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Environmental performance, financial development, systemic risk and economic uncertainty: What are the linkages?

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ABSTRACT

The paper studies the relationships among the composite indicators of environmental performance, financial development, systemic risk and economic uncertainty for a balanced panel of 57 countries during 2010–2020. The analysis builds on panel local projections by Jordá (2005). In addition to the whole panel, this technique also applies to two sub-panels obtained via the K-means clusterization conditional on a set of composite indicators of environmental performance. We underscore a two-way relationship between systemic risk and environmental performance. An increase in systemic risk improves the environmental quality, albeit to the detriment of economic growth and energy consumption, whereas ex ante higher values of the key composite indicators of environmental performance mitigate systemic risk. Financial development adversely affects environmental performance. Contrary to the prevailing view, this effect is mostly related to the development of financial markets compared to the development of financial institutions. Economic uncertainty is found totally unrelated to the composite indicators of environmental performance. The aforementioned key findings generally hold after splitting the whole panel into the two sub-panels. Overall, our results induce policymakers to treat with caution certain policy recommendations aimed at improving environmental quality, since reducing systemic risk, increasing financial development as a whole or shifting towards a market-based financial system do not necessarily help accomplish this goal.

1. Introduction

Much attention is now riveted on the relationship between environmental indicators and various dimensions of economic, financial and institutional development. This is a wide field covering multiple research programs which are reasonably hard to generalize. This mainly arises from the diverse indicators used to proxy the dimensions mentioned above. For example, based on the World Bank data catalogue, the number of financial development indicators totals nearly 110, whereas the number of measures aimed at capturing environmental performance exceeds 140.[1] There is also a myriad of indicators capturing various facets of institutional quality and economic agents' sentiment which can be borrowed from public sources, e.g. the World Bank Governance indicators, and from private ones. Although a greater fraction of these indicators contains missing data, thereby inhibiting their widespread application, there still remain dozens of measures characterized by a comprehensive cross-country coverage and widely used in research. While an ample choice of indicators allows to develop numerous research programs, which is generally beneficial for science, it also entails an important controversy related to the robustness and applicability of findings. When these numerous indicators are interacted across different country samples, time series length, to say nothing of the different methodologies applied, inconclusive results often emerge. This makes policymakers face a lack of robust findings to elaborate policies promoting environmental sustainability along with socioeconomic development.

In this study, we seek to partly mitigate this problem by dissecting relationships among environmental performance and three dimensions of socioeconomic development, namely, financial development, financial stability and economic uncertainty, using composite rather than granular proxies. Applying the composite measures allows for a holistic analysis of the linkages among the dimensions enlisted above instead of

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[1] See https://www.worldbank.org/en/publication/gfdr/data/global-financial-development-database and https://data.worldbank.org/topic/6.

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dealing with numerous individual metrics which underlie them. Given that these composite indicators are properly constructed, e.g. do not include confounding input variables, they can be useful for elaborating policy measures. Besides using the composite indicators, we examine the relationships among the four dimensions jointly. Meanwhile, as far as we know, the extant literature typically considers bivariate or, at best, trivariate relationships involving the aforementioned dimensions, e.g. environmental performance and financial development (Acheampong, 2019; Acheampong et al., 2020; Uddin, 2020; Habiba and Xinbang, 2022); environmental performance, financial development and economic uncertainty (Zhang and Razzaq, 2022).

To proxy environmental performance, we exploit a number of composite indices, accounting for this dimension within broader "Beyond GDP" measures or as standalone metrics: (i) the Yale Environmental Performance Index (EPI) as a whole introduced by the Yale Center for Environmental Law and Policy; (ii) the environmental well-being dimension from the Sustainable Society Index (SSI) maintained by TH Köln-University of Applied Sciences; (iii) the ecological footprint as a component of the Happy Planet Index (HPI) introduced by New Economics Foundation; (iv) green GDP computed by Stjepanovic et al. (2022). In addition, we derive one more composite indicator (PC) by extracting the first principal component from the four metrics enlisted above. As for financial development, we adopt the IMF index of financial development covering depth, access and efficiency across both financial institutions and markets (Svirydzenka, 2016). In addition to this broad-based index, we also exploit its sub-indices for financial institutions and markets, respectively. Financial stability is proxied by the nationwide measure of systemic risk - conditional capital shortfall (SRISK) proposed by Brownlees and Engle (2017). Country-level uncertainty measures track the frequency of the word "uncertain" (or its variant) in corresponding country reports by the Economist Intelligence Unit (Ahir et al., 2022). Building on the data described above, we compile a balanced panel covering 57 countries for the period 2010–2020.

We conduct our analysis by applying panel local projections (LP), a method proposed by Jordá (2005) to derive dynamic relationships among multiple variables which is robust to short time series, non-linearities and model misspecification, thereby presenting a viable alternative to panel VAR estimation. The LP method applies to the whole panel and to the two sub-panels obtained via the K-means clusterization based on all the five composite indicators of environmental performance. The first sub-panel includes 33 countries and is predominantly made up of emerging market economies (EMEs), whereas the second sub-panel consists of 24 high income countries. Predictably, the first sub-sample is characterized by lower scores in terms of environmental performance than the second one.

We find that the composite measures of environmental performance are not tightly connected with the aggregate indicators of financial development, systemic risk and economic uncertainty. Of the environmental indicators considered, the EPI index and the composite measure, PC, which we derive as the first principal component from the four input indicators are characterized by the highest number of linkages. For the whole panel and both sub-panels, the EPI and PC indices are unidirectionally and positively driven by SRISK. This finding suggests that an increase in systemic risk tends to improve countries' scores in terms of environmental performance. Since the build-up of systemic risk is often a precursor of an economic downturn, the positive impact of SRISK on the EPI index and PC captures an improved environmental performance stemming from a decline in economic activity. Thus, financial instability triggers an economic recession, which in its turn deters environmental degradation. This effect is confirmed by the existing literature, e.g. Yang et al. (2020), Safi et al. (2021a,b), Zhao et al. (2021). Against this backdrop, the SSI index appears the only exception, since higher values of SRISK lower this composite measure of environmental performance. As for the HPI index and green GDP, these indicators are unrelated to systemic risk in case of the whole panel and the two sub-panels.

As for the broad-based index of financial development, it tends to lower countries' scores in terms of environmental performance, though this effect is less pronounced in comparison with that of systemic risk. The adverse impact of financial development on environmental performance is found for the EPI and PC indices in case of the whole panel. For the sub-panel mostly comprising EMEs, it holds only for the EPI index, while for the sub-panel composed by high income countries this effect relates to the PC index. We also find that green GDP appears the only indicator which is positively driven by financial development, but, unlike the EPI and PC, this relationship is valid only for the first sub-panel. The prevailing negative effect of financial development on environmental performance emerges as in most cases an increase in the former enhances real economic activity, which undermines environmental sustainability. Our finding is consistent with a number of panel studies confirming the dampening effect of financial development on environmental performance, e.g. Xu et al. (2021) who attribute such impact precisely to industrialization and economic growth. Similar evidence is reported by Bui (2020) and Horobet et al. (2022).

We arrive at additional notable findings by sequentially replacing the broad-based index of financial development with the two sub-indices measuring the development of financial institutions and markets, respectively. First, there is a bi-directional linkage between the EPI index and SRISK for the whole panel. In line with the baseline results, higher values of systemic risk improve the environmental performance, while ex ante higher scores of the EPI index ameliorate SRISK. The same bi-directional linkage is observed for the PC index and SRISK. These relationships are found for both sub-indices of financial development. Thus, regardless of the financial structure of an economy, deliberate actions aimed at improving environmental sustainability are likely to dampen systemic risk. This finding is consistent with the studies emphasizing the positive effect of environmental sustainability on financial stability, e.g. Jadoon et al. (2021), Peiró-Signes et al. (2022) and Aloui et al. (2023).

Overall, we come up with the findings reported above which echo the related literature. Nonetheless, one has to bear in mind that the extant literature builds on the granular measures of environmental performance, primarily, the amount of CO_2 emissions, rather than on the composite indicators. This adds value to the results of our study, since they are obtained at the aggregate level.

