputed through cubic spline interpolation (Waggoner, 1997). See Figure 10, Appendix, for a visual example of this procedure.

2.3 Macroeconomic and financial variables

To control for effects due to short-term growth variables, we include monthly GDP growth and consumer price index (CPI) growth, to capture the most important macroeconomic factors Ludvigson et al. (2009) identified as determinants of bond returns. We use quarterly GDP data and monthly CPI data from the IMF International Financial Statistics database. To obtain monthly GDP figures, we first calculate quarterly growth rates, $\Delta GDP_t^Q / GDP_{t-1}^Q$ and then use the benchmarking method of Denton (1971), as advocated by the IMF (Di Fonzo et al., 2012; Marini, 2016). See Figure 12, Appendix for an example of this benchmarking method. For inflation figures, we calculate the monthly percentage change as $\Delta CPI_t^M / CPI_{t-1}^M$. We restrict our attention to these two variables due to limited data availability of other country-specific indicators.

Further, we include debt-to-GDP ratios to account for a country's fiscal deficit and reserves-to-GDP ratios to account for its liquidity in foreign reserves. Both indicators are obtained from the

IMF's Government Finance Statistics and International Financial Statistics. To account for varying degrees of capital market developments, we obtained the Financial Market Depth variable from the IMF's Financial Development Index data set.

In the factor analysis in Section 4.7, we will compare extracted latent factors with observed global financial variables (see Figure 9, Appendix). We consider the following candidates.

1. Monthly *federal funds rate* data are provided by the Federal Reserve Economic Data (FRED) database of the Federal Reserve Bank of St. Louis. It serves as a proxy for global liquidity conditions (Csonto et al., 2013). This is particularly relevant for exchange rate volatilities, for instance due to the US federal reserve large-scale asset purchase programs, which Gadanecz et al. (2018) demonstrate to have influenced local currency bond yields.

2. We include the *TED spread* and the Chicago Board Options Exchange's Volatility Index to control for global credit risk and volatility conditions (Hilscher et al., 2010).

3. To mirror equity market conditions in developed markets, we include end-of-month values of the *MSCI World Index*.

4. For global bond market conditions, we also obtain end-of-month values of *J.P. Morgan Global Bond Index (GBI)* for emerging markets and the European monetary union, which captures developments in local currencies.

5. Furthermore, we obtain end-of-month values of *J.P. Morgan Emerging Markets Bond Index (EMBI)* suite to reflect bond market developments in foreign currencies.

3 Preliminary analysis

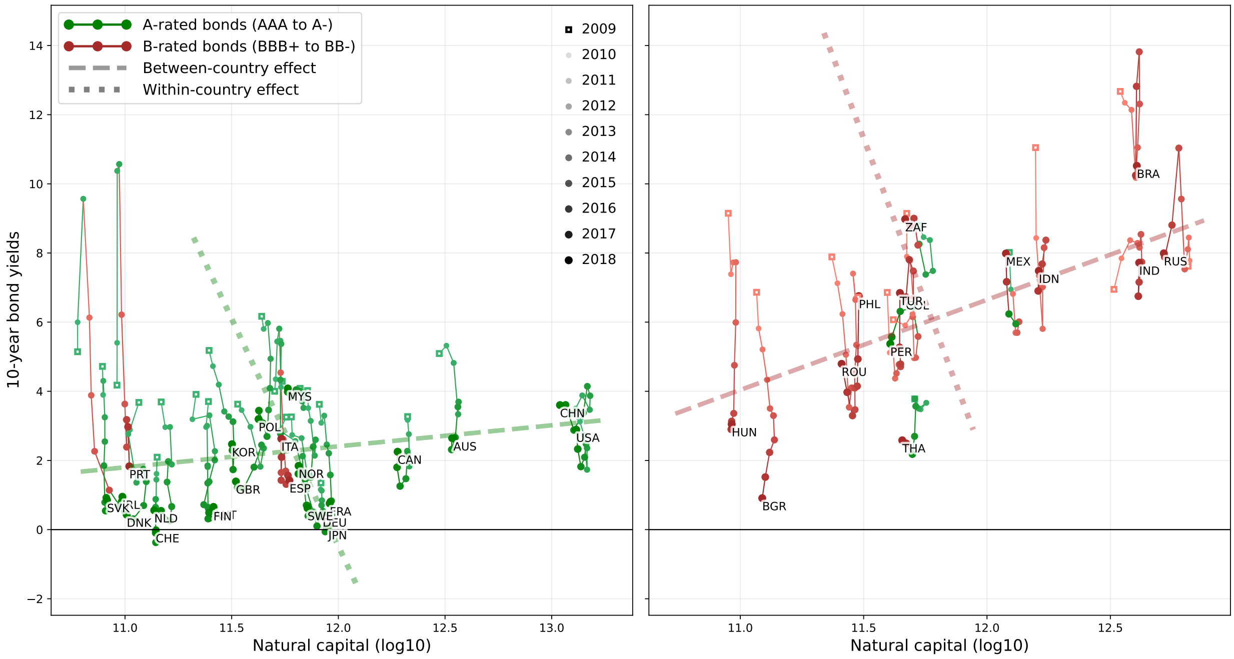
When a country raises capital on bond markets, it needs to set the return on the bond. This return, or yield, will determine the market appetite for this debt issuance. To simplify and focus the subsequent discussion, we treat bond yields as the price of borrowing. Considering the importance of natural capital to the economy and thereby to its bonds, we ask: Is it worth investing into forest expansion, sustainable agriculture or national parks? Figure 5 suggests two answers.

If we follow the dashed lines, it seems that more natural capital either raises or does not affect borrowing costs of B- and A-rated issuers, respectively. This is the **between-country view** or long-run view. Countries richer in natural capital, such as Brazil or the Russian Federation, tend to have higher bond yields than countries that have less natural wealth, such as Bulgaria or Hungary. This view effectively ignores the changes over time and compares the average yield with the average natural capital across countries.

If we instead follow the dotted lines, we find the exact opposite. As countries grow richer in natural wealth, the cost of borrowing drops. This is the **within-country view** or short-run view. Rather than comparing countries with each other, the within view compares the countries with themselves at different points in time. For instance, Colombia in 2019 is wealthier in natural capital and has lower yields than it did in 2009. China or Malaysia, in contrast, moved sideways, indicating that their yields were largely unaffected by changes in their natural capital.

Figure 5: Long-term yields and natural capital (2009–2018)

The plot traces out the relationship between natural capital and 10-year bond yields over a decade. Darker colors indicate more recent data. The bonds are divided into A-rated bonds (20) and B-rated bonds (17), see Table 1. The dashed lines describe the between-country effect, which is positive for B-rated bonds and no clear effect for A-rated bonds, see equation (1). B-rated issuers with more natural wealth tend to pay higher yields. The dotted lines describe the within-effect which is negative for both groups, see equation (3). As countries grow richer in natural wealth, their yields tend to decrease.



The two views are complementary and have each their own insights and challenges. However, while the challenges of the within-view are more of technical nature, the problem with the between-view is conceptual. This problem, which we refer to as the *ingrained income bias*, also affects many sovereign ESG scores (see Box 1). The following sections describe the between-view and point out its fundamental problem. We then demonstrate how the within-view resolves this problem and leads to a more appropriate estimate of how much natural capital is worth to a sovereign issuer.

3.1 Between-country view

Let us for now disregard what happens along the country paths in Figure 5 and focus on the differences between countries (thick dashed lines). We observe two different regimes. For A-rated bonds, more natural capital is tenuously associated with lower yields. For B-rated issuers, we find a strong upwards sloping relationship. These observations are borne out statistically. The thick dashed lines are the results of between-country regressions. These compare the average yield, $\overline{yields}_i := \frac{1}{T}\sum_t yields_{it}$, with the average natural capital, $\overline{natcap}_i := \frac{1}{T}\sum_t natcap_{it}$, across all N countries.

$$\overline{yields}_i = \underset{4.379}{-4.9} + \underset{0.161}{0.3}\ \overline{natcap}_i \qquad\qquad \overline{yields}_i = \underset{13.609}{-19.4} + \underset{1.078^{*}}{2.0}\ \overline{natcap}_i \tag{1}$$

A-rated bonds B-rated bonds

Figure 6: Ingrained income bias and endogeneity

In a cross-country analysis, the hypothesized effect of natural capital on bond yields may in fact be driven by the unobserved level of income or development. Neglecting $develop_i$ will bias the results and overestimate the effect of interest (dashed arrow).

Level of development or income

$$\begin{tikzcd} & develop_i \arrow[dl, <->] \arrow[dr, <->] & \\ \overline{natcap}_i \arrow[rr, dashed] & & \overline{yields}_i \end{tikzcd}$$

Average natural capital | Average bond yields

[The $\hat{\beta}$ coefficient in $\overline{yields}_i = \hat{\alpha} + \hat{\beta}\overline{natcap}_i$ can be interpreted as the percentage point change in the average yield associated with a 1% increase in average natural capital. The standard errors are reported below the coefficients. The stars indicate the level of significance with *** p<0.01, ** p<0.05, * p<0.1.]

The statistical results suggest no substantial relationship for A-rated issuers, but provide strong evidence that resource-rich issuers with B-ratings tend to pay higher yields.

3.2 The ingrained income bias

From a long-term growth perspective, this finding makes sense. Natural wealth is an essential input for long-term, sustainable growth. This raises the (natural) rate of interest which drives up inflation expectations and ultimately bond yields. Thus, countries with higher resource endowments are reasonably associated with higher growth potential. This is consistent with the fact that the wealth data was constructed with the explicit goal of capturing long-term growth potential in mind.

Although this finding is intuitively appealing, its simplicity does not rule out any alternative explanation. Higher yields can also indicate higher default risk, for example due to the resource curse. Natural wealth alone does not necessitate a positive economic growth path. In a system with little protection of private property rights and weak rule of law, resource rents can be misappropriated. This can lead to corruption and in extreme cases constitute a source for armed conflict. Neither of these foster the creditworthiness of a country. Political uncertainty and questionable ability for debt repayment will thereby raise the bond returns necessary for investors.

Hence, while it is true that countries richer in natural resources have higher yields, it is entirely unclear why. Upon further consideration, a much more detrimental problem emerges (Figure 6). The between-country view compares countries at their respective stages of development. However, as countries become more prosperous, the relevance of natural capital changes. The resource curse would predominantly affect resource-dependent economies. Countries further down their growth paths will have transitioned from resource-reliant growth into economies where industry and technology constitute the major share of GDP. One could even argue that more prosperous countries will in fact invest back into natural capital and protect ecosystem services. Comparing countries in this manner therefore becomes a comparison of income. Therefore, any conclusions about the effect of natural wealth on borrowing costs will be dominated by the ingrained income bias. This is not only a technical or an epistemological problem.[8] From a developing country's perspective, the bias is particularly discouraging. The levels of development and prosperity are results of decades or even centuries of human history. No short-term efforts will move these ingrained variables, let alone affect a country's bond yields.[9]

3.3 Within-country view

In the within-view, we bring countries onto a "level playing field" and entirely focus on their developments over time. By adopting the within-view we also switch from the long-run to the short-run, where different factors come into play. For instance, the Keynesian liquidity preference emerges in the bond's term premium, where default risk and foregone liquidity influence the price of money. While natural wealth can be considered fixed in the long-run, this assumption is difficult to maintain in the short-run. Even though natural capital follows a persistent process, Figure 3 shows that it has grown by 86% since 1995. On a disaggregated level, forest wealth in A-rated countries grew as much as 95.3% in the same period.

The main benefit of the within-view is that it eliminates the ingrained income bias. To see how, let $develop_i$ be the unobserved level of income of country i. The within perspective removes this

Box 1: The ingrained income bias in Sovereign ESG

Sustainability has entered mainstream financial discussions with a growing share of institutional investors allocating funds towards Sustainable Development Goals through Environmental, Social and Governance (ESG) scores. Sovereign ESG scores, however, are often affected by the ingrained income bias. Gratcheva, Emery, et al. (2021) document an average correlation of 85% between the sovereign ESG score and GNI per capita across seven major ESG score providers, ranging from 69% to 98%. Cross-country comparisons emphasize the long-run view and therefore tend to favor prosperous countries in all three ESG dimensions (Boitreaud et al., 2020; Gratcheva, Gurhy, Emery, et al., 2021). Richer countries score higher on the Environmental pillar, for example, given their capacity to designate and enforce national parks. The same countries also score higher in the Social and Governance dimensions since, among others, labor force participation and strong legal rights are key drivers of economic development.

