AUA Working Paper Series No. 2021-1
October 10, 2021

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Abstract :

This paper examines the links between globalisation and environmental policy stringency with the environmental terms of trade. The existence of dynamic links among the variables were explored using cross-correlations and Granger Causality tests. According to the results, the *de jure* and the *de facto* globalisation measures have different environmental impacts. Also, despite the fact that all V4 countries have introduced strict environmental policies, especially since 2000, the relative strength of these policies lag behind the maximum OECD stringency. As a result, the pollution heaven hypothesis cannot be excluded. The policy implications of the results are briefly discussed.

Keywords: Pollution Haven Hypothesis, Globalisation, Ecological Footprint of exports/ imports, Environmental Terms of Trade.

Acknowledgment: We wish to thank the Global Footprint Network for providing the unpublished data concerning the Ecological Footprint of exports and imports. A. Kampas wishes to thank the Department of Bioeconomy and Systems Analysis, Institute of Soil Science and Plant Cultivation, Puławy, for its hospitality.

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1) Introduction

International trade can detach production from consumption pressures on the environment. By doing so, trade may modify the pollution intensity of a country's output according to the stringency of the existing environmental policy (Copeland and Taylor 2003). Antweiler (1996) coined the term Pollution Terms of Trade (PTT) to describe an index that captures the pollution embodied in imports and exports.

Although there is a consensus that international trade improves the welfare of trading countries (Havrylyshyn 1990), its impact on the environment is often debated. Some scholars highlight the positive role of trade on the environment by facilitating the spread of cleaner and efficient technologies, see Tokito et al. (2016).

On the contrary, another strand of the scholarly literature emphasizes the fact that in some countries, natural resources are often under-priced and used inefficiently which exacerbates pollution problems (Chichilnisky 1994). If the prevailing institutional setting (i.e. strict environmental policies) induce pollution relocation, then we might have the case of a 'pollution haven hypothesis' (henceforth PHH). According to Copeland and Taylor (2003) a PHH refers to a region characterised by pollution intensive activities resulting from a relatively weak environmental policy.

Since trade openness represents the most commonly discussed dimension of globalisation (Arribas et al. 2009; Panić 2003), the ambiguous link between trade and environment produces an inconclusive association between globalisation and environment (Destek 2020; Leal and Marques 2019).

Against this background this paper examines the difficult issue concerning the impact of globalisation on the environment, as well as exploring the validity of the PHH for the Visegrad (V4) countries, namely Hungary, the Czech Republic, Slovakia, and Poland. The analysis spans the period from 1990 to 2014, a choice exclusively dictated by data availability. By virtue of the fact that common political and economic traits characterize the V4 countries, they are often examined as a group, see for example Nerudová et al. (2020), Melikhova et al. (2015) and Tereszkiewicz (2018). The V4 is an informal association that aims at deepening the cooperation in a broad spectrum of issues, such as culture, education, economy, foreign affairs, and shared identity (Braun 2020; Fawn 2013).

One novel element of this paper concerns the use of a new data set to define the environmental terms of trade. To our best knowledge, this is the first time that the ETT is assessed using the concept of ecological footprint. Another novel element of this paper is that it employs a recent approach, put forward by Narayan et al. (2016), to identify the dynamic association between two variables based on the cross-correlation estimates. The latter used in conjunction with the Granger Causality tests allows a thorough investigation of the possible association between two variables. We are unaware of any previous research that examines the links between globalisation, policy stringency and environmental terms of trade using a similar approach.

The analysis provides mixed evidence concerning the impact of globalisation on the environment. At the same time, the introduction of strict environmental policies does not necessarily trigger pollution relocation. A PHH might be possible only if the introduced policies considerably lag behind the policy stringency applied by other countries.

The structure of the paper is as follows. The next section presents the representative evidence of the related literature. Section 3 presents the data employed and the stylized facts for the V4. Section 4 briefly discusses the methodology and the results are discussed in section 5. The final section, six, gives the summary and concludes the paper.

2) Literature Review

The empirical evidence concerning the impact of trade and globalisation on the environment and the possibility of a PHH is controversial. Cole (2004) found evidence for the PHH between certain trading nations and during certain periods. Michida and Nishikimi (2007) confirmed that the PHH is a valid hypothesis and the pollution-intensive industries relocate from the tightly regulated North to the leniently regulated South.

Kellenberg (2008) found evidences in favour of the PHH, but these were conditional on the type of pollution examined. Likewise, Baek et al. (2009) provide evidence in favour of the PHH for the SO_2 emissions. Aklin (2016) argued that developing countries emit relatively more carbon dioxide emissions, whereas, at the same time, the diffusion of cleaner technologies cannot offset this surplus of CO_2. Mixed evidence are also provided by (Rosado-Anastacio 2020) and (Halliru et al. 2020).

By stark contrast, Kearsley and Riddel (2010) rejected the PHH because of negligible evidence concerning the correlation of high emissions and trade openness. In addition, the results provided by Grether et al. (2012) question the robustness of the PHH, while Hille (2018) did not find any support for a PHH (i.e. the one related to CO2 emissions). Damania et al. (2004) argue that the level of a country's corruption determines whether globalisation has an impact on environmental policy stringency, and consequently on the possibility of PHH. Aşici and Acar (2015) argue that while environmental policy stringency modifies domestic production, is not likely to modify the composition of imports.