However, the study also yields some results contradicting the existing literature. First, we find evidence against the view that stock market development secures better environmental performance than the development of financial intermediaries, as posited, for instance, by De Haas and Popov (2023). Our analysis reveals that higher values of the sub-index accounting for the development of financial markets leads to a decline in the EPI and PC indices. Moreover, such linkage is not only found for the whole panel, but also for the sub-panel consisting of high income countries. Second, we report no relationship linking economic uncertainty and the composite indicators of environmental performance, albeit there are studies capturing such relationship when granular measures are used, e.g. Sohail et al. (2022), Tee et al. (2023).

Taking stock of the empirical results obtained, we conclude that there is no room for straightforward and easy-to-implement policy recommendations based on the relationships among the composite measures of environmental performance, financial development, financial stability and economic uncertainty. Contrary to many papers building on granular rather than composite indicators, reducing systemic risk, promoting financial development as a whole or shifting towards market-based financial systems do not necessarily entail better environmental performance. Thus, our analysis questions, if not de-mystifies, the trivial policy recommendations how to achieve better environmental performance which are frequently proposed in the literature. Meanwhile, by fostering environmental sustainability, countries are indeed likely to curb the build-up of systemic risk, thereby safeguarding financial stability.

Overall, the contribution of our study to the literature is three-fold.

First, in a single empirical exercise we test for dynamic relationships within a tangle of four dimensions: environmental performance, financial development, financial stability and economic uncertainty. Second, unlike the previous studies, we build on the composite indicators of environmental performance and financial development, which are complemented by nationwide measures of systemic risk and economic uncertainty. Such combination of variables appears completely novel in the empirical analysis. Furthermore, in addition to the existing composite measures of environmental performance, e.g. ecological footprints of nations employed, for instance, by Ashraf et al. (2022), we propose our own aggregate indicator based on the principal component analysis. Third, we attempt to account for the potential heterogeneity of the baseline results by decomposing the broad-based index of financial development into two sub-indices and by splitting the whole panel into sub-panels using cluster analysis.

The remainder of the paper is as follows. Section 2 reviews the literature linking environmental indicators with financial development, systemic risk and uncertainty. Section 3 describes the data and presents the econometric methodology to pin down the relationships among the variables enlisted above in the panel data framework. Section 4 discusses the estimation results for the whole panel of countries and the two sub-panels. Section 5 concludes.

2. Literature review

2.1. Environmental performance and financial development

In the cross-country framework, there is still much controversy regarding the direction of the relationship between environmental performance and financial development as well as its statistical significance.

The prevailing body of literature considers the relationship running from financial development to environmental performance (which encapsulates such terms as environmental sustainability, quality or, conversely, degradation).[2] In contrast to our study, environmental performance in the previous research tends to be proxied by this or that parsimonious measure which is available for a vast majority of countries. Most often the amount of CO_2 emissions is exploited as such proxy. There are also several studies adopting the measures of renewable energy consumption, e.g. Ponce et al. (2021). However, it is also important to mention a number of studies exploiting composite metrics from the Global Footprint Network, e.g. ecological footprints of countries in consumption, production as well as in exports and imports, e.g. Ashraf et al. (2022), Usman et al. (2021).

Al-Mulali et al. (2015) investigate a panel of 129 countries, finding that financial development reduces CO_2 emissions for the period 1980–2011, irrespective of the income level. Acheampong et al. (2020) conduct a panel data study covering 83 countries during 1980–2015 and conclude that financial development is largely beneficial for environmental quality, except for a group of frontier financial economies which do not belong in the group of conventional EMEs and developed countries. The positive impact of financial development on environmental sustainability is also reported by Uddin (2020) who examines a panel of 115 countries during 1990–2016, as well as by Habiba and Xinbang (2022) focusing on a panel of 46 countries during 2000–2018. Based on ecological footprints, the benign effect of financial development is documented by Pata and Yilanci (2020) for G7 countries, Usman and Hammar (2021) for 16 APEC countries, Usman et al. (2021) for 15 highest emitting countries in the world.

Based on a panel of 42 countries during 1990–2018, Xu et al. (2021) identify several channels transmitting the effect of financial development on CO_2 emissions and find that the former increase the latter when industrialization and energy consumption intensify. Bui (2020) arrives at a similar conclusion, based on a panel of 100 countries for the period between 1990 and 2012. The adverse effect of financial development on environmental quality is found by Khan et al. (2022) for a panel of 15 emerging and growth-leading economies. Interestingly and somewhat surprisingly, Horobet et al. (2021) show that financial development tends to increase CO_2 emissions even in case of the EU countries over 1996–2018 in spite of the efforts to promote green finance. Building on the ecological footprints and considering a sample of 27 industrialized countries, Ibrahim and Vo (2021) also report an adverse impact of financial development on the environment.

There are also studies arguing that financial development is neutral to environmental performance. Such conclusion is derived, for instance, by Omri et al. (2015) for MENA countries over 1990–2011. There is also evidence that the relationship may be bi-directional, as found by Ngo et al. (2022) for a panel of 36 countries during 1996–2014.

Interestingly, there are also studies underscoring a non-monotonic effect of financial development on the environmental performance. For example, exploiting the data on ecological footprints for 124 countries, Ashraf et al. (2022) find that initially the development of financial institutions aggravates environmental degradation, but then this effect turns beneficial. Meanwhile, they do not report any consistent effects of financial markets development on the ecological footprints.

Finally, a number of studies unveil the relationship running from environmental performance to financial development. Analyzing top-10 countries by the volume of CO_2 emissions, Kayani et al. (2020) find that these emissions Granger cause financial development, producing a stimulative effect on the latter. Meanwhile, Ding (2023) concludes that elevated renewable energy consumption inhibits financial development in the G7 countries.

2.2. Environmental performance and financial (in-)stability

Similar to the relationship between environmental performance and financial development, the direction of the linkage between environmental performance and financial (in-)stability remains highly controversial.

Most studies argue that this linkage runs from financial (in-)stability to environmental sustainability. Using a panel of 62 countries for 2003–2018, Zhao et al. (2021) show that an increase in country-level financial risk accounting for the fragility of external debt, exchange rate and other financial sector indicators tends to decrease CO_2 emissions. Conversely, by analyzing a panel of 47 countries over 1996–2018, Zhao et al. (2022) document that increased financial risks inhibit green growth. Building on ecological footprints, Lee and Chen (2021) as well as Ashraf (2022) confirm this conclusion for a large international sample of countries and Belt and Road economies, respectively. By investigating a panel of G7 economies for the period 1990–2018, Safi et al. (2021a,b) also lend an empirical support to the view that financial stability spurs environmental sustainability by reducing CO_2 emissions. Similar evidence is provided by Abbas (2023) for a panel of South Asian countries during 1980–2021 as well as by Khan and Yoon (2021) who consider a panel of 88 EMEs over 1980–2014.

Also, some studies argue that the relationship may run from environmental performance to financial stability. Building on a panel of 90 countries for 2010–2015, Jadoon et al. (2021) find that better environmental performance consolidates financial stability. Analyzing a panel of 163 countries, Peiró-Signes et al. (2022) find that the EPI index is positively correlated with country risk scores, including the financial one. In a similar vein, Aloui et al. (2023) conclude that environmental degradation in 35 Sub-Saharan African countries is conducive to financial instability.

[2] For brevity and in order to follow a coherent layout of the paper, we review only cross-country studies examining the link between financial development and environmental performance, leaving aside country-level analyses. Similar approach is pursued in case of other linkages described in Sections 2.2 and 2.3.

2.3. Environmental performance and economic uncertainty

The extant literature mostly posits that elevated economic uncertainty usually proxied by economic policy uncertainty (EPU) indices has a detrimental effect on environmental performance. Such impact does not seem to vary significantly across income groups. For example, the adverse effect is reported for a panel of BRICS countries during 1990–2020 (Liu et al., 2023), for BRICST (Zhang and Razzaq, 2022), and G7 economies where uncertainty leads to lower renewable energy consumption (Khan and Su, 2022). Building on broader country panels, such evidence is corroborated by Sohail et al. (2022) and Tee et al. (2023). Building on the ecological footprints, Hussain et al. (2022) show that the EPU exerts a negative effect on the environment in the BRICS countries.