Not accounting for the ingrained income bias may therefore have two unintended consequences. First, the *income bias* in ESG scores may lead to perverse investment outcomes, since ESG-based portfolio weights likely incentivize capital flows towards wealthy countries. Second, the *ingrainedness* may lead to disheartening policy incentives, since short-run efforts are unlikely to significantly affect either a country's income level or its ESG scores. The short-run, within-country view described in this paper suggests an alternative approach, as it effectively removes the ingrained income bias and allows the evaluation of recent environmental efforts on a "level playing field". Practical implications of this approach are studied in Gratcheva, Gurhy, and Wang (2021).

[8] To provide some econometric intuition, suppose the actual model reads $yields_{it} = develop_i + natcap_{it}\beta + u_{it}$. The variable $develop_i$ is unobserved and affects both yields and natural capital. In the Mankiw et al. (1992) framework, $develop_i$ is part of the random country-specific technology intercept. The intercept, however, is not exogenous (Lee et al., 1997). If $develop_i$ is not modeled, it will become part of the error term. This, however, leads to biases in $\hat{\beta}$ since $Cov(natcap_{it}, develop_i + u_{it})$ are now correlated, violating the exogeneity assumption in the Gauss-Markov theorem.

[9] Although we continue the analysis with the within-country view, the between-country view is not entirely uninformative. Table 9, Appendix, shows the results of an extended model with additional controls. The results should be seen as purely descriptive.

Table 2: Average value of 1% capital in $US million

The values are calculated using the 2018 values of the Changing Wealth of Nations dataset. These are expressed in constant 2018 $US million.

	Total capital			Natural capital	
Issuer	Human capital	Natural capital	Produced capital	Non-renewables	Renewables
All	182,179.8	15,203.8	88,338.3	3,378.6	11,825.2
A-rated	266,865.3	16,690.8	122,465.6	2,977.1	13,713.7
B-rated	57,974.3	13,022.9	38,285.0	3,967.6	9,055.4

	Renewables			Forests		Agricultural land	
Issuer	Forests	Agricultural land	Protected areas	Non-timber	Timber	Cropland	Pastureland
All	6,535.2	4,380.3	769.5	6,073.9	461.3	3,170.4	1,209.8
A-rated	8,629.0	4,261.4	656.5	8,203.5	425.5	3,202.0	1,059.4
B-rated	3,464.2	4,554.6	935.3	2,950.5	513.7	3,124.1	1,430.5

variable, along with other time-invariant characteristics, by subtracting the country-average. If the original process reads

$$yields_{it} = develop_i + natcap_{it}\beta + u_{it} \tag{2}$$

then the within model is $yields^{\star}_{it} = yields_{it} - \overline{yields}_i$ which implies

$$\begin{aligned} yields^{\star}_{it} &= (develop_i - \overline{develop}_i) + (natcap_{it} - \overline{natcap}_i)\beta + (u_{it} - \overline{u}_i) \\ &= natcap^{\star}_{it}\beta + u^{\star}_{it} \end{aligned}$$

since $develop_i = \overline{develop}_i$. This allows us to ask a more refined question: If overall resource endowments and level of income were irrelevant, how much does growth in natural resources affect the cost of borrowing? In Figure 5, this corresponds to following countries along their paths from lighter to darker colors. Interestingly, the paths do not fall straight down, which would have meant that yields fell regardless of how natural capital develops. Instead, we observe a slight drift to the right, particularly for A-rated issuers. This suggests, at least visually, that growth in natural capital over time has a lowering effect on bond yields. This is depicted by the thick dotted lines in Figure 5, which are the result of within-regressions, or fixed-effects (FE) regressions,

$$\underset{\text{A-rated bonds}}{yields^{\star}_{it} = -\underset{1.940^{***}}{5.71}\ natcap^{\star}_{it}} \qquad \underset{\text{B-rated bonds}}{yields^{\star}_{it} = -\underset{4.949^{***}}{8.24}\ natcap^{\star}_{it}} \tag{3}$$

The within coefficients emerge as negative and strongly statistically significant. As a country grows richer in natural capital, its yields drop significantly.[10] This result may be encouraging for sovereign issuers. To gain some perspective, a 1% natural capital growth in 2018 is worth $US 15.2 billion on average. The estimated effect, however, is likely biased due to other unobserved, confounding variables. Fortunately, these issues can be dealt with in a straightforward manner, as we will discuss in the following sections.

[10] A negative coefficient also implies that decreasing natural capital leads to higher yields. A glance at Figure 3 reveals that natural capital and its components have been growing steadily. In the subsequent analysis and discussion we will therefore concentrate on the effect of natural capital growth.

3.4 Unobserved common bond factors

Exploiting the time variation greatly increases the sample size, but also introduces the problem of unobserved common factors. This is aggravated by the nature of bond yields. First, bond yields are highly autocorrelated. For the 10-year tenor we find an average AR(1) coefficient of $\hat{\rho} = 0.956^{***}$, leading to serial correlation in the residuals. Second, the integrated nature of international bond markets leads to significant co-movements between the bond prices, see Figure 5. This is a particularly severe problem since these common factors, which reflect global liquidity conditions or market turmoils such as the 2011-12 European debt crisis, affect both bond yields as well as observed macro-financial control variables. Third, these global common factors do not affect countries equally. If this were the case, they could be dealt with through time fixed-effects. This strongly suggests the existence of at least one unobserved common factor that influences some or all bonds. Since the FE estimates in (3) did not account for any common factors, its estimates are likely biased.[11]

It is useful to clearly define the data-generating process we have in mind when we speak of latent common factors, as it will be the basis for all subsequent results. For clarity of notation, we let y_{it} denote the dependent variable, c_i the country fixed-effects, which contains all time-invariant characteristics such as $develop_i$, X_{it} natural capital or its components, and W_{it} denotes a set of control variables

$$y_{it} = c_i + X_{it}^{\top}\beta + W_{it}^{\top}\gamma + u_{it} \qquad \text{with} \qquad u_{it} = \lambda_i^{\top} F_t + e_{it} \tag{4}$$

$$F_t = AF_{t-1} + v_t \tag{5}$$

with $e_{it} \sim N(0, \sigma_i^2)$ and $v_t \sim N(0, \Sigma)$ with diagonal covariance matrix Σ. The key novelty of this architecture lies in the factor component $\lambda_i^{\top} F_t$. In words, it asserts that the error term u_{it} contains global common factors F_t that affect each country with varying degrees λ_i. The factor equation (5) is vector-valued with A denoting a $K \times K$ matrix of autoregressive coefficients. Section 4.7 discusses the number of factors K. The endogeneity problem arises if we neglect $\lambda^{\top} F_t$ when F_t and X_{it}, W_{it} or λ_i and X_{it}, W_{it} are in fact correlated.

Against this background, it becomes clear that the FE we employed for (3) is insufficient. It only accounts for cross-country heterogeneity but does not address the omission of the global common factors F_t. Including lagged dependent variables will not alleviate this issue either since they will be correlated with the persistent common factors as well. A first-difference estimator is also inappropriate due to low variation in the wealth variables. However, even if differencing were a viable option, the author believes that it is more insightful for researchers and policy makers to model unobserved variables as much as possible instead of eliminating them, as we will see in Section 4.7. For all these arguments we opt for the interactive fixed-effects estimator (IFE) which was described in the seminal paper of Bai (2009). The corresponding IFE estimates to the FE

[11] In the Appendix, Section A.2, we demonstrate in a Monte Carlo study how a conventional within estimator, which does not account for the factor component, will lead to biased estimates. The severity of the bias increases with the strength of autocorrelation in (5). We then show how the IFE approach correctly recovers the true coefficients, even when F_t is highly autocorrelated.

estimates of (3) with $K = 1$ are

$$\underset{\text{A-rated bonds}}{yields^{\star}_{it} = -\underset{0.571^{**}}{1.44}\ natcap^{\star}_{it}} \qquad \underset{\text{B-rated bonds}}{yields^{\star}_{it} = -\underset{1.401^{***}}{5.28}\ natcap^{\star}_{it}} \tag{6}$$

In contrast to the FE estimates in (3), the natural capital coefficient in A-rated bonds drops from -5.71 to -1.44, which is a larger difference than the coefficient change of B-rated bonds from -8.24 to -5.28. This is reasonable since bond yields in developed countries are much more integrated, as is the case with the 10 Eurozone countries (see Figure 5). After isolating the common factor, we see that natural capital affects B-rated bond yields much stronger. This resonates with the larger importance of the primary sector in these countries, as we will see later.

3.5 Aggregate time effects

In addition to the common factor component, it is also possible to have aggregate time effects. As a robustness exercise, we also include time fixed-effects d_t into (4), which then reads

$$y_{it} = c_i + d_t + X_{it}^{\top}\beta + W_{it}^{\top}\gamma + u_{it} \tag{7}$$

Time fixed-effects assume that countries are exposed equally to d_t. This is a special case of the common factor component. To see this, let f_t be a scalar valued factor, i.e. F_t if $K = 1$. Then $d_t = \lambda_i f_t$ if $\lambda_i = \lambda$ for all i.

3.6 Pace of development

The within-view removes the level of income effect that afflicted the cross-country analysis. However, the pace of development is likely still different between countries. That is, although we brought countries on a level playing field, the speed at which they are moving will still affect the results.[12] Countries higher up the development ladder not only have lower yields, which we now account for. The yields are also decreasing at a different pace than developing countries. We test the robustness of our results by extending (4) to

$$y_{it} = c_i + p_i t + X_{it}^{\top}\beta + W_{it}^{\top}\gamma + u_{it} \tag{8}$$

The term $p_i t$ models the different paces of development through country-specific time trends.

4 Main empirical analysis

The previous models prioritized simplicity and intuition over completeness. This section builds on models (6)-(8) and includes other wealth variables, macroeconomic and financial control variables, and breaks natural capital down into its components. In addition to the 10-year bond yields, which describes the overall level of the yield curve, we will also refer to the short-term, or 2-year bond

[12] In the Mankiw et al. (1992) framework, which estimates the linearized form of the exogenous technological growth $A_{it} = A_i^0 e^{gt}$, the within-transformation effectively removes the country-specific level of technology $\ln A_i^0$ but does not affect the exponential growth rate gt.

yields (see Figure 11). This allows us to think about the slope of the yield curve, which is often proxied by the difference between 10-year and 2-year yields. A positive slope is generally seen as an indicator for optimistic economic prospects.

4.1 Model

The full model specification used for the subsequent results reads

$$y_{it} = c_i + d_t + p_i t + X_{it}^\top \beta + W_{it}^\top \gamma + u_{it} \tag{9}$$

where the error term follows the dynamic factor structure

$$u_{it} = \lambda_i^\top F_t + e_{it} \qquad \text{with} \qquad F_t = AF_{t-1} + v_t \tag{10}$$

Here, c_i is the country fixed-effect, d_t denotes the time fixed-effects, $p_i t$ are the country-specific time trends, X_{it} are the wealth variables, W_{it} are macro-financial controls. We assume that the factors F_t follow a stationary, autoregressive process. Section 4.7 discusses the number of factors K and the rationale for our choice, $K = 2$. The disturbance e_{it} is $N(0, \sigma_i^2)$ and the innovation v_t is Gaussian with diagonal covariance matrix. Table 5 introduces an interaction $G_{it} \times X_{it}^\top \delta$ where the group variable G_{it} is a binary variable for the bond rating group.[13]

4.2 Estimation

In this section we discuss the various econometric challenges when estimating the effects of natural capital and its components. It discusses how these challenges are dealt with in the proposed framework (9)-(10), estimated with the IFE method.

The main concern is the unobserved confounding variable $develop_i$. This is a well-known issue in microeconometrics, such as when studying the relationship between schooling and earnings (Angrist et al., 1999). Similar to how the unobserved *ability* affects both sides of returns-to-schooling problems, the level of development also affects both bond yields and natural capital. The main results will therefore include a set of variables to control for observed confounding factors, X_{it}. However, this does not entirely resolve the omitted variable bias due to $develop_i$. For this purpose, we model country fixed-effects, c_i, which contain $develop_i$ among other time-invariant characteristics. Over the period of 10 years, the assumption of $develop_i$ being time-invariant appears justifiable.