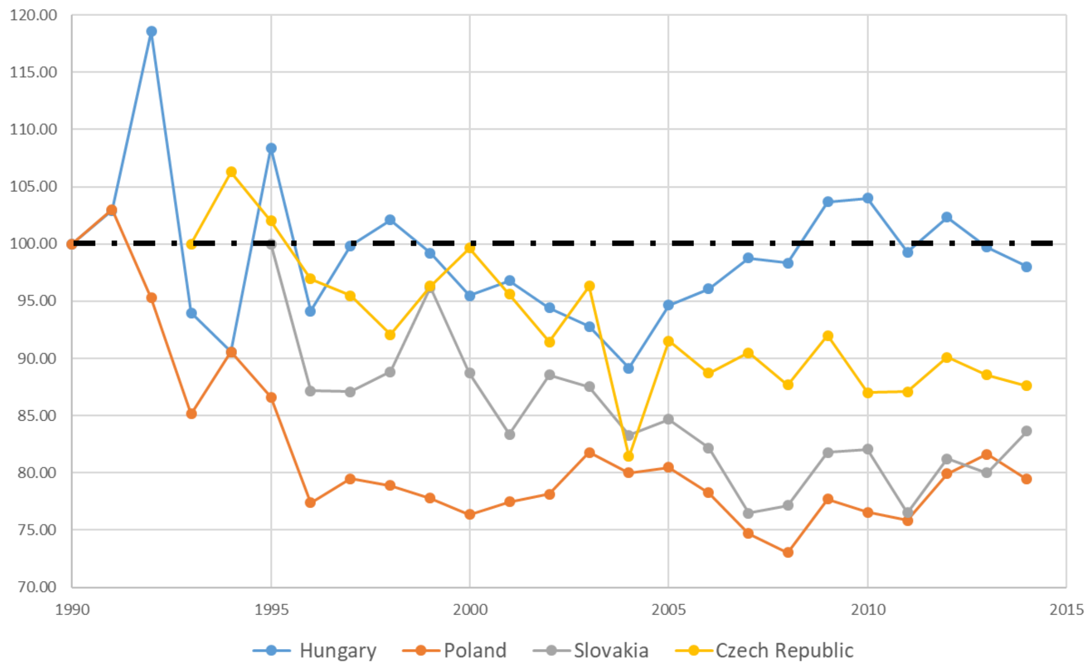
3) Data and Stylized Facts

In line with Muradian et al. (2002), this paper adopts the term of "environmental terms of trade" (ETT) which is an extension of the pollution terms of trade. ETT is defined as the ratio of the environmental pressures embodied in exports (EPE) over the environmental pressures embodied in imports $\left(EPI\right)$, $ETT = EPE/EPI$. Precisely, the paper uses the concept of ecological footprint as a proxy for the environmental pressures. According to Weinzettel et al. (2014) the ecological footprint is an indicator of human requirements on bio-productive land that is necessary to produce all the resources a country consumes and to absorb the waste it generates. Therefore, the ecological footprint of exports (EFE) refers to the ecological footprint embodied in domestically produced products but consumed by other countries. Likewise, the ecological footprint of imports (EFI) refers to the footprint embodied in the domestically consumed products but produced abroad.

A country i achieves environmental gains through trade if $ETT_i < 1 \Rightarrow EFE_i < EFI_i$. By contrast, if $ETT_i > 1 \Rightarrow EFE_i > EFI_i$ this country suffers environmental losses through trade. By definition, a declining value of $ETT_i = EPE_i/EPI_i \downarrow$ requires either a declining $EFE_i \downarrow$ or an increasing $EFI_i \uparrow$ or both. In all cases, international trade reduces the ecological footprint of the country in question, or put differently, the specific country gains environmentally through trade. The Global Footprint Network provided the data for the ecological footprints of exports and imports [1]. Figure 1 displays the proportional changes of ETT for the V4 countries during the examined period.

[1] https://www.footprintnetwork.org/about-us/contact/

Figure 1: The Evolution of ETT for the V4 countries (1990-2014)



From Figure 1 it is evident that international trade is environmentally beneficial for Poland, Slovakia and the Czech Republic. The case of Hungary is inconclusive.

In turn, this paper deploys the versions of the KOF Globalisation Index (GI)[2], namely the *de facto* and the *de jure* ones (Yashodha et al. 2018). Figge et al. (2017) found that the GI significantly determines the ecological footprint of trade. The GI combines several variables that capture the social, economic and political dimensions of globalisation. In particular, the *de facto* GI measures the actual international flows and trade activities, while the *de jure* GI focuses on conditions that, in principle, make possible these flows and trade activities. Data on the KOF GI indices were taken from Gygli et al. (2019). Figure 2 depicts the de facto GI Index for the V4 countries during the examined period, while the *de jure* GI index is outlined to Figure 3.

[2] KOF stands for Konjunkturforschungsstelle (Economic Research Center)

Figure 2: The *de facto* GI Index for the V4 countries