However, it is also worth mentioning the studies whose conclusions deviate from the prevailing literature. For instance, Adams et al. (2020) find a bidirectional relationship between CO_2 emissions and EPU, confirming that the EPU index increases the volume of emissions, while receiving a feedback from them. Moreover, considering a panel of 22 countries over 1985–2019, Feng and Zheng (2022) argue that higher values of the EPU index spur renewable energy innovation, though this impact appears conditional on institutional quality.

3. Data and methodology

3.1. Data

As for the composite indicators of environmental performance, we adopt the corresponding components of broader "Beyond GDP" measures capturing environmental impacts. In choosing the "Beyond GDP" measures, we are guided by Malay (2019) who identifies several such measures which are initiated by influential stakeholders and, thus, are widespread in research. Since not all of the "Beyond GDP" measures contain an environmental/ecological pillar, we deal with the composite indicators of environmental performance derived from only four measures. Namely, our dataset includes (i) the environmental well-being dimension from the Sustainable Society Index (SSI) maintained by TH Köln-University of Applied Sciences; (ii) the ecological footprint as a component of the Happy Planet Index (HPI) introduced by New Economics Foundation; (iii) green GDP computed by Stjepanovic et al. (2022). Additionally, as a standalone composite indicator of environmental performance, we adopt the Yale Environmental Performance Index (EPI) proposed by the Yale Center for Environmental Law and Policy.

Based on the principal component analysis (PCA) applied to these four metrics in every country considered, we derive our own composite indicator, PC. On average, this measure accounts for 56% of the variance of these input indicators for each country. Fig. 1 reports the proportion of variance explained by the PC index for each country, while Table 1 presents the component loadings.

We document that the variance explained by our composite indicator PC lies in the range between 43% (for Ireland) and 70% (for Brazil). The component loadings also vary within a relatively narrow interval. The average component loadings appear very close for green GDP, the ecological footprint from the HPI index and the environmental well-being dimension from the SSI index. Meanwhile, our PC index incorporates somewhat less information from the EPI index as an input indicator, though the mean component loading equal to 0.39 is not small, being shaped by extremely low values for Hungary and India. Overall, the evidence indicates that the PC index we construct effectively captures the information embedded in the four input composite indicators of environmental performance.

Financial development is proxied by the broad-based IMF index of financial development introduced by Svirydzenka (2016). This index covers such dimensions of financial development as depth, access and efficiency across financial institutions and financial markets. It is methodologically based on computing the first principal component from multiple input variables which constitute each of the three dimensions. In this study, besides the broad-based index of financial development, we exploit its two sub-indices for institutions and markets, FI and FM, since there is evidence that bank-based and market-based financial systems can have a differential impact on environmental performance.[3]

Since unbalanced financial development often leads to the build-up of risks and eventually to financial crises, we also consider country-level conditional capital shortfall (SRISK) as a proxy of financial instability. This measure of systemic financial risk developed by Brownlees and Engle (2017) is available for a wide range of countries from the Volatility Laboratory (V-Lab) at the New York University Stern School of Business.[4] SRISK assesses the overall shortage of equity experienced by a country's financial system as a result of a strong shock in the world stock market proxied as a 40% decline in the World MSCI index. In terms of country coverage, SRISK appears the most appropriate proxy of financial instability thanks to the uniform methodology of its computation across countries. In order to account for countries' variation in the size of economy, SRISK is scaled to GDP.

We also include an economic uncertainty measure into our analysis. On the one hand, this is motivated by its revealed linkage with environmental performance, as discussed in Section 2.3. One the other hand, it is now an ubiquitous covariate of both financial development and systemic risk in cross-country studies, e.g. Karaman and Yildirim-Karaman (2019), Phan et al. (2021). While previous research mostly builds on economic policy uncertainty (EPU) indices developed by Baker et al. (2016) and based on the count of various terms associated with uncertainty in leading business newspapers, we adopt uncertainty indices (UI) proposed by Ahir et al. (2022). They are available for a much bigger number of countries compared to the EPU indices and are perfectly comparable across countries, as they track the frequency of the word "uncertain" (or its variant) in corresponding country reports by the Economist Intelligence Unit.

By merging the above indicators into a single dataset, we eventually compile a balanced panel of 57 countries for the period 2010–2020. The list of these economies, a brief description of the composite indicators of environmental performance as well as corresponding descriptive statistics for all the variables are reported in Tables A1-A3 of the Appendix.

3.2. Econometric methodology

In the study, we apply panel local projections (LPs) introduced by Jordá (2005), with a conventional fixed effects estimator. It is an alternative method to obtain impulse responses, which in certain respects appears superior to conventional vector autoregressions (VAR), e.g. Li et al. (2022). LPs allow to derive impulse responses by estimating forecasts at each period of interest rather than extrapolating at distant horizons as it is performed in VARs. Moreover, LPs are quite flexible, since they do not require a preliminary specification of a multivariate

[3] For example, Ehigiamusoe et al. (2019) find that bank-based financial systems improve the environmental quality, whereas market-based ones do not exert any significant effect. Meanwhile, Paramati et al. (2018) as well as Yao and Tang (2021) report a heterogeneous effect of financial structure on environmental performance proxied with CO_2 emissions: in developed countries market-based finance decreases them, while in developing economies the impact is opposite. Azeem et al. (2023) also emphasize a non-linear effect of stock market development on environmental performance: the former worsens the latter in the countries where the ratio of stock market capitalization to GDP is below 100%, while once this threshold is reached, the situation reverses. De Haas and Popov (2023) comport with the view that more developed stock markets are favorable for environmental quality. At the same time, Musah (2023) does not document any statistically significant causality between stock market development and environmental degradation for EU countries.

[4] See https://vlab.stern.nyu.edu/srisk for details.

Fig. 1. Share of explained variance by the first principal component, PC, %, by country.

dynamic system to derive impulse responses. They are robust to misspecification, non-linearities and short time series. Therefore, this method is a good fit for our panel dataset characterized by a large *N* and small *T* structure. Another advantageous feature is that lag-augmented LPs are asymptotically valid over both stationary and non-stationary data (Olea and Plagborg-Møller, 2021). Overall, in light of the relatively short time series in our dataset and the assumption that there could be bi-directional relationships within the tangle of the variables we consider, panel LPs outperform panel VAR or panel GMM estimation in our empirical setting.

The general set-up of the equation for panel LPs is represented as follows:

$$y_{i,t+s} = \alpha_{i,s} + shock_{i,t-1}\beta_s + x_{i,t-1}\gamma_s + u_{i,t+s} \tag{1}$$

where $y_{i,t+s}$ refers to the dependent variable; in our case, the dependent variable iteratively takes on the value of one of the indicators in the following vector – [economic uncertainty measure (UI), composite indicator of environmental performance (PC), financial development sub-index ($FD\ sub-\ index$) and systemic risk (D_SRISK)]; $\alpha_{i,s}$ stands for country fixed effects. $\mathrm{Shock}_{i,t-1}$ is one of the first-differenced variables from the above mentioned vector. The vector $x_{i,t-1}$ contains the control variables which are the same as the first-differenced variables from the above vector, excluding the variable which is regarded as a shock. The impulse-response $y_{i,t+s}$ is estimated with respect to a change in the shock and control variables over the horizon *s=0, …,4*.