Another source for confounding variables are country-specific time trends in bond yields, that would have led to falling rates irrespective of other variables. We introduced this notion as the pace of development in Section 3.6. The endogeneity problem arising from country-specific trends likely affects B-rated countries more, since A-rated bonds follow similar, global trends. We therefore introduce country-specific time trends, $p_i t$.

Aside from these cross-sectional concerns, we also have to pay careful attention to problems often encountered in long (dynamic) panels and multivariate time-series. The large T, small N

[13] Since the bond rating category has only minor changes over time, it is largely absorbed by the country fixed-effects. Hence, Table 5 does not include G_{it} by itself.

property of the data makes identification through time-variation feasible. However, the persistent and co-moving nature of bond yields induces serial correlation that cannot be fully explained by X_{it} or W_{it}. Not only could u_{it} be correlated with u_{it-1}, but it could also be correlated with u_{jt-1}. Section A.2 illustrates the severity of the thereby induced bias. Furthermore, global financial and economic conditions are not fully captured by X_{it} and affect both bond yields and macro-financial controls in X_{it}, such as GDP growth or inflation. Section 4.7 presents evidence for at least one latent factor in u_{it}, which is highly correlated with global bond indices and equity indices. Neglecting the possibility for unobserved common factors in u_{it} violates the strict exogeneity assumption of $\mathbb{E}[u_{it}|X_{is}, W_{it}, c_i] = 0$. The factor component $\lambda_i^\top F_t$ elegantly resolves the above problems. The latent factors in F_t allow for $K > 1$ unobserved global factors in u_{it}. This accounts for autocorrelation in the residuals and models any cross-sectional dependency between u_{it} and u_{jt-1} through the factor loadings λ_i and λ_j, which load on the latent factors in F_t. Different from country fixed-effects c_i, the term $\lambda_i^\top F_t$ models cross-country heterogeneities that vary over time.

The interactive fixed-effects (IFE) estimator (Bai, 2009; Bai et al., 2016; Moon et al., 2015, 2017) employed here belongs to a strand of literature that is concerned with inference under cross-sectional dependence and time-varying common factors (Eberhardt et al., 2011). An alternative approach to the IFE is the Common Correlated Effects estimator (Chudik et al., 2015; Pesaran, 2006; Pesaran et al., 2011). These types of models generalize two-way fixed effects and are also known as models with multi-factor error structure or linear factor models in panels. This class of models has been applied to estimate causal treatment effects that usually rely on difference-in-difference estimators or synthetic controls (Gobillon et al., 2016; Mäkelä, 2017; Xu, 2017). This approach has also been used in non-stationary panel models (Kapetanios et al., 2011), to identify structural breaks in panels (Li et al., 2016) or consistently estimate panel models with errors that are serially and spatially correlated (Bertoli et al., 2013).

Finally, it is worth emphasizing the predetermined nature of the wealth variables. While bond yields fluctuate on a monthly frequency, wealth variables are a function of resource rents, which are computed on a 5-year moving average, annual frequency (World Bank, 2018). It is therefore more probable for slow-moving wealth variables to steer long-term bond prices, than monthly bond fluctuations changing the accumulation of natural capital. A possible channel for reverse causality could stem from long-term bond trends affecting the growth of natural capital. While possible, the author deems this less of a concern since these long-term trends are already contained in the time fixed-effects d_t, common bond factor component $\lambda_i^\top F_t$ and the country-specific time trends $p_i t$.

4.3 Results

Table 3 shows the main results of (9)-(10) for the 10-year yields. In contrast to the simple IFE model (6), which only allows for $\lambda_i f_t$ with $K = 1$, the coefficient sign on total natural capital reverses in the full specification with $K = 2$ and other control variables. However, once we distinguish between non-renewables and renewables, it becomes clear that renewables have a predominantly negative effect which is offset by non-renewable subsoil assets. Countries that have become richer in renewable natural wealth between 2009-2019 have significantly lower borrowing costs, even after controlling for an array of macro-financial variables.

This effect is strongest for forest capital and to a lesser degree agricultural land. Table 4 shows the corresponding values for short-term, 2-year yields. Taking together, renewable forest and agricultural capital lowers the entire curve but also steepens it. Economically, this can be interpreted as a lowering of overall borrowing costs while also improving economic prospects in the short-run. The effect is different for protected areas, which carries a positive coefficient. While sharing the same sign with non-renewables, both effects should not be equated with each other. Table 4 shows that the effect of protected areas is insignificant in the short-run. In terms of coefficient magnitudes, the long-term effect outweighs the short-term effect, indicating an upwards tilting effect on the yield curve. In comparison, subsoil assets are significant for both 2-year and 10-year maturities and have a depressing effect on the yield curve slope. To give context to the positive coefficient on protected areas, it is worth mentioning that its value is based on opportunity cost calculations (World Bank, 2018). In other words, it is the value of foregone rents that could have otherwise been derived from agricultural production. This implies that growth in protected areas will have a stronger impact in countries that rely more on the agricultural sector. We will revisit this issue in Section 4.6. Albeit significant, it is important not to overemphasize this effect, since protected areas constitute less than 5% of overall natural capital (Table 2).

The following paragraphs suggest and discuss two possible economic explanations behind these findings.[14]

- **Worthwhile investment**
  Investments into natural wealth foster sustainable growth, improve the country's fundamentals and thereby decrease the default risk. Lower bond yields are the result of the improving the economic foundations.
- **Luxury investment**
  Growth in natural capital is the result of prosperity. Lower yields are a reflection of the higher income of the issuers. Only developed countries have the capacity to invest into non-productive natural capital.

To determine which explanation is most suitable, we turn to the underlying data sources of natural capital. Figure 7 indicates that agriculture and forests lower borrowing costs because they are worthwhile investments, while the effect of protected areas is more likely the result of a luxury investment.

4.4 Forests

Forest capital serves as a primary input for production through logging of trees, generates employment for more than 13 million people (IPBES, 2019) and is necessary for other ecological benefits such as improved air and water quality (Lange et al., 2018). For instance, non-timber forest capital reflects the value of watershed protection, hunting, fishing, along with other ecosystem services that are usually not accounted for, but are relevant for food production, biodiversity and human health (Lange et al., 2018). Tourism in forest-covered protected areas constitutes a major share of the 8 billion visits (FAO and UNEP, 2020).

[14] Theoretically, a third option is also possible, where (labelled) bond proceeds are directly invested into environmental projects. This explanation is likely to become more relevant as the number sovereign green bond issuances grows, but it is outside the scope of this study.

In addition to the size of the forests, the diversity of tree species is also worth mentioning, since five of the ten countries with the most tree species are in the B-rated category (FAO and UNEP, 2020). The FAO (2014) discusses the importance of forest genetic resources in developing economies and economies in transition in the context of their "actual or potential economic, environmental, scientific or societal value".

Given the direct productive capabilities of forests and their indirect socioeconomic benefits, investing into this renewable resource is an economically worthwhile decision. We see support for this in the underlying data. Figure 7a shows the average annual percentage increase in planted forest areas between 2009 and 2020. A planted forest is a "[f]orest predominantly composed of trees established through planting and/or deliberate seeding" (FAO, 2020) and is to be distinguished from natural regrowth. The fact that countries, where agriculture, forestry and fishing constitute a larger share of GDP value-added largely coincide with the countries with the most planted forest expansion, renders luxury investment explanation unlikely. This is further supported by Table 5, Appendix, which decomposes the negative coefficient by rating category. The same investment into forests lowers yields significantly more in B-rated countries.

Table 6, Appendix, shows disaggregated results where forest capital is divided into timber and non-timber forests. Interestingly, the latter type mainly drives the yield lowering effect of forests. Identifying whether this reflects tourism revenues based on non-timber forest capital or in fact captures the hard-to-quantify benefits of its external effects is left for future studies.

4.5 Agriculture

The agricultural sector in the broad sense is the largest employer in the world and faces a monumental task: Feeding 10 billion people in 2050 (FAO, 2018). Ensuring that agricultural land does not become a non-renewable resource due to land degradation is of paramount importance to the economy of a nation and the world.

This wealth category is divided into cropland, which represents the value of primary crops of cereals, fruits, vegetables for human consumption, and pastureland, which is mainly concerned with indigenous livestock production for meat, milk and other products (World Bank, 2018). The value of land is also partly derived from "water supply, soil fertility and pollination services" (Lange et al., 2018). FAOSTAT data shows that agricultural land area has been steadily growing for B-rated countries (annual growth rate of 0.14% or total growth rate of 1.32% between 2009–2018, excluding Italy and Spain) and shrinking for A-rated countries (annual growth rate of -0.15% or total growth rate of -1.29%). Given that agriculture, forestry and fishing constitute a larger share of GDP value-added in B-rated countries, this discrepancy is not entirely unexpected.

At the same time, both cropland and pastureland deteriorate the environment. The IPBES (2019) estimates that "[a]pproximately 25 per cent of the globe's greenhouse gas emissions come from land clearing, crop production and fertilization, with animal-based food contributing 75 per cent of that." Livestock has a disproportionately strong social and environmental impact compared to its economic relevance, as it is the main factor for deforestation and accounts for 18 percent of greenhouse gas emissions (Steinfeld et al., 2006). The FAO cites soil loss and degradation as threats to agriculture itself (FAO, 2018). IPBES (2019) estimates that 23 percent of the world's

Table 3: Long-term yields

The coefficients are estimated via the IFE approach for the model (9)-(10), that is $y_{it} = c_i + d_t + p_i t + X_{it}^\top \gamma + W_{it}^\top \beta + u_{it}$ with $u_{it} = \lambda_i^\top F_t + e_{it}$ and $F_t = AF_{t-1} + v_t$, where W_{it} are base-10 logarithm transformed wealth variables, X_{it} are macro-financial controls, c_i country fixed-effects and g_i country-specific time trends. The wealth coefficients can be interpreted as the percentage point change in the yield associated with a 1% increase in the wealth component.The long-term yields are represented by the 10-year yields (see Figure 11).

	Wealth components	Natural capital components				
Model name	*IFE.1*	*IFE.2*	*IFE.3*	*IFE.4*	*IFE.5*	*IFE.6*
Wealth variables						
Human capital	1.060***	0.611*	0.978***	0.858**	0.307	0.187
	(0.338)	(0.342)	(0.340)	(0.356)	(0.355)	(0.368)
Produced capital	3.821***	3.383***	3.211***	3.347***	3.845***	3.826***
	(0.282)	(0.303)	(0.293)	(0.409)	(0.303)	(0.401)
Natural capital	0.672**	.	.	.	.	.
	(0.285)					
Non-renewables	.	0.011**	0.009*	0.011**	0.010*	0.010*
		(0.006)	(0.005)	(0.005)	(0.006)	(0.005)
Renewables	.	-0.858***	.	.	.	.
		(0.283)				
Protected areas	.	.	0.329**	.	.	0.373**
			(0.156)			(0.172)
Agricultural land	.	.	.	-0.552	.	-0.657*
				(0.376)		(0.391)
Forests	.	.	.	.	-1.016***	-1.146***
					(0.145)	(0.174)
Macroeconomic and financial variables						
GDP growth% (lag=1)	0.003	0.003	0.003	0.003	0.003	0.003
CPI inflation (lag=1)	0.207***	0.202***	0.202***	0.202***	0.202***	0.197***
Debt/GDP	-0.003	-0.008***	-0.001	-0.004*	-0.016***	-0.013***
Reserves/GDP	-0.190	0.045	0.048	0.046	0.032	-0.005
Country fixed-effects c_i	Yes	Yes	Yes	Yes	Yes	Yes
Country time trends $p_i t$	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed-effects d_t	Yes	Yes	Yes	Yes	Yes	Yes
Number of factors	2	2	2	2	2	2
R-squared	0.420	0.407	0.398	0.398	0.440	0.430
F-statistic	19.1	18.0	17.3	17.4	20.7	19.5
Log-likelihood	-3,329.7	-3,329.5	-3,326.9	-3,331.0	-3,323.8	-3,314.4
Countries	37	37	37	37	37	37
Observations	4,440	4,440	4,440	4,440	4,440	4,440

Country-clustered standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

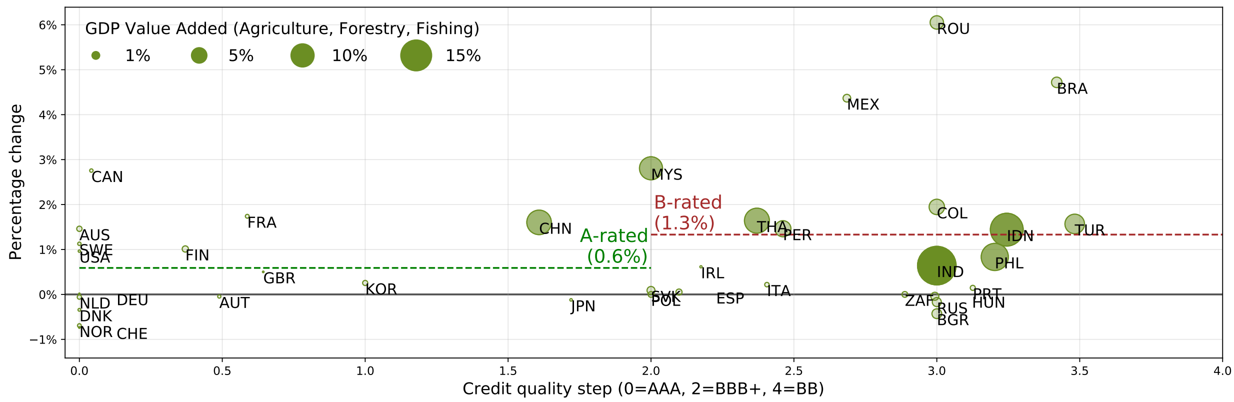
terrestrial area has already been impacted by land degradation. The disaggregated results in Table 6 reflect of this discrepancy. While cropland growth lowers borrowing costs significantly, pastureland capital raises costs significantly.