Thus, we essentially estimate the following set of equations:

$$\mathrm{UI}_{i,t+s} = \alpha_{i,s} + \mathrm{D\_UI}_{t-1} + \mathrm{D\_PC}_{t-1} + \mathrm{D\_FD\ sub-index}_{t-1} + \mathrm{D\_SRISK}_{t-1} + \mathrm{u}_{i,t+s} \tag{2}$$

$$\mathrm{PC}_{i,t+s} = \beta_{i,s} + \mathrm{D\_UI}_{t-1} + \mathrm{D\_PC}_{t-1} + \mathrm{D\_FD\ sub-index}_{t-1} + \mathrm{D\_SRISK}_{t-1} + \epsilon_{i,t+s} \tag{3}$$

$$\mathrm{FD\ sub-index}_{i,t+s} = \gamma_{i,s} + \mathrm{D\_UI}_{t-1} + \mathrm{D\_PC}_{t-1} + \mathrm{D\_FD\ sub-index}_{t-1} + \mathrm{D\_SRISK}_{t-1} + \varphi_{i,t+s} \tag{4}$$

$$\mathrm{SRISK}_{i,t+s} = \omega_{i,s} + \mathrm{D\_UI}_{t-1} + \mathrm{D\_PC}_{t-1} + \mathrm{D\_FD\ sub-index}_{t-1} + \mathrm{D\_SRISK}_{t-1} + \varepsilon_{i,t+s} \tag{5}$$

In each of the equations, we treat one of the regressors iteratively as a shock whereas the other variables are controls. These equations are estimated by means of OLS. We use the Cholesky identification with the following variable ordering: economic uncertainty→composite indicator of environmental performance→index of financial development (sub-indices of financial development)→systemic risk. We believe that such ordering adequately captures the increasing degree of variable endogeneity in our analysis.

We implement a STATA code for panel local projections developed by Jordá (2005).[5] The main output of our estimations are impulse response functions (IRFs) which graphically demonstrate lead-lag relationships among the variables. The IRFs are reported with 95% confidence intervals for five periods ahead the initial shock represented by one standard deviation in each of the variables.

Since we conjecture that the relationships among the variables may differ, conditional on the countries' environmental performance, the whole panel is split into two sub-panels. They are obtained via the K-means clusterization applied to our five composite measures of environmental performance. The first of them includes 33 countries, 21 out of them being EMEs. The second sub-panel comprises 24 high income countries (see Table A4 of the Appendix). Thus, our LP estimations are not only carried out for the whole panel, but also for each of the sub-panels considered.

[5] The code is publicly available at https://sites.google.com/site/oscarjorda/home/local-projections.

Table 1
Component loadings by country.

Country	EPI	GREEN	HPI	SSI
Argentina	0.22	0.61	0.49	0.58
Australia	0.66	0.34	0.66	0.14
Austria	0.52	0.18	0.65	0.53
Belgium	0.46	0.21	0.66	0.55
Brazil	0.05	0.58	0.59	0.56
Bulgaria	0.23	0.62	0.48	0.58
Canada	0.49	0.64	0.54	0.24
Chile	0.43	0.60	0.17	0.65
China	0.11	0.63	0.58	0.51
Colombia	0.22	0.69	0.13	0.67
Croatia	0.56	0.38	0.58	0.46
Cyprus	0.53	0.60	0.56	0.23
Czech Republic	0.38	0.63	0.38	0.57
Denmark	0.32	0.33	0.60	0.66
Egypt	0.66	0.09	0.40	0.63
Finland	0.46	0.18	0.63	0.60
France	0.51	0.46	0.57	0.45
Germany	0.32	0.37	0.65	0.58
Greece	0.42	0.58	0.56	0.42
Hungary	0.02	0.69	0.67	0.27
India	0.03	0.61	0.67	0.43
Indonesia	0.43	0.64	0.56	0.30
Ireland	0.33	0.65	0.39	0.56
Israel	0.54	0.62	0.16	0.54
Italy	0.45	0.59	0.57	0.36
Japan	0.58	0.57	0.50	0.29
Kazakhstan	0.21	0.60	0.54	0.56
Lithuania	0.09	0.67	0.65	0.34
Malaysia	0.55	0.58	0.55	0.24
Mexico	0.27	0.48	0.57	0.61
Morocco	0.15	0.63	0.61	0.46
Netherlands	0.54	0.15	0.67	0.49
New Zealand	0.30	0.45	0.66	0.52
Norway	0.46	0.57	0.54	0.41
Pakistan	0.09	0.57	0.53	0.62
Peru	0.23	0.06	0.69	0.68
Philippines	0.17	0.62	0.56	0.52
Poland	0.57	0.58	0.43	0.38
Portugal	0.49	0.62	0.40	0.46
Qatar	0.47	0.52	0.26	0.66
Romania	0.37	0.59	0.60	0.38
Russia	0.42	0.59	0.56	0.40
Saudi Arabia	0.51	0.33	0.66	0.45
Slovakia	0.34	0.54	0.44	0.64
Slovenia	0.58	0.53	0.55	0.28
South Africa	0.32	0.58	0.57	0.49
South Korea	0.51	0.67	0.54	0.08
Spain	0.46	0.59	0.55	0.37
Sweden	0.40	0.48	0.58	0.51
Switzerland	0.30	0.05	0.70	0.64
Thailand	0.51	0.58	0.40	0.50
Turkey	0.42	0.58	0.44	0.55
Ukraine	0.51	0.55	0.52	0.41
United Arab Emirates	0.50	0.32	0.48	0.65
UK	0.49	0.12	0.63	0.58
USA	0.50	0.65	0.51	0.27
Vietnam	0.51	0.24	0.57	0.60
Mean	*0.39*	*0.49*	*0.53*	*0.48*
SD	*0.16*	*0.18*	*0.13*	*0.14*

4. Results and discussion

4.1. Results for the whole panel

We begin by presenting the results for the whole panel, including those when the broad-based index of financial development is sequentially replaced with the sub-indices accounting for the development of intermediaries and markets. Given the goal of the study, we only report the linkages which involve the composite indicators of environmental performance. The corresponding IRFs are represented in Panel 1 of the figures.

We report a relatively limited number of linkages involving the composite indicators of environmental performance. The ecological footprint from the HPI index has no statistically significant relationship with financial development, systemic risk and economic uncertainty at all. Green GDP is involved in these linkages only when the sub-indices of financial development apply. The EPI and PC indices are characterized by the highest number of connections. However, the distribution of these revealed linkages is skewed. Most of them are with SRISK which exerts a unidirectional and positive influence over the EPI and PC indices when the broad-based index of financial development is used in the estimations. In case of the sub-indices, FI and FM, we find that the nexus between systemic risk and the two composite measures of environmental performance becomes bidirectional. SRISK still tends to increase the countries' EPI and PC scores, while ex ante higher values of these environmental indices ameliorate systemic risk. All in all, although SRISK dampens the SSI index scores, the prevailing effect of systemic risk on the set of composite environmental indicators is positive. We attribute this finding to the fact that the build-up of systemic risk often precedes economic recessions. The latter lead to a decline in economic activity, temporarily improving the environmental quality. This result is consistent with the existing literature, e.g. Yang et al. (2020), Safi et al. (2021a,b), Zhao et al. (2021). As for ex ante higher values of the EPI and PC indices mitigating systemic risk, this empirical finding is in line with Jadoon et al. (2021), Peiró-Signes et al. (2022) and Aloui et al. (2023). Besides the EPI and PC indices, it is also valid in case of green GDP.

The broad-based index of financial development entails a deterioration in the EPI and PC indices. This finding complies with the studies asserting that financial development tends to undermine rather than promote the environmental quality, e.g. Xu et al. (2021), Bui (2020). A plausible mechanism of such effect is that financial development contributes to economic growth and energy consumption, which first and foremost accelerate the dynamics of "brown" industries. Moreover, this effect is in line with the micro-level evidence that banks formally portraying themselves environmentally conscious keep on extending a greater volume of credit to borrowers in "brown" industries, e.g. Giannetti et al. (2023). In a similar vein, Degryse et al. (2020) show that banks may be reluctant to finance "green" firms, fearing to undermine their legacy positions held with the incumbent "brown" customers. That is, banks may be afraid of value losses related to the collateral pledged by the "brown" firms and their elevated probabilities of default in the face of credit re-allocation towards "green" borrowers. They also find that such effect is more tangible in concentrated banking sectors. Similarly, alongside banks, hedge and mutual funds still actively invest in assets from "brown" industries, though formally declaring commitment to ESG principles, e.g. Liang et al. (2021), Dumitrescu et al. (2022).

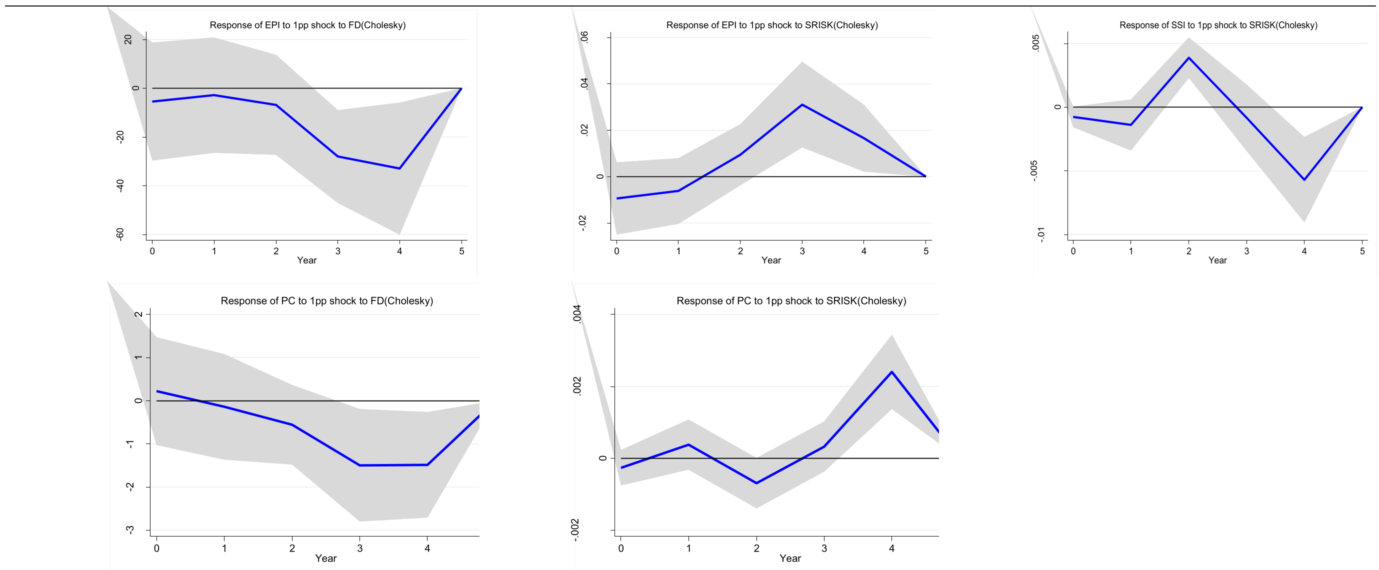
As for the role of financial structure, we find that any changes in the sub-index capturing the development of financial institutions appear neutral to environmental performance, whereas the sub-index accounting for the development of financial markets lowers the EPI and PC indices. Thus, our results are at odds with the research claiming that market-based financial systems impede environmental degradation, e.g. Paramati et al. (2018), Yao and Tang (2021), De Haas and Popov (2023). In light of our result obtained for a panel of 57 countries, one cannot recommend a shift towards a market-based financial system as a way to improve environmental performance. Also, higher levels of green GDP are associated with lower FM values, but higher FI.

Finally and somewhat surprisingly, economic uncertainty is found totally unrelated to any composite indicator of environmental performance within our tangle of variables.

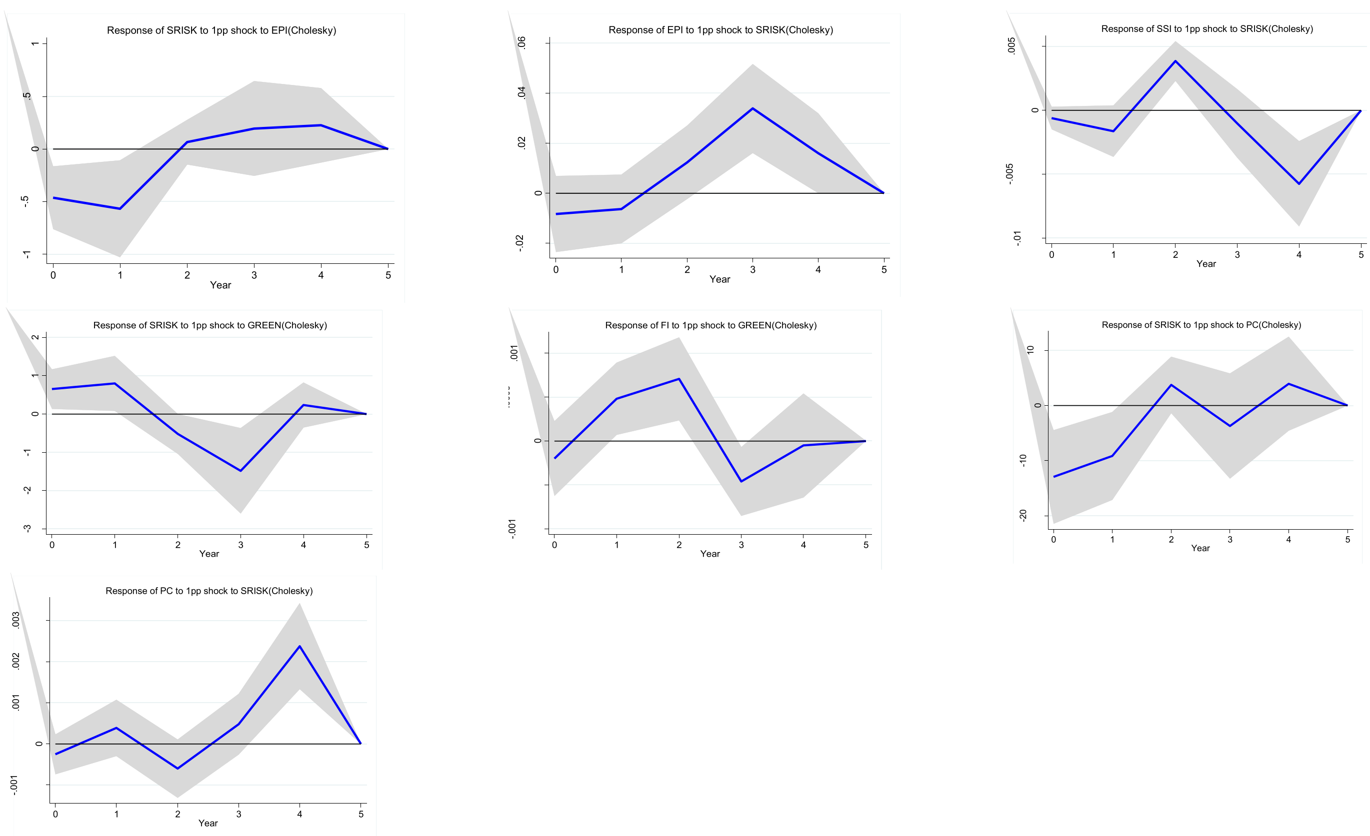
4.2. Results for the sub-panels

The corresponding IRFs are reported in Panel 2 of the figures. For both sub-panels, the overall number of statistically significant relationships is almost twice less compared to the whole panel. However, the key results obtained for the whole panel are generally corroborated.