Looking at the underlying data, we find an interesting trend in the context of cropland capital. Figure 7b plots the average growth of area under organic agriculture (Willer et al., 2020), which is defined as "[...] a production system that sustains the health of soils, ecosystems, and people." (IFOAM, 2020). Almost all B-rated countries have invested into organic agriculture, which are also the countries in which agriculture, forestry and fishing constitute a large share of GDP value-added. The investment into sustainable agriculture is not only an economically-sensible investment on the macroeconomic level. Badgley et al. (2007) find that organic agriculture produces higher yields than conventional agriculture in developing countries and the opposite for developed economies. The worthwhile investment explanation therefore appears compelling.

Figure 7: Changes in renewable natural capital components

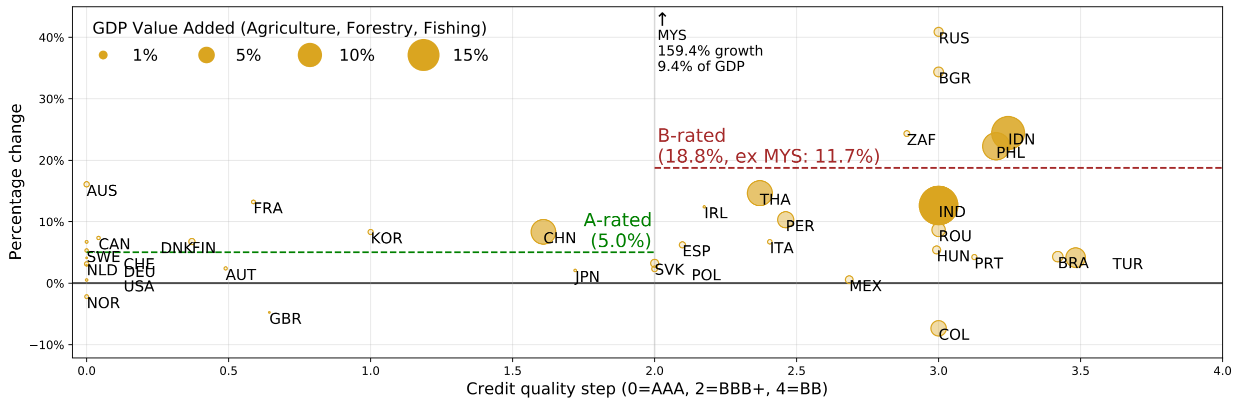
(a) Growth in planted forest area

Planted forests refers to “Forest predominantly composed of trees established through planting and/or deliberate seeding” (FAO, 2020). These values therefore do not include naturally regenerating forests. Percentages on the y-axis refer to average annual growth rates between 2009 and 2020, obtained from FAOSTAT. The size of the bubbles reflects the GDP value-added of agriculture, forestry and fishing.



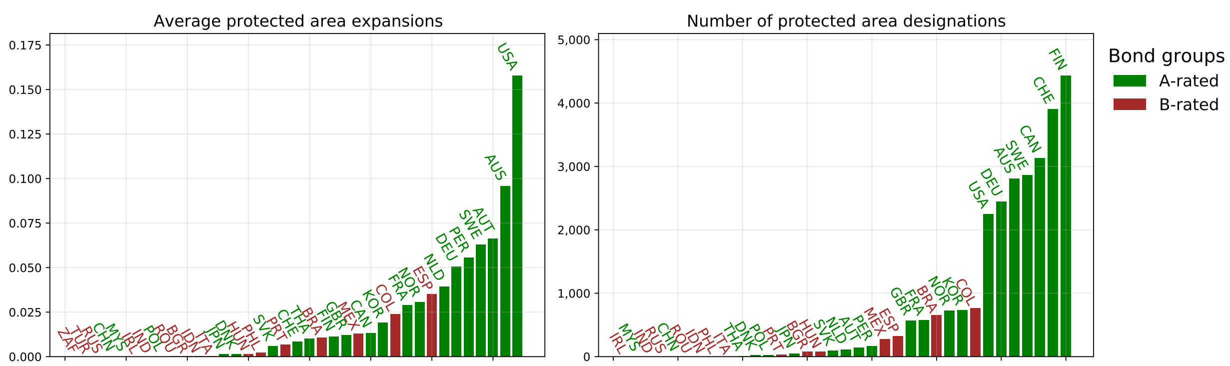
(b) Growth in area under organic agriculture

Organic agriculture refers to “area certified organic and/or in conversion to organic” (Willer et al., 2020). Percentages on the y-axis refer to average annual growth rates between 2009 and 2020, obtained from FAOSTAT. The size of the bubbles reflects the GDP value-added of agriculture, forestry and fishing.



(c) Growth in protected areas

The left panel shows the total area expansions under national and sub-national protection (as share of total country area). The right panel shows the number of new protected areas designated per country. Areas are included if they have an IUCN designation (I-VI) between 2009 and 2020. Marine protected areas are excluded.



4.6 Protected areas

The strong reliance on the agriculture, forestry and fishing for economic growth gives context to the negative coefficient estimates of forests and agriculture. Growth in these renewable resources is in the interest of the economic growth. The story is less clear-cut for protected areas, which account for wildlife reserves and ecosystem services, such as billions of dollars saved in drinking water treatment costs due to forests and wetlands, or revenues from international tourism (Dudley et al., 2010; World Bank, 2018). Biodiversity and the loss thereof is a core issue that has been gaining importance. The loss of pollinators is associated with a loss of global crop yield between US$235 and US$577 billion (IPBES, 2019). van Toor et al. (2020) estimate that investments worth EUR 510 billion by Dutch financial institutions are highly dependent on ecosystem services.

Table 3 presents evidence that higher borrowing costs may be related to expansion in protected areas. Earlier, we explained this finding through the opportunity cost motive, which underlies the valuation of protected areas (World Bank, 2018). This explanation finds further support in Table 5, which shows that borrowing costs mainly increase in B-rated countries and have no noteworthy effect in A-rated countries. At the same time, Figure 7c shows that areas under protection and conservation were predominantly designated in A-rated countries. Thus, even though A-rated countries experienced a much larger growth in protected areas, both in terms of area and number, it did not affect their borrowing costs. The opposite holds for B-rated issuers, which lends credibility to the opportunity costs of foregone agricultural rents. This suggests that protected areas are costly, non-productive investments that are unlikely undertaken because they are economically worthwhile. Thus, the luxury investment explanation seems more plausible.

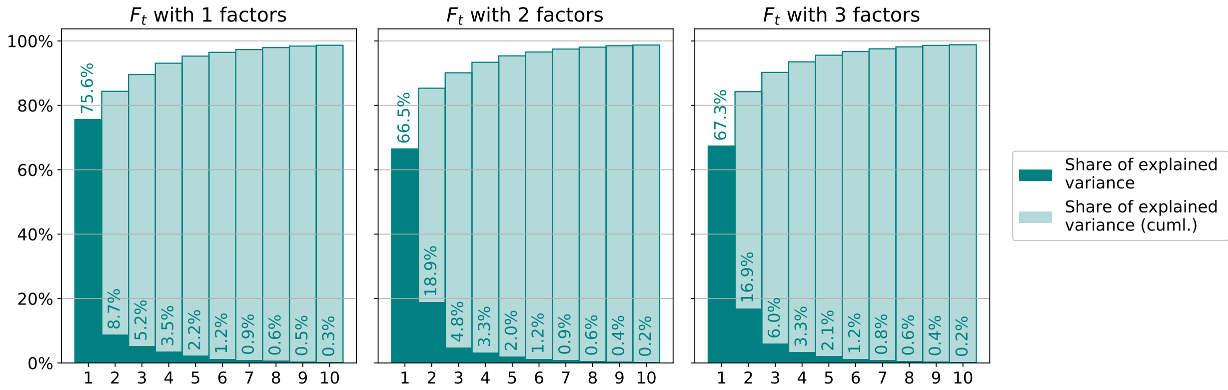
4.7 Latent factor analysis

The question of how many factors to choose for F_t can be answered in various ways. Unfortunately, the limited size of the cross-section $N = 37$ renders popular approaches infeasible. Information criteria in the spirit of Bai et al. (2002) proved inappropriate as they tended to select as many factors as there are observations, a problem described in Elliott et al. (2016). The eigenvalue-ratio test and growth-ratio test (Ahn et al., 2013) indicate $K = 1$, as shown in Figure 8. However, Figure 8 also reveals that a second factor may be relevant as well. We turn to economic arguments to decide between $K = 1$ and $K = 2$.

We follow Stock et al. (2005) and correlate the first and second factors of a specification assuming $K = 2$ with observed macro-financial variables in Figure 9. Figure 9a shows that the first latent factor is most highly correlated with the J.P. Morgan Global Bond Index for the European Monetary Union (GBI-EMU) with correlation coefficient $r = 98.2\%$, the MSCI World Index with $r = 89.2\%$, and the J.P. Morgan Emerging Market Bond Index family (EMBI, EMBI-div, EMBI+) with $r \approx 87.3\%$. The relevance of the GBI-EMU is sensible since our sample includes 10 Eurozone countries and eight additional European Economic Area members. Figure 9b shows that the second factor is most correlated with the J.P. Morgan Global Bond Index for the Emerging Markets (GBI-EM), which tracks local currency government bonds in emerging markets. Since the composition of the B-rated countries contains several emerging market economies, it makes sense to include this factor as well. This gives us confidence that $K = 2$ factors are necessary to isolate the relevant global bond dynamics.

Figure 8: Shares of explained variance by latent factors

Each panel depicts the share of variance explained by fitting model (9)-(10) with $K = 1, 2, 3$ factors respectively.



This conclusion is further supported by statistical arguments. The first latent factor accounts for two-thirds of residual variance and has an AR(1) coefficient of $\hat{\rho} = 0.989^{***}$ which is comparable with the average autocorrelation coefficient for bond yields. The second factor accounts for more than half of the remaining residual variance and has an AR(1) coefficient of $\hat{\rho} = 0.965^{***}$. These characteristics emphasize the necessity of the employed IFE method. The change in coefficients between the FE estimates in (3) and the IFE estimates (6), together with the simulation study in Appendix, Section A.2, give an idea of how strong the bias of a misspecified model is. We proceed with $K = 2$.

5 Limitations

5.1 Lack of biodiversity

For the sake of consistent, global coverage, the wealth data made the deliberate decision to calculate aggregated numbers on the country level. This prevents decompositions beyond what Table 6 presents. One interesting component that affects all renewables is biodiversity. The wealth of species diversity and ecosystem services is currently only accounted for indirectly. These are restricted to terrestrial areas and do not include the blue economy. Loss of biodiversity and collapse of the ecosystem is ranked as top five global risks (WEF, 2020a). Regulators, pension funds and banks are paying more and more attention to the effects on the financial sector (Schellekens et al., 2019; van Toor et al., 2020).

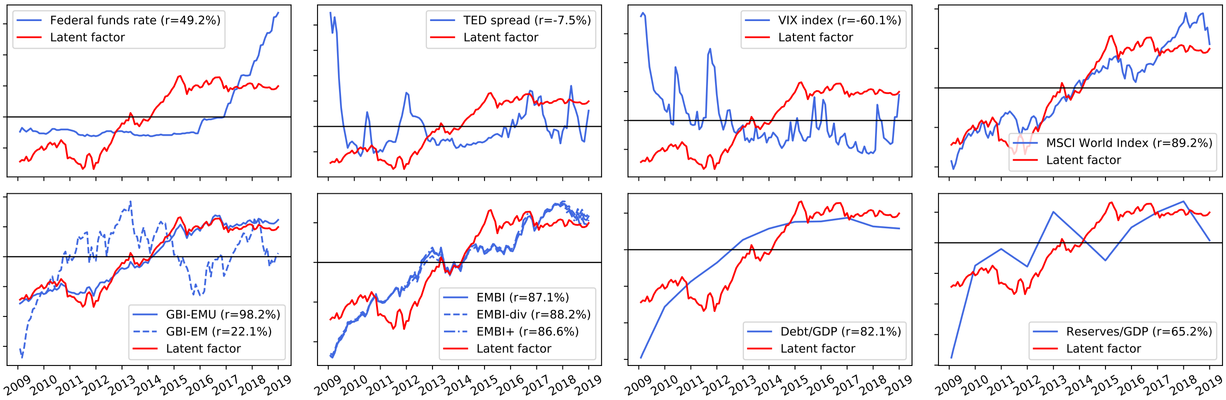
5.2 Low data frequency

A further limitation imposed by the wealth data is its annual frequency. Seasonal effects and other business cycle dynamics that possibly affect bond prices cannot be addressed. The immediate impacts of droughts and floods are not discernible. One promising possibility to address this issue is to include high-frequency and objective geospatial data, such as remote-sensing satellite data or weather station measurements (WWF et al., 2020). This type of data, which has the added benefit of being exogenous by nature, would shed light onto short-term dynamics and enable causal inferences. The statistical framework used in this analysis could be easily extended

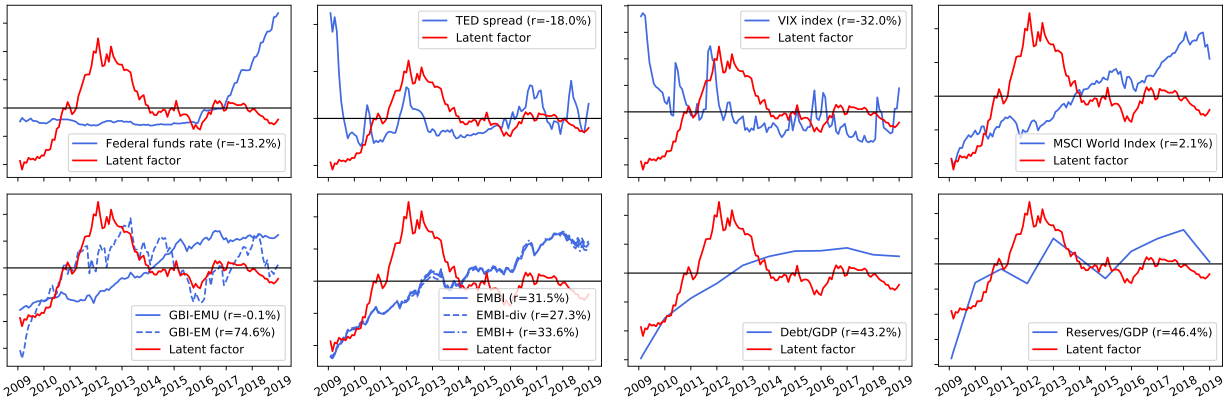
Figure 9: Latent bond factors and observed global factors

Each panel compares the largest two extracted latent factors F_t from (5) with observed global factors. All variables shown are standardized to facilitate interpretation.

(a) First latent factors



(b) Second latent factor



to incorporate such data. However, remote-sensing data requires considerable geospatial pre-processing, domain-specific expertise as well as significant computational resources.

5.3 Lack of regional focus

At the outset of this study, we selected the largest possible set of countries to identify general relationships between natural capital and government yields. This meant, however, that country- or region-specific characteristics had to be abstracted from for the sake of generality. There is little doubt that narrowing the scope to a region, e.g. Latin America and Caribbean or Southeast Asia, would allow us to account for relevant variables such as local crop types, resource dependencies or the effect of the El Niño–Southern Oscillation. Comparison of such regional studies with this extended set of countries would produce interesting insights and lead to relevant takeaways for local governments and policy makers.

6 Summary

This paper has explored whether natural capital is priced in sovereign bonds yields. The data suggests two answers. Looking across countries, wealth in natural capital seems to raise the price of government debt. This is consistent with the long-term view of economic growth and capital accumulation. However, when looking within countries, which compares the same country with itself at an earlier point in time, the opposite emerges. As a country's renewable natural wealth grew, its borrowing costs tended to fall. This is the short-run view, where natural capital can grow and sovereign default risks are relevant.

While both approaches seems to be viable, the long-term view is affected by the *ingrained income bias* (see Figure 6). This bias refers to the problem of comparing countries at different stages of development and levels of income. High income countries will have transitioned into an economic system where growth is less reliant on natural capital. Hence, explanations for higher yields due to natural wealth, such as the resource curse or inflation expectations, will more likely affect developing economies. This presents not only an econometric problem, but the long-run view also leads to a disheartening conclusion. Since the level of income is the result of decades or centuries of human history, there is nothing a country can accomplish in the short-run to affect it. This bias also affects sovereign ESG scores (see Box 1).

Thus, there are few novel insights to be gained from cross-country comparisons, because the level of development will dominate and permeate any findings. Adopting the within-country view resolves this problem. By bringing countries onto a "level playing field", cross-country differences, such as resource endowments or levels of income, are taken out of the picture. Instead, the relationship between natural capital and borrowing costs is estimated using changes of time, within each country. This means that recent efforts to foster renewable natural capital, such as afforestation trends or expansion in organic agriculture, had room to impact short-run borrowing costs of governments.

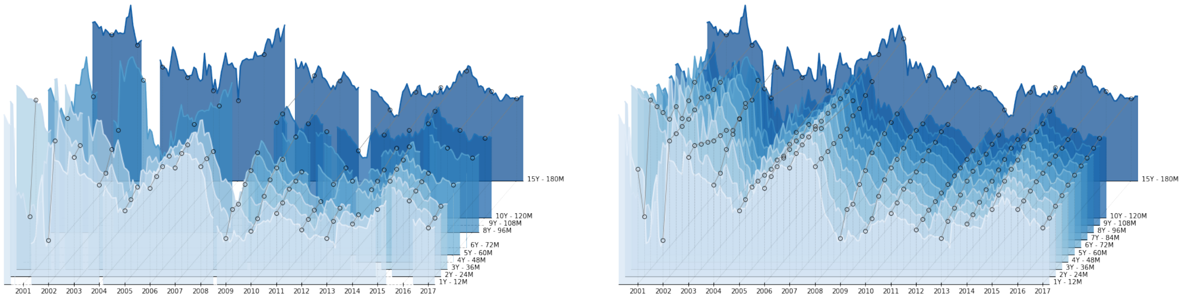
After introducing the appropriate statistical framework, we found a significant, negative association between renewable natural capital growth and government debt costs. Expansions in protected areas, agricultural land and forest capital affected bond yields for two possible reasons: First, because they are worthwhile investments that improve country fundamentals and thereby lower borrowing costs. Second, low bond yields are in fact a reflection of accumulated wealth and therefore the capacity to invest into natural capital. Looking at the underlying data, we found that the negative effects of forests and agricultural land are more likely explained by the worthwhile investment narrative. Countries invest into these resources simply because they are more reliant on natural capital for economic growth. Fostering this type of renewables is an economically worthwhile investment. The effects of protected areas, which expanded the most in A-rated countries, are better explained by the luxury investment narrative. Designating areas under conservation and protection is costly and incurs opportunity costs in terms of foregone agricultural rents. High income countries can afford to expand protected areas as they have the fiscal capabilities and rely more on produced and human capital for growth.

In sum, this paper found evidence that government borrowing costs reflect a country's recent growth in natural capital. These findings emerged after accounting for various issues, such as the ingrained income bias or unobserved common bond factors, as well as controlling for relevant macro-financial variables. The empirical model, however, does not reveal the economic mechanism behind this finding. A direct channel seems unlikely, as it would imply that markets actively prioritize natural capital considerations in their bond purchase decisions. What seems more plausible is that natural wealth is accounted for indirectly through its effect on the wider economy. We found support for this hypothesis in the data. Borrowing costs of B-rated issuers, whose economies are more reliant on natural capital, were also affected more significantly by renewable capital growth. Formulating and identifying the exact channel is left for future research.

A Appendix

Figure 10: Yield curve reconstruction for the case of Colombia

We illustrate the result of reconstructing the entire yield curve based on available bond data for the case of Colombia. To fill in the gaps, we use cubic spline interpolation, as suggested by Waggoner (1997). The x-axis denotes the time, the y-axis shows the yield and the z-axis shows the maturities/tenors.



(a) Raw data **(b) Reconstructed data**

Figure 11: Level and slope of the yield curve

The 10-year bond yield is often used to represent the overall level of the yield curve and the long-term yields. The slope characterizes the economic prospectus, where an upwards sloping curve is generally seen as a positive indicator while a downwards sloping curve has been a reliable predictor for recessions.

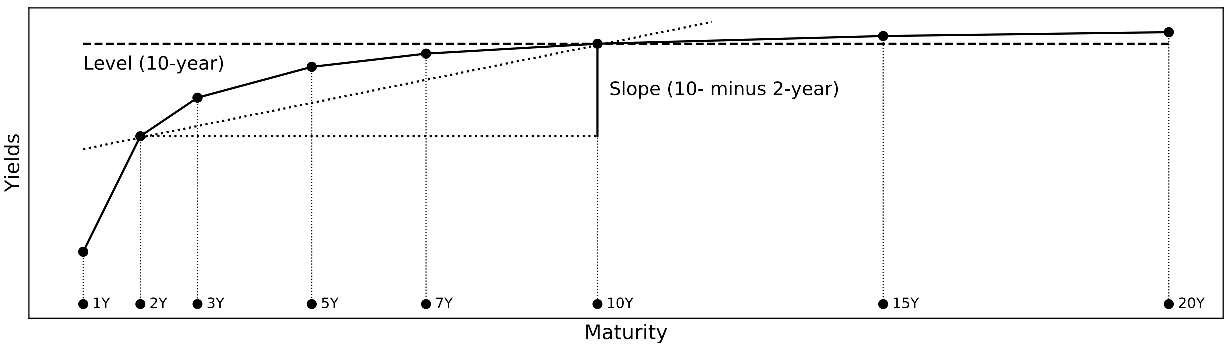
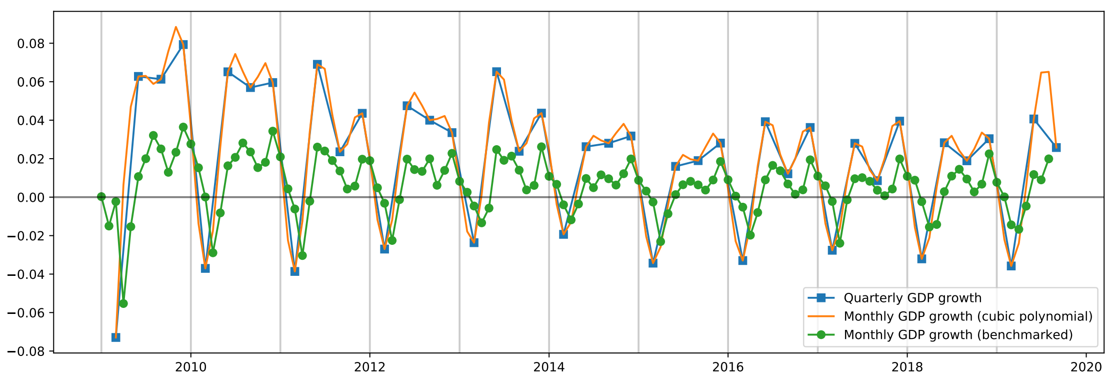


Figure 12: Example for GDP growth benchmarking

We illustrate the output of the Denton (1971)'s benchmarking method. It calculates the monthly GDP growth (green line) based on quarterly figures (blue line) by benchmarking it against monthly industrial output data. This ensures that the growth rates of the benchmarked output are consistent with the quarterly figures. This is not the case for cubic polynomial interpolating (orange line), which can also be unstable (e.g. end of the period). We employ the benchmarked solution in our analysis.