First, we confirm the positive impact of SRISK on the EPI and PC



a) FD index

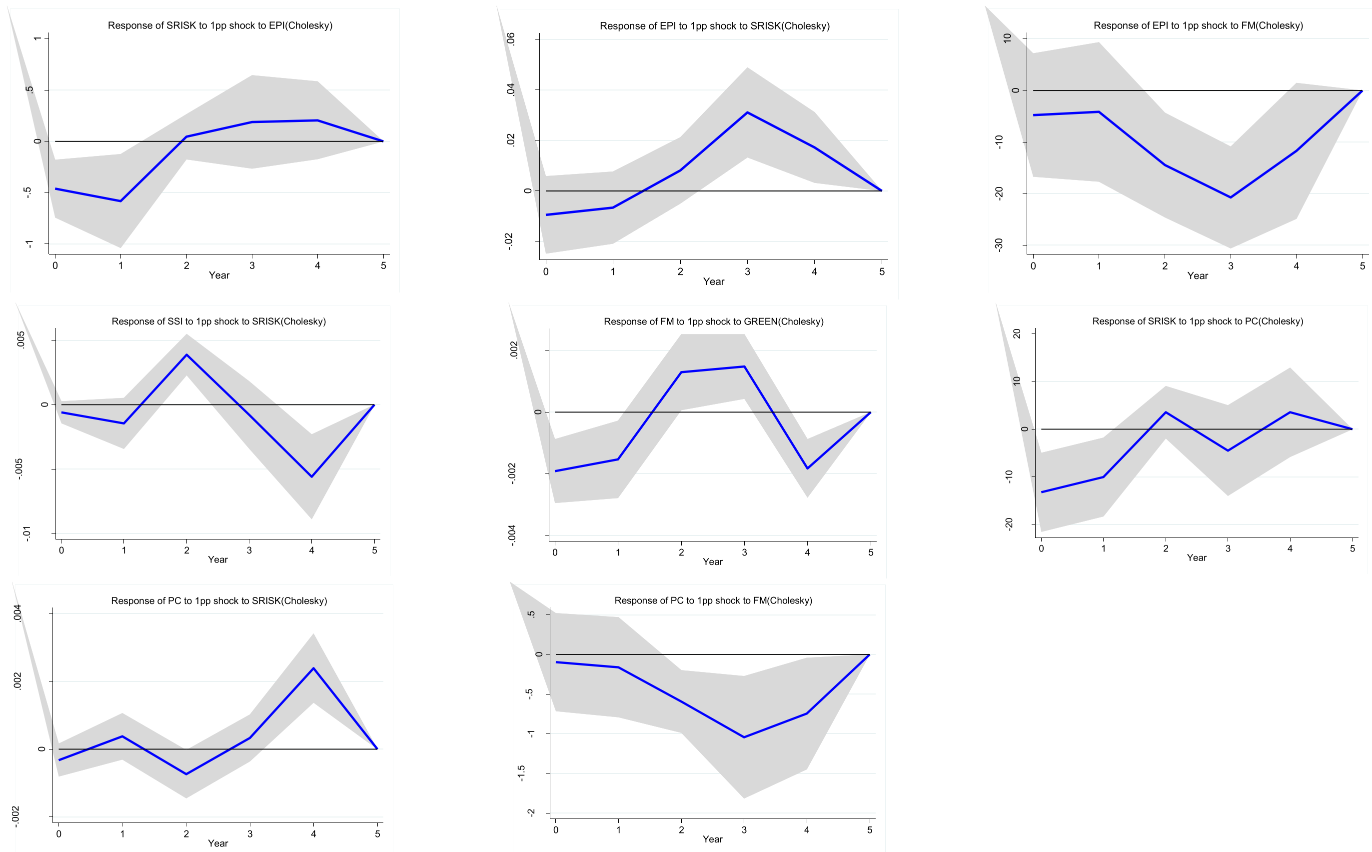


b) FI sub-index

Panel 1. a)-c). Impulse response functions with the FD index and FI, FM sub-indices for the whole panel of countries.

indices. Similar to the results for the whole panel, SRISK entails a decline in the SSI index.

Second, the effect of financial development manifests itself in the same direction as for the whole sample, but appears less pronounced. Namely, for sub-panel 1 which primarily encompasses EMEs, an increase in the broad-based index of financial development decreases the EPI index, while increasing green GDP. For sub-panel 2, we document three linkages: the broad-based index of financial development lowering the PC index and the sub-index capturing the development of financial markets decreasing the EPI and PC indices. Thus, the adverse impact of market-based finance on environmental performance observed for the sub-panel embracing high income countries appears to underpin the same result for the whole panel. We offer two tentative explanations for this result, which are subject to further empirical investigation. The first of them is that our observation period covers the aftermath of the Global Financial Crisis and the first year of the COVID-19 pandemic, which



c) FM sub-index

Panel 1. (*continued*).

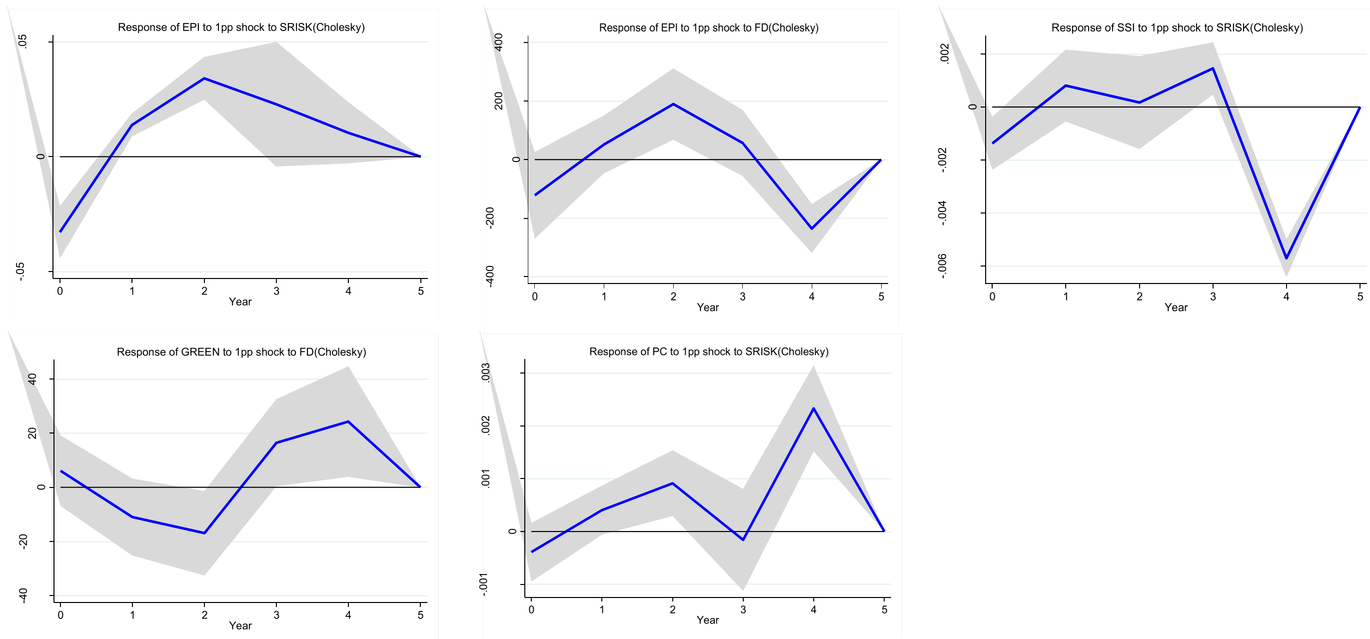
affects the average ratio of stock market capitalization to GDP. For the whole panel and sub-panel 2, this indicator equals 61 and 78%, respectively. Both values are quite far from the 100% GDP threshold found by Azeem et al. (2023), exceeding which stock market depth makes a reversal, starting to stimulate environmental quality instead of dampening it. The second possible explanation posits that although stock market development generally favors environmental information disclosure, thereby incentivizing listed firms to get “greener”, the magnitude of such disciplinary effect remains moderate even in the jurisdictions with a highly developed stock market, e.g. in the USA. For example, Carpentier and Suret (2022) find that wealth losses in the US stock market following environmental crises have remained stable since the early 1960s. Thus, listed polluting companies face quite modest, if any, penalties by the stock market. Besides, there is evidence that malpractices related to environmental information disclosure are widespread among asset management companies and investment funds as well. For example, Dumitrescu et al. (2023) find that around 34% of US mutual funds are engaged in greenwashing. Thus, stock markets may still be largely, though implicitly oriented towards “brown” firms. This orientation may be even more pronounced when stock market depth declines or just starts to rebound following major financial shocks. Against such backdrop, the sub-index capturing the development of financial institutions is found neutral to environmental performance, regardless of the sub-panel. On the sub-panel level, this suggests that deliberately switching from bank-based to market-based financial systems to improve environmental performance is an inappropriate policy option.