A.1 Additional results

Table 4: Short-term yields

The coefficients are estimated via the IFE approach for the model (9)-(10), that is $y_{it} = c_i + d_t + p_i t + X_{it}^\top \gamma + W_{it}^\top \beta + u_{it}$ with $u_{it} = \lambda_i^\top F_t + e_{it}$ and $F_t = AF_{t-1} + v_t$, where W_{it} are base-10 logarithm transformed wealth variables, X_{it} are macro-financial controls, c_i country fixed-effects and g_i country-specific time trends. The wealth coefficients can be interpreted as the percentage point change in the yield associated with a 1% increase in the wealth component. The short-term yields are represented by the 2-year yields (see Figure 11).

	Wealth components	Natural capital components				
Model name	*IFE.7*	*IFE.8*	*IFE.9*	*IFE.10*	*IFE.11*	*IFE.12*
Wealth variables						
Human capital	1.992***	1.664***	2.108***	2.077***	1.392***	1.343***
	(0.390)	(0.404)	(0.379)	(0.405)	(0.394)	(0.415)
Produced capital	5.273***	5.059***	5.430***	5.305***	6.525***	6.151***
	(0.377)	(0.409)	(0.372)	(0.557)	(0.356)	(0.557)
Natural capital	-0.436	.	.	.	.	.
	(0.390)					
Non-renewables	.	0.021***	0.020***	0.020***	0.020***	0.020***
		(0.008)	(0.007)	(0.008)	(0.008)	(0.007)
Renewables	.	-1.769***	.	.	.	.
		(0.401)				
Protected areas	.	.	0.050	.	.	0.107
			(0.178)			(0.185)
Agricultural land	.	.	.	-0.334	.	-0.437
				(0.664)		(0.672)
Forests	.	.	.	.	-1.751***	-1.775***
					(0.181)	(0.221)
Macroeconomic and financial variables						
GDP growth% (lag=1)	0.010**	0.010**	0.010**	0.010**	0.009**	0.009**
CPI inflation (lag=1)	0.289***	0.283***	0.290***	0.288***	0.288***	0.284***
Debt/GDP	-0.024***	-0.027***	-0.022***	-0.022***	-0.039***	-0.038***
Reserves/GDP	0.545***	0.570**	0.719***	0.679***	0.855***	0.755***
Country fixed-effects c_i	Yes	Yes	Yes	Yes	Yes	Yes
Country time trends $p_i t$	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed-effects d_t	Yes	Yes	Yes	Yes	Yes	Yes
Number of factors	2	2	2	2	2	2
R-squared	0.440	0.424	0.445	0.433	0.517	0.496
F-statistic	20.7	19.3	21.0	20.1	28.1	25.5
Log-likelihood	-4,592.4	-4,583.1	-4,591.4	-4,591.3	-4,575.9	-4,575.3
Countries	37	37	37	37	37	37
Observations	4,440	4,440	4,440	4,440	4,440	4,440

Country-clustered standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Table 5: Long-term yields and bond rating categories

The coefficients are estimated via the IFE approach for the model (9)-(10), that is $y_{it} = c_i + d_t + p_i t + X_{it}^\top \gamma + W_{it}^\top \beta + bond_i \times W_{it}^\top \delta + u_{it}$ with $u_{it} = \lambda_i^\top F_t + e_{it}$ and $F_t = AF_{t-1} + v_t$, where W_{it} are base-10 logarithm transformed wealth variables, X_{it} are macro-financial controls, c_i country fixed-effects and g_i country-specific time trends. The long-term yields are represented by the 10-year yields (see Figure 11). The wealth coefficients can be interpreted as the percentage point change in the yield associated with a 1% increase in the wealth component. The rating groups $bond_i$ are based on Table 1 where AAA to A- are A-rated and BBB+ to BB- are B-rated.

	Wealth components	Natural capital components				
Model name	*IFE.13*	*IFE.14*	*IFE.15*	*IFE.16*	*IFE.17*	*IFE.18*
Wealth variables						
Human capital	1.019***	1.051***	1.262***	1.066***	0.748**	0.380
	(0.337)	(0.329)	(0.335)	(0.329)	(0.361)	(0.319)
Produced capital	3.445***	3.390***	3.161***	2.899***	3.887***	3.699***
	(0.325)	(0.437)	(0.288)	(0.465)	(0.337)	(0.436)
Natural capital	0.588**	.	.	.	.	.
	(0.277)					
× Bond rating=B	-0.712	.	.	.	.	.
	(1.154)					
Non-renewables	.	0.014**	0.013**	0.019***	0.012**	0.022***
		(0.005)	(0.005)	(0.005)	(0.006)	(0.005)
× Bond rating=B	.	0.056	0.258	-0.128	0.243	-0.150
		(0.262)	(0.209)	(0.277)	(0.224)	(0.240)
Renewables	.	0.010	.	.	.	.
		(0.211)				
× Bond rating=B	.	-3.981***	.	.	.	.
		(1.050)				
Protected areas	.	.	-0.058	.	.	-0.142
			(0.089)			(0.115)
× Bond rating=B	.	.	1.409***	.	.	1.718***
			(0.354)			(0.405)
Agricultural land	.	.	.	1.625***	.	0.807***
				(0.282)		(0.272)
× Bond rating=B	.	.	.	-5.501***	.	-5.363***
				(0.806)		(0.688)
Forests	.	.	.	.	-0.740***	-0.384***
					(0.120)	(0.103)
× Bond rating=B	.	.	.	.	-1.958***	-1.660***
					(0.544)	(0.437)
Macroeconomic and financial variables						
GDP growth% (lag=1)	0.003	0.003	0.003	0.003	0.003	0.003
CPI inflation (lag=1)	0.205***	0.194***	0.197***	0.187***	0.195***	0.183***
Debt/GDP	-0.003	-0.004	0.006*	-0.000	-0.011***	-0.003
Reserves/GDP	-0.200	0.044	0.538***	0.277	0.153	0.727***
Country fixed-effects c_i	Yes	Yes	Yes	Yes	Yes	Yes
Country time trends $p_i t$	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed-effects d_t	Yes	Yes	Yes	Yes	Yes	Yes
Number of factors	2	2	2	2	2	2
R-squared	0.404	0.446	0.431	0.472	0.464	0.473
F-statistic	17.8	20.8	19.6	23.1	22.5	22.6
Log-likelihood	-3,329.8	-3,306.3	-3,288.7	-3,287.7	-3,307.6	-3,233.2
Countries	37	37	37	37	37	37
Observations	4,440	4,440	4,440	4,440	4,440	4,440

Country-clustered standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Table 6: Long-term yields and natural capital components

The coefficients are estimated via the IFE approach for the model (9)-(10), that is $y_{it} = c_i + d_t + p_i t + X_{it}^\top \gamma + W_{it}^\top \beta + u_{it}$ with $u_{it} = \lambda_i^\top F_t + e_{it}$ and $F_t = AF_{t-1} + v_t$, where W_{it} are base-10 logarithm transformed wealth variables, X_{it} are macro-financial controls, c_i country fixed-effects and g_i country-specific time trends. The long-term yields are represented by the 10-year yields (see Figure 11). The wealth coefficients can be interpreted as the percentage point change in the yield associated with a 1% increase in the wealth component. This table is an extension of Table 9. Cropland and pastureland constitute agricultural land, timber and non-timber forests constitute forests.

	Natural capital components					
Model name	*IFE.19*	*IFE.20*	*IFE.21*	*IFE.22*	*IFE.23*	*IFE.24*
Wealth variables						
Human capital	0.743**	1.131***	0.896**	0.925***	0.265	0.263
	(0.355)	(0.342)	(0.350)	(0.352)	(0.351)	(0.359)
Produced capital	3.441***	2.457***	2.754***	3.440***	4.035***	4.254***
	(0.403)	(0.289)	(0.370)	(0.321)	(0.300)	(0.309)
Non-renewables	0.012**	0.008	0.009*	0.008	0.009	0.006
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Cropland	-0.799***	.	-1.127***	.	.	.
	(0.284)		(0.290)			
Pastureland	.	1.344***	1.567***	.	.	.
		(0.358)	(0.355)			
Forests (timber)	.	.	.	0.273	.	0.318**
				(0.167)		(0.159)
Forests (non-timber)	.	.	.	.	-0.988***	-1.000***
					(0.142)	(0.140)
Macroeconomic and financial variables						
GDP growth% (lag=1)	0.003	0.003	0.003	0.003	0.003	0.003
CPI inflation (lag=1)	0.202***	0.198***	0.197***	0.205***	0.204***	0.206***
Debt/GDP	-0.003	-0.001	0.001	-0.004	-0.016***	-0.016***
Reserves/GDP	0.045	0.122	0.095	0.118	0.010	0.061
Country fixed-effects c_i	Yes	Yes	Yes	Yes	Yes	Yes
Country time trends $p_i t$	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed-effects d_t	Yes	Yes	Yes	Yes	Yes	Yes
Number of factors	2	2	2	2	2	2
R-squared	0.396	0.409	0.407	0.405	0.445	0.453
F-statistic	17.2	18.2	17.9	17.9	21.0	21.6
Log-likelihood	-3,327.6	-3,319.6	-3,309.6	-3,331.4	-3,324.0	-3,322.5
Countries	37	37	37	37	37	37
Observations	4,440	4,440	4,440	4,440	4,440	4,440

Country-clustered standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Table 7: Long-term yields without country-specific time trends

The coefficients are estimated via the IFE approach for the model (7) and error process (10), that is $y_{it} = c_i + d_t + X_{it}^{\top}\gamma + W_{it}^{\top}\beta + u_{it}$ with $u_{it} = \lambda_i^{\top}F_t + e_{it}$ and $F_t = AF_{t-1} + v_t$, where W_{it} are base-10 logarithm transformed wealth variables, X_{it} are macro-financial controls, c_i country fixed-effects and g_i country-specific time trends. The wealth coefficients can be interpreted as the percentage point change in the yield associated with a 1% increase in the wealth component. The long-term yields are represented by the 10-year yields (see Figure 11).

	Wealth components	Natural capital components				
Model name	*IFE.25*	*IFE.26*	*IFE.27*	*IFE.28*	*IFE.29*	*IFE.30*
Wealth variables						
Human capital	1.018***	0.567*	0.936***	0.816**	0.296	0.172
	(0.329)	(0.335)	(0.334)	(0.348)	(0.345)	(0.361)
Produced capital	3.882***	3.411***	3.284***	3.385***	3.904***	3.862***
	(0.268)	(0.289)	(0.275)	(0.396)	(0.289)	(0.389)
Natural capital	0.650**	.	.	.	.	.
	(0.265)					
Non-renewables	.	0.011*	0.008	0.010*	0.010*	0.009*
		(0.006)	(0.005)	(0.005)	(0.006)	(0.005)
Renewables	.	-0.908***	.	.	.	.
		(0.271)				
Protected areas	.	.	0.308**	.	.	0.371**
			(0.148)			(0.168)
Agricultural land	.	.	.	-0.580	.	-0.662*
				(0.371)		(0.389)
Forests	.	.	.	.	-1.029***	-1.165***
					(0.137)	(0.168)
Macroeconomic and financial variables						
GDP growth% (lag=1)	0.003	0.003	0.003	0.003	0.003	0.003
CPI inflation (lag=1)	0.207***	0.203***	0.203***	0.203***	0.203***	0.198***
Debt/GDP	-0.004	-0.009***	-0.003	-0.006**	-0.016***	-0.014***
Reserves/GDP	-0.244	0.008	-0.029	-0.013	0.021	-0.019
Country fixed-effects c_i	Yes	Yes	Yes	Yes	Yes	Yes
Country time trends $p_i t$	No	No	No	No	No	No
Time fixed-effects d_t	Yes	Yes	Yes	Yes	Yes	Yes
Number of factors	2	2	2	2	2	2
R-squared	0.454	0.411	0.425	0.406	0.444	0.433
F-statistic	28.4	23.7	25.1	23.3	27.2	25.5
Log-likelihood	-3,331.4	-3,331.5	-3,329.1	-3,333.1	-3,325.4	-3,316.1
Countries	37	37	37	37	37	37
Observations	4,440	4,440	4,440	4,440	4,440	4,440

Country-clustered standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Table 8: Long-term yields without time fixed-effects

The coefficients are estimated via the IFE approach for the model (8) and error process (10), that is $y_{it} = c_i + p_i t + X_{it}^{\top}\gamma + W_{it}^{\top}\beta + u_{it}$ with $u_{it} = \lambda_i^{\top} F_t + e_{it}$ and $F_t = AF_{t-1} + v_t$, where W_{it} are base-10 logarithm transformed wealth variables, X_{it} are macro-financial controls, c_i country fixed-effects and g_i country-specific time trends. The wealth coefficients can be interpreted as the percentage point change in the yield associated with a 1% increase in the wealth component. The long-term yields are represented by the 10-year yields (see Figure 11).