Third, similar to the estimations for the whole panel, there are no relationships involving an interaction between economic uncertainty and the composite indicators of environmental performance.[6]

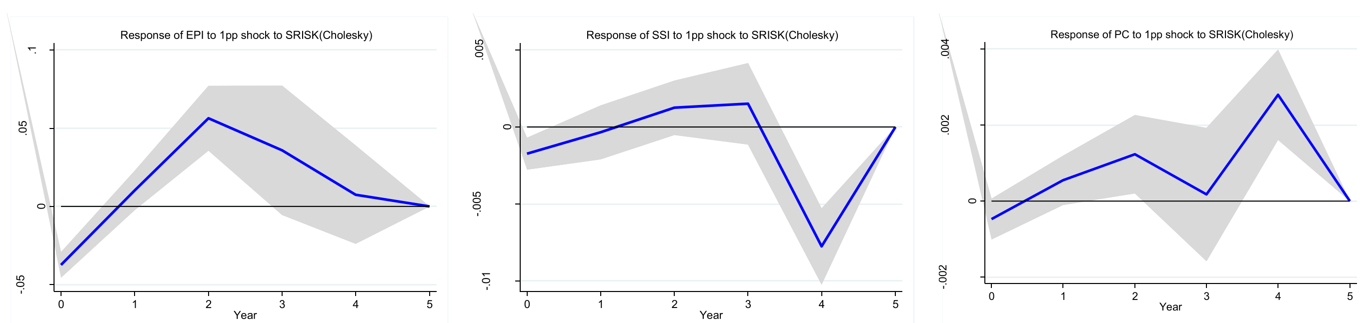
5. Conclusion

The paper investigates the relationships among the composite indicators of environmental performance, financial development, financial instability and economic uncertainty for a balanced panel of 57 countries during 2010–2020. Our analysis builds on panel local projections by Jordá (2005). In addition to the whole panel, this technique also applies to two sub-panels obtained via the K-means clusterization conditional on several composite indicators of environmental performance. In sub-panel 1, 21 out of 33 countries are emerging market economies, whereas sub-panel 2 totally consists of 24 high income countries. The major contribution of our analysis is that we seek to explore the relationships based on composite indicators rather than

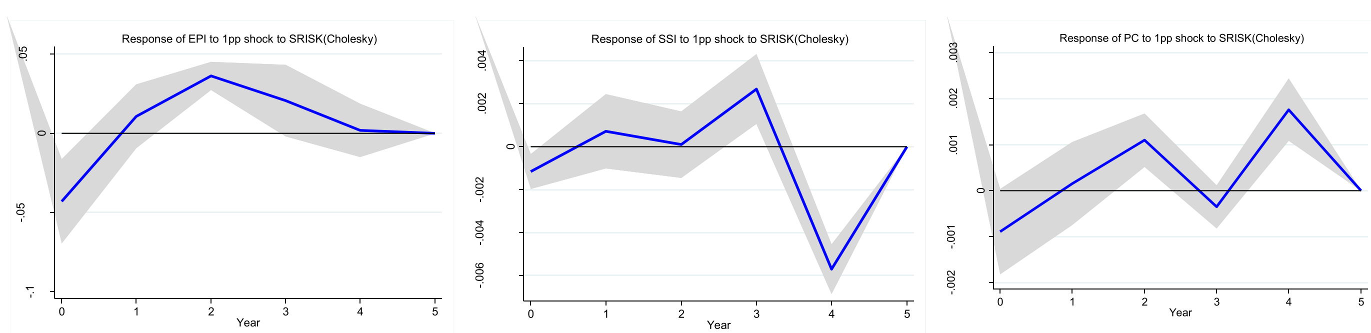
[6] However, in unreported results which are obtained when the whole panel is just divided into a sub-panel of high income countries (36) and the other sub-panel encompassing the rest of the economies (21), the EPI index consistently reduces economic uncertainty, but only in case of high income countries. The rest of the key linkages described in Section 4 hold under this alternative approach to splitting the whole panel. These additional results are available from the authors upon request.



a) FD index for sub-panel 1



b) FI sub-index for sub-panel 1



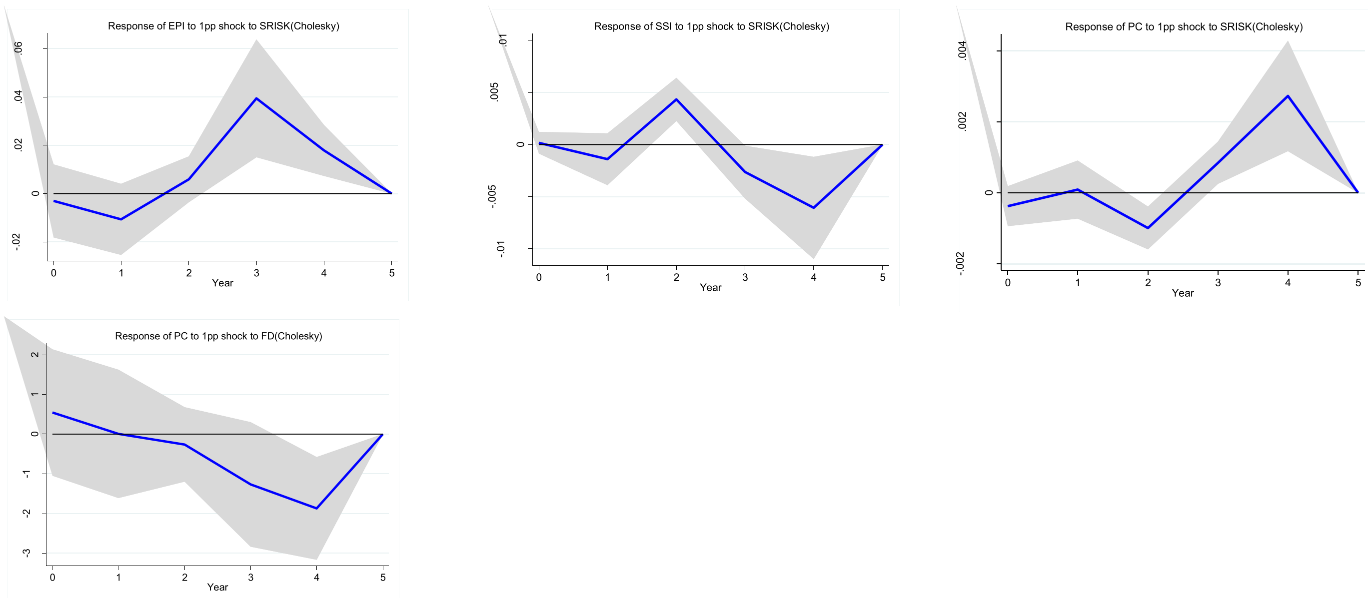
c) FM sub-index for sub-panel 1

Panel 2. a)-f). Impulse response functions with the FD index and FI, FM sub-indices for sub-panels 1 and 2, respectively.

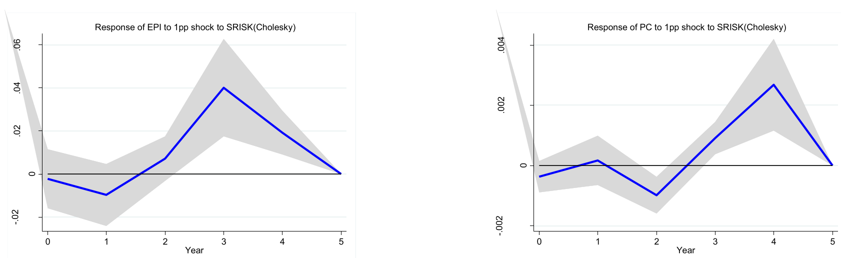
multiple individual metrics.