	Wealth components	Natural capital components				
Model name	*IFE.31*	*IFE.32*	*IFE.33*	*IFE.34*	*IFE.35*	*IFE.36*
Wealth variables						
Human capital	1.060***	0.611*	0.978***	0.858**	0.307	0.187
	(0.338)	(0.342)	(0.340)	(0.356)	(0.355)	(0.368)
Produced capital	3.821***	3.383***	3.211***	3.347***	3.845***	3.826***
	(0.282)	(0.303)	(0.293)	(0.409)	(0.303)	(0.401)
Natural capital	0.672**	.	.	.	.	.
	(0.285)					
Non-renewables	.	0.011**	0.009*	0.011**	0.010*	0.010*
		(0.006)	(0.005)	(0.005)	(0.006)	(0.005)
Renewables	.	-0.858***	.	.	.	.
		(0.283)				
Protected areas	.	.	0.329**	.	.	0.373**
			(0.156)			(0.172)
Agricultural land	.	.	.	-0.552	.	-0.657*
				(0.376)		(0.391)
Forests	.	.	.	.	-1.016***	-1.146***
					(0.145)	(0.174)
Macroeconomic and financial variables						
GDP growth% (lag=1)	0.003	0.003	0.003	0.003	0.003	0.003
CPI inflation (lag=1)	0.207***	0.202***	0.202***	0.202***	0.202***	0.197***
Debt/GDP	-0.003	-0.008***	-0.001	-0.004*	-0.016***	-0.013***
Reserves/GDP	-0.190	0.045	0.048	0.046	0.032	-0.005
Country fixed-effects c_i	Yes	Yes	Yes	Yes	Yes	Yes
Country time trends $p_i t$	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed-effects d_t	No	No	No	No	No	No
Number of factors	2	2	2	2	2	2
R-squared	0.420	0.407	0.398	0.398	0.440	0.430
F-statistic	19.1	18.0	17.3	17.4	20.7	19.5
Log-likelihood	-3,329.7	-3,329.5	-3,326.9	-3,331.0	-3,323.8	-3,314.4
Countries	37	37	37	37	37	37
Observations	4,440	4,440	4,440	4,440	4,440	4,440

Country-clustered standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

Table 9: Long-term yields (between view)

The coefficients are estimated via a between-estimator for the model (1) with additional control variables. The long-term yields are represented by the 10-year yields (see Figure 11). Wealth variables are transformed with the base-10 logarithm. The wealth coefficients can be interpreted as the percentage point change in the average yield associated with a 1% increase in the average wealth component. These results are purely descriptive, due to the ingrained income bias described in Section 3.2.

	Wealth components	Natural capital components				
Model name	*BE.1*	*BE.2*	*BE.3*	*BE.4*	*BE.5*	*BE.6*
Wealth variables						
Human capital	1.541**	1.603**	1.556**	1.557**	1.708***	1.374*
	(0.598)	(0.619)	(0.604)	(0.752)	(0.565)	(0.790)
Produced capital	-1.659***	-1.632**	-1.574**	-1.567**	-1.740***	-1.630**
	(0.555)	(0.600)	(0.596)	(0.615)	(0.601)	(0.644)
Natural capital	0.382	.	.	.	.	.
	(0.325)					
Non-renewables	.	0.039	0.010	0.054	0.032	0.007
		(0.095)	(0.102)	(0.091)	(0.092)	(0.105)
Renewables	.	0.252	.	.	.	.
		(0.365)				
Protected areas	.	.	0.220	.	.	0.105
			(0.219)			(0.280)
Agricultural land	.	.	.	0.186	.	0.215
				(0.428)		(0.436)
Forests	.	.	.	.	0.257	0.202
					(0.232)	(0.299)
Macroeconomic and financial variables						
GDP growth% (lag=1)	-2.616***	-2.727***	-2.464**	-2.767**	-2.535**	-2.706**
CPI inflation (lag=1)	7.691***	7.994***	8.876***	7.834***	8.219***	8.075***
Debt/GDP	-0.005	-0.006	-0.006	-0.007	-0.006	-0.006
Reserves/GDP	-0.954	-0.578	-0.629	-0.559	-0.687	-0.815
Financial market depth	-1.404	-1.429	-1.059	-1.359	-1.319	-1.133
Bond grade (A-rated=1)	-3.551***	-3.558***	-3.265***	-3.478***	-3.594***	-3.288***
Constant	-0.543	-0.467	0.728	0.602	-0.416	0.056
R-squared	0.862	0.860	0.863	0.859	0.864	0.867
F-statistic	18.8	16.0	16.4	15.8	16.6	13.0
Log-likelihood	-50.0	-50.3	-49.9	-50.5	-49.8	-49.4
Countries	37	37	37	37	37	37
Observations	37	37	37	37	37	37

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

A.2 Monte Carlo study

Setup In this simulation study we illustrate what problems arise when latent common factors are not properly accounted for. We follow the structure of Bai (2009) but differ in that we allow the factors to be autocorrelated. We then show how the interactive fixed-effects (IFE) approach resolves this problem, even with dynamic factors. The data-generating process reads as follows,

$$y_{it} = \beta_0 + X_{it}\beta_1 + u_{it} \tag{11}$$

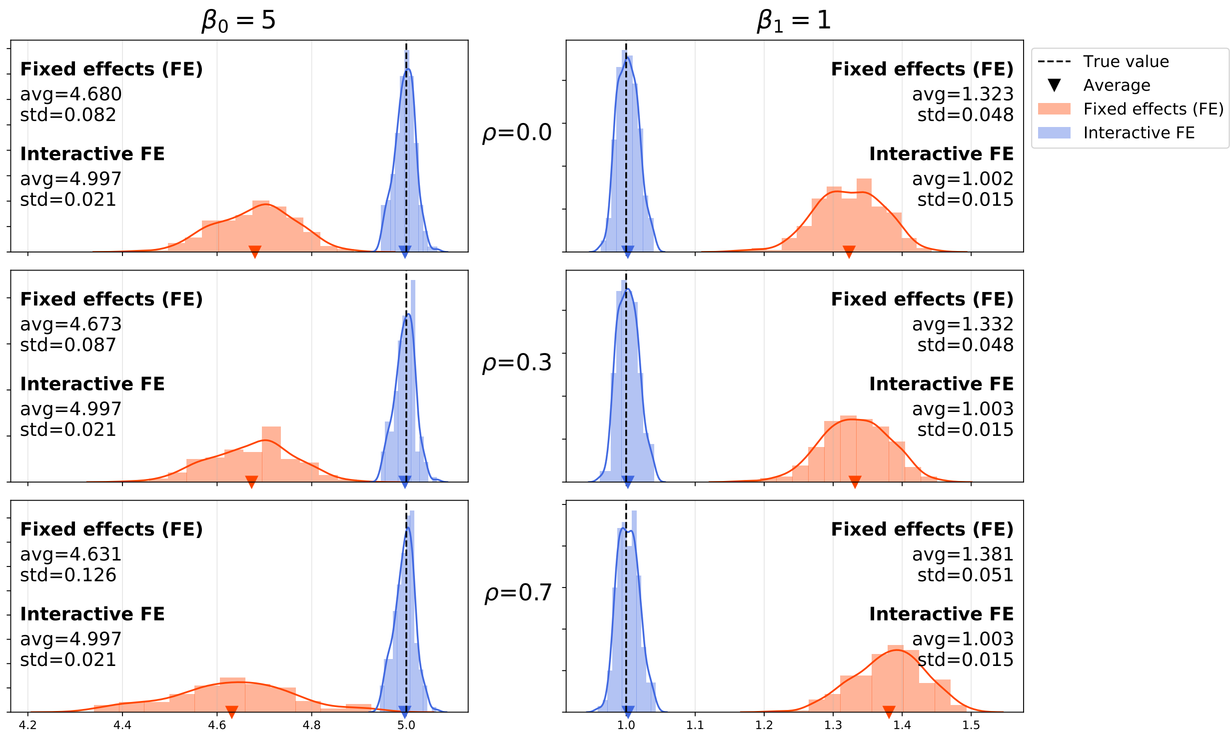
$$X_{it} = \mu + \lambda_i f_t + \lambda_i + f_t + w_{it} \tag{12}$$

The true parameters are $\beta_0 = 5, \beta_1 = 1$. The disturbances contain a latent factor, $u_{it} = \lambda_i f_t + e_{it}$ with randomly drawn λ_i and an autoregressive latent factor process $f_t = \rho f_{t-1} + v_{it}$. The innovations e_{it}, v_{it} are sampled from $N(0, 1)$. We examine three values of $\rho \in \{0.0, 0.3, 0.7\}$. The regressor X_{it} is constructed to induce an endogeneity problem through the common factor, such that $\mathbb{E}[u_{it}|X_{it}] \neq 0$. The disturbances w_{it} are sampled from $N(0, 1)$ and $\mu = 1$.

Results We simulate (11) and (12) 1,000 times and use a conventional fixed-effects model (FE) and the interactive fixed-effects (IFE) approach to estimate $\hat{\beta}_0, \hat{\beta}_1$. The results are shown in Figure 13. As expected, the FE estimators (red) are heavily affected by an omitted variable bias due to the induced endogeneity. This mirrors the case where global common factors, such as the global economy or the Eurozone crises, affect both the bond prices and regressors, such as GDP growth or debt-to-GDP ratios. Note that with increasing autocorrelation in the factors, the FE residuals suffer from serial correlation, leading to increasingly less efficient estimators. The interactive fixed-effects approach (blue) estimates the latent factor which resolves both the endogeneity and serial correlation problems. The estimates are unbiased and more efficient.

Figure 13: Interactive fixed-effects (IFE) vs. fixed-effects (FE) estimator

The two kernel densities show the distribution of estimated coefficients β_0, β_1 based on 1,000 simulations. The red density shows the coefficients from a traditional FE estimator while the blue density depicts the IFE estimates. We observe that the bias and inefficiency of the FE estimates increases, the stronger the unobserved factor f_t is autocorrelated. The IFE remains unbiased and efficient.



References

Abrahams, M., Adrian, T., Crump, R. K., Moench, E., & Yu, R. (2016). Decomposing real and nominal yield curves. *Journal of Monetary Economics*, *84*, 182–200.

Ahn, S. C., & Horenstein, A. R. (2013). Eigenvalue ratio test for the number of factors. *Econometrica*, *81*(3), 1203–1227.

Amstad, M., Packer, F., & Shek, J. (2020). Does sovereign risk in local and foreign currency differ? *Journal of International Money and Finance*, *101*, 102099.

Angrist, J. D., & Krueger, A. B. (1999). Empirical strategies in labor economics. *Handbook of labor economics* (pp. 1277–1366). Elsevier.

Badgley, C., Moghtader, J., Quintero, E., Zakem, E., Chappell, M. J., Avilés-Vázquez, K., Samulon, A., & Perfecto, I. (2007). Organic agriculture and the global food supply. *Renewable Agriculture and Food Systems*, *22*(2), 86–108.

Bai, J. (2009). Panel data models with interactive fixed effects. *Econometrica*, *77*(4), 1229–1279.

Bai, J., & Ng, S. (2002). Determining the number of factors in approximate factor models. *Econometrica*, *70*(1), 191–221.

Bai, J., & Wang, P. (2016). Econometric analysis of large factor models. *Annual Review of Economics*, *8*(1), 53–80.

Bertoli, S., & Fernández-Huertas Moraga, J. (2013). Multilateral resistance to migration. *Journal of Development Economics*, *102*, 79–100.

Boitreaud, S., Gratcheva, E. M., Gurhy, B., Paladines, C., & Skarnulis, A. (2020). *Riding the wave: Navigating the ESG landscape for sovereign debt managers* (EFI Insight-Finance). World Bank. Washington, DC.

Bolton, P., Despres, M., Pereira da Silva, L. A., Samama, F., & Svartzman, R. (2020). *The green swan - central banking and financial stability in the age of climate change*. Bank for International Settlements.

Brand, C., & Bielecki, M. (2018). *The natural rate of interest: Estimates, drivers, and challenges to monetary policy.* (ECB Occasional Paper Series No. 217). European Central Bank. LU.

Chudik, A., & Pesaran, M. H. (2015). Common correlated effects estimation of heterogeneous dynamic panel data models with weakly exogenous regressors. *Journal of Econometrics*, *188*(2), 393–420.

Claessens, S., Klingebiel, D., & Schmukler, S. L. (2007). Government bonds in domestic and foreign currency: The role of institutional and macroeconomic factors. *Review of International Economics*, *15*(2), 370–413.

Csonto, B., & Ivaschenko, I. V. (2013). *Determinants of sovereign bond spreads in emerging markets: Local fundamentals and global factors vs. ever-changing misalignments* (IMF Working Papers No. 13-164). International Monetary Fund.

Dasgupta, P. (2021). *The economics of biodiversity: The dasgupta review* [OCLC: 1203556473]. HM Treasury. London.

Dasgupta, P., & Heal, G. (1974). The optimal depletion of exhaustible resources. *The Review of Economic Studies*, *41*, 3.

Denton, F. T. (1971). Adjustment of monthly or quarterly series to annual totals: An approach based on quadratic minimization. *Journal of the American Statistical Association*, *66*(333), 99–102.

Di Fonzo, T., & Marini, M. (2012). *On the extrapolation with the denton proportional benchmarking method* (IMF Working Paper No. 12/169). International Monetary Fund.

Dudley, N., Stolton, S., Belokurov, A., Krueger, L., Lopoukhine, N., MacKinnon, K., Sandwith, T., & Sekhran, N. (Eds.). (2010). *Natural solutions: Protected areas helping people cope with climate change* [OCLC: 646807821]. IUCN-WCPA, TNC, UNDP, WCS, The World Bank; WWF.

Eberhardt, M., & Teal, F. (2011). Econometrics for grumblers: A new look at the literature on cross-country growth empirics [_eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1467-6419.2010.00624.x]. *Journal of Economic Surveys*, *25*(1), 109–155.

Eichengreen, B., & Hausmann, R. (1999). *Exchange rates and financial fragility* (NBER Working Paper No. 7418). National bureau of economic research.

Eichengreen, B., Hausmann, R., & Panizza, U. (2002). The pain of original sin.

Elliott, G., & Timmermann, A. (2016, April 5). *Economic forecasting*. Princeton University Press.

FAO. (2014). *Global plan of action for the conservation, sustainable use and development of forest genetic resources*. Commission on Genetic Resources for Food; Agriculture, FAO.

FAO. (2018). *Transforming food and agriculture to achieve the SDGs: 20 interconnected actions to guide decision-makers.* (Technical Reference Document). Food and Agriculture Organization of the United Nations. Rome.

FAO. (2020). *Global forest resources assessment 2020 - terms and definitions* (Forest Resources Assessment Working Paper No. 188). Food and Agriculture Organization of the United Nations. Rome.

FAO and UNEP. (2020). *The state of the world's forests 2020. forests, biodiversity and people* (THE STATE OF THE WORLD). Food and Agriculture Organization of the United Nations. Rome.

Gadanecz, B., Miyajima, K., & Shu, C. (2018). Emerging market local currency sovereign bond yields: The role of exchange rate risk. *International Review of Economics & Finance*, *57*, 371–401.

Gobillon, L., & Magnac, T. (2016). Regional policy evaluation: Interactive fixed effects and synthetic controls. *Review of Economics and Statistics*, *98*(3), 535–551.

Gratcheva, E., Emery, T., & Wang, D. (2021). *Demystifying sovereign ESG scores: A practical guide for policymakers* (EFI Insight-Finance). World Bank. Washington, D.C.

Gratcheva, E., Gurhy, B., Emery, T., & Wang, D. (2021). *A new dawn - rethinking sovereign ESG* (EFI Insight-Finance). World Bank. Washington, D.C.

Gratcheva, E., Gurhy, B., & Wang, D. (2021). *1% growth in natural capital: Why it matters for sovereign bonds* (EFI Insight-Finance). World Bank. Washington, D.C.

Gylfason, T. (2001). Natural resources, education, and economic development. *European Economic Review*, *45*(4), 847–859.

Hamilton, K., Ruta, G., Bolt, K., Markandya, A., Pedroso-Galinato, S., Silva, P., Ordoubadi, S., M., Lange, G.-M., & Tajibaeva, L. (2006). *Where is the wealth of nations?: Measuring capital for the 21st century*. World Bank Group.

Hausmann, R., & Panizza, U. (2003). On the determinants of original sin: An empirical investigation. *Journal of International Money and Finance*, *22*(7), 957–990.

Hilscher, J., & Nosbusch, Y. (2010). Determinants of sovereign risk: Macroeconomic fundamentals and the pricing of sovereign debt. *Review of Finance*, *14*, 235–262.

IFOAM. (2020). *Definition of organic agriculture*. Retrieved November 16, 2020, from https://ifoam.bio/why-organic/organic-landmarks/definition-organic

Inderst, G., & Stewart, F. (2018). *Incorporating environmental, social and governance (ESG) factors into fixed income investment* (World Bank Group Publication). The World Bank.

IPBES. (2019). *Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the intergovernmental science-policy platform on biodiversity and ecosystem services* (IPBES Global Assessment). IPBES secretariat. Bonn, Germany.

Kapetanios, G., Pesaran, M. H., & Yamagata, T. (2011). Panels with non-stationary multifactor error structures. *Journal of Econometrics*, *160*(2), 326–348.

Kim, D. H., & Wright, J. H. (2005, August 1). *An arbitrage-free three-factor term structure model and the recent behavior of long-term yields and distant-horizon forward rates* (SSRN Scholarly Paper ID 813267). Social Science Research Network. Rochester, NY.

Lange, G.-M., Cust, J., Peszko, G., Garcia, L. D. H., & Naikal, E. (2021). *The changing wealth of nations 2021: Managing assets for the future*. World Bank Group.

Lange, G.-M., Hamilton, K., Ruta, G., Chakraborti, L., Desai, D., Edens, B., Ferreira, S., Fraumeni, B., Jarvis, M., Kingsmill, W., & Li, H. (2018). *The changing wealth of nations 2018: Building a sustainable future*. World Bank Group.

Lange, G.-M., Ruta, G., Chakraborti, L., Desai, D., Edens, B., Ferreira, S., Fraumeni, B., Jarvis, M., Kingsmill, W., Li, H., & Hamilton, K. (2011). *The changing wealth of nations: Measuring sustainable development in the new millennium*. World Bank Group.

Lee, K., Pesaran, M. H., & Smith, R. (1997). Growth and convergence in a multi-country empirical stochastic solow model. *Journal of Applied Econometrics*, *12*, 357–392.

Li, D., Qian, J., & Su, L. (2016). Panel data models with interactive fixed effects and multiple structural breaks [Publisher: Taylor & Francis]. *Journal of the American Statistical Association*, *111*(516), 1804–1819.

Ludvigson, S. C., & Ng, S. (2009). Macro factors in bond risk premia. *Review of Financial Studies*, *22*(12), 5027–5067.

Mäkelä, E. (2017). The effect of mass influx on labor markets: Portuguese 1974 evidence revisited. *European Economic Review*, *98*, 240–263.

Mankiw, N. G., Romer, D., & Weil, D. N. (1992). A contribution to the empirics of economic growth. *Quarterly Journal of Economics*, *107*(2), 407–437.

Marini, M. (2016). *Nowcasting annual national accounts with quarterly indicators: An assessment of widely used benchmarking methods* (IMF Working Paper No. 16/71). International Monetary Fund.

Moon, H. R., & Weidner, M. (2015). Linear regression for panel with unknown number of factors as interactive fixed effects. *Econometrica*, *83*(4), 1543–1579.

Moon, H. R., & Weidner, M. (2017). Dynamic linear panel regression models with interactive fixed effects [Publisher: Cambridge University Press]. *Econometric Theory*, *33*(1), 158–195.

NGFS. (2020a). *The macroeconomic and financial stability impacts of climate change research priorities* (NFGS Technical Document). Network for Greening the Financial System.

NGFS. (2020b). *Overview of environmental risk analysis by financial institutions* (NFGS Technical Document). Network for Greening the Financial System.

Pesaran, M. H. (2006). Estimation and inference in large heterogeneous panels with a multifactor error structure. *Econometrica*, *74*(4), 967–1012.

Pesaran, M. H., & Tosetti, E. (2011). Large panels with common factors and spatial correlation. *Journal of Econometrics*, *161*(2), 182–202.

Ramsey, F. P. (1928). A mathematical theory of saving. *The Economic Journal*, *38*(152), 543–559.

Romer, P. M. (1986). Increasing returns and long-run growth. *Journal of Political Economy*, *94*(5), 1002–1037.

Schellekens, G., & van Toor, J. (2019). *Values at risk? sustainability risks and goals in the dutch financial sector* (DNB Report). De Nederlandsche Bank.

Shiller, R. J., & McCulloch, J. H. (1987, August 1). *The term structure of interest rates* (NBER Working Paper No. 2341). National Bureau of Economic Research.

SIFMA. (2019). *SIFMA capital markets fact book, 2019* (SIFMA Report). Securities Industry and Financial Markets Association.

Smets, F., & Tsatsaronis, K. (1997, September). *Why does the yield curve predict economic activity?: Dissecting the evidence for germany and the united states.* (BIS Working Papers No. 49). Bank for International Settlements.

Smulders, S., & Withagen, C. (2012, October). *Green growth - lessons from growth theory* (World Bank Policy Research Working Papers No. 6230). The World Bank.

Solow, R. M. (1974). Intergenerational equity and exhaustible resources. *The Review of Economic Studies*, *41*, 29.

Solow, R. M. (1956). A contribution to the theory of economic growth. *The Quarterly Journal of Economics*, *70*(1), 65.

Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M., & de Haan, C. (2006). *Livestock's long shadow: Environmental issues and options*. Food; Agriculture Organization of the United Nations.

Stiglitz, J. E. (1974). Growth with exhaustible natural resources: The competitive economy. *The Review of Economic Studies*, *41*, 139.

Stock, J., & Watson, M. (2005, July). *Implications of dynamic factor models for VAR analysis* (NBER Working Paper No. 11467). National Bureau of Economic Research. Cambridge, MA.

van der Ploeg, F. (2011). Natural resources: Curse or blessing? *Journal of Economic Literature*, *49*(2), 336–420.

van Toor, J., Piljic, D., Schellekens, G., van Oorschot, M., & Kok, M. (2020, June 18). *Indebted to nature: Exploring biodiversity risks for the dutch financial sector* (DNB Report). De Nederlandsche Bank.

Venables, A. J. (2016). Using natural resources for development: Why has it proven so difficult? *Journal of Economic Perspectives*, *30*, 161–184.

Waggoner, D. F. (1997). *Spline methods for extracting interest rate curves from coupon bond prices* (Federal Reserve Bank of Atlanta Working Paper No. 97-10).

WEF. (2020a). *The global risks report 2020* (Insight Report 15th Edition). World Economic Forum.

WEF. (2020b, January). *Nature risk rising: Why the crisis engulfing nature matters for business and the economy*. World Economic Forum. Cologny/Geneva.

Willer, H., Schlatter, B., Trávníček, J., Kemper, L., & Lernoud, J. (Eds.). (2020). *The world of organic agriculture. statistics and emerging trends 2020*. Research Institute of Organic Agriculture (FiBL); IFOAM – Organics International.

World Bank. (2018, January 30). *Building the world bank's wealth accounts: Methods and data* (Report). Environment and Natural Resources Global Practice, World Bank.

WWF, & World Bank. (2020). *Spatial finance: Challenges and opportunities in a changing world* (EFI Insight-Finance). World Bank Group. Washington, D.C.

Xu, Y. (2017). Generalized synthetic control method: Causal inference with interactive fixed effects models [Publisher: Cambridge University Press]. *Political Analysis*, *25*(1), 57–76.