We conclude that the composite indicators of environmental performance are most strongly influenced by systemic risk, a proxy of financial instability. Across the majority of the environmental measures, an increase in systemic risk improves the environmental quality, though to the detriment of economic growth and energy consumption. There is also evidence that ex ante higher values of the EPI and PC indices help mitigate systemic risk.

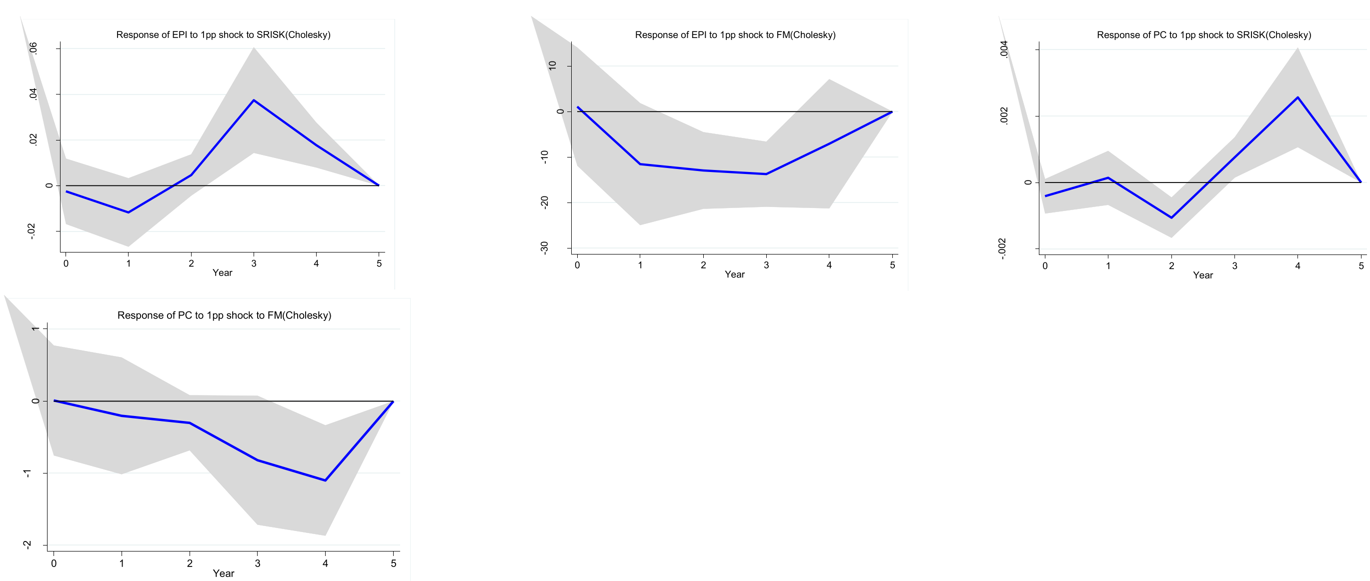
Financial development adversely affects environmental performance, since it is largely targeted at the incumbents in the non-financial industries which tend to adhere to "brown" technologies. Hence, more financial development implies more energy consumption, higher rates of economic growth, but also an increase in environmental degradation. Importantly, our empirical findings do not support the view that market-based financial development favors environmental quality. Conversely, we find that the sub-index of financial development accounting for



d) FD index for sub-panel 2



e) FI sub-index for sub-panel 2



f) FM sub-index for sub-panel 2

Panel 2. (*continued*).

markets leads to a deterioration in the composite indicators of environmental performance.

Since our analysis builds on the composite rather than granular measures, the findings appear more robust, which makes them more applicable in elaborating and implementing economic policies aimed at promoting environmental sustainability along with socioeconomic development. In this regard, our study clearly warns against certain trivial recommendations present in the literature.

However, we have to acknowledge that although the use of composite measures alleviates the curse of dimensionality, it does not completely resolve this problem, since we still come up with several potentially competing indicators. Horse races among the composite indicators of environmental performance and financial development could be conducted to identify a single most informative composite indicator for each dimension. Also, generalizing the existing composite measures by means of various dimensionality reduction techniques could be proposed. Besides, once a sufficient time series length is achieved, it would be feasible to assess the relationships for the post-Paris Agreement period, i.e. starting from the year 2016. These are plausible avenues for future research, enabling to further refine the findings obtained in our study.

Ethical approval

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all the authors.

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CRediT authorship contribution statement

Mikhail Stolbov: Writing – original draft, Supervision, Methodology, Investigation, Conceptualization. **Maria Shchepeleva:** Writing – original draft, Investigation, Formal analysis, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix

Table A1. List of countries

Argentina, Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, China, Colombia, Croatia, Cyprus, Czech Republic, Denmark, Egypt, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Israel, Italy, Japan, Kazakhstan, Lithuania, Malaysia, Mexico, Morocco, Netherlands, New Zealand, Norway, Pakistan, Peru, Philippines, Poland, Portugal, Qatar, Romania, Russia, Saudi Arabia, Slovakia, Slovenia, South Africa, South Korea, Spain, Sweden, Switzerland, Thailand, Turkey, Ukraine, United Arab Emirates, the UK, the USA, Vietnam.

Table A2
Brief description of the "beyond GDP" measures

Index	Description	Source
Environmental Performance Indicator (EPI)	The EPI index aggregates 40 performance indicators across 11 issue categories, including climate change performance, environmental health, and ecosystem vitality. It provides a summary of the state of economic sustainability for different countries.	Yale Center for Environmental Law and Policy Welcome | Environmental Performance Index (yale.edu)
Sustainable Society Index (SSI)	The SSI index shows the overall level of country' sustainability, summarizing information on human, environmental and economic well-being.Human well-being sub-index is based on three categories – basic needs, personal development and health and some characteristics of the well-balanced society. Environmental well-being includes the state of natural resources, climate and energy stance. Economic well-being is estimated based on transition to green economy characteristics and purely economic indicators, like GDP, employment and public debt.	TH Köln-University of Applied Sciences SSI by TH Köln (th-koeln.de)
Happy Planet Index (HPI)	The HPI is a measure of sustainable well-being, ranking countries by how efficiently they can guarantee happy lives to its population using limited environmental resources. It combines three elements: well-being (subjective estimate of the quality of life), life expectancy and ecological footprint.	New Economics Foundation The data over time – Happy Planet Index
Green GDP	Green GDP is a measure of economic growth, which accounts for environmental consequences of this growth. It takes into account the loss of biodiversity and costs caused by the climate change.	Stjepanovic et al. (2022)
Principal Component (PC)	The first principal component derived from the 4 composite indices of environmental performance: EPI, SSI, HPI and green GDP, by the use of Principal Component Analysis	Developed by the authors of the paper

Table A3
Descriptive statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
EPI	627	64.69	13.44	27.60	90.68
HPI	627	4.50	2.24	0.00	15.04
SSI	627	4.11	1.37	1.20	9.60
GREEN	627	26.61	22.20	0.89	95.73
PC	627	0.00	1.51	−3.31	4.72
SRISK	627	0.59	1.49	0.00	12.30
FD	605	0.55	0.21	0.15	0.99
FI	627	0.60	0.20	0.24	1.00
FM	627	0.49	0.24	0.02	0.97
UI	616	0.23	0.18	0.00	1.34

Table A4
Composition of sub-panels based on the K-means clusterization

Sub-panel 1	Sub-panel 2
Argentina, Brazil, Bulgaria, Chile, China, Colombia, Croatia, Cyprus, Czech Republic, Egypt, Hungary, India, Indonesia, Kazakhstan, Lithuania, Malaysia, Mexico, Morocco, Pakistan, Peru, Philippines, Poland, Portugal, Romania, Russia, Saudi Arabia, Slovakia, Slovenia, South Africa, Thailand, Turkey, Ukraine, Vietnam	Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Israel, Italy, Japan, Netherlands, New Zealand, Norway, Qatar, South Korea, Spain, Sweden, Switzerland, the United Arab Emirates, the UK, the USA

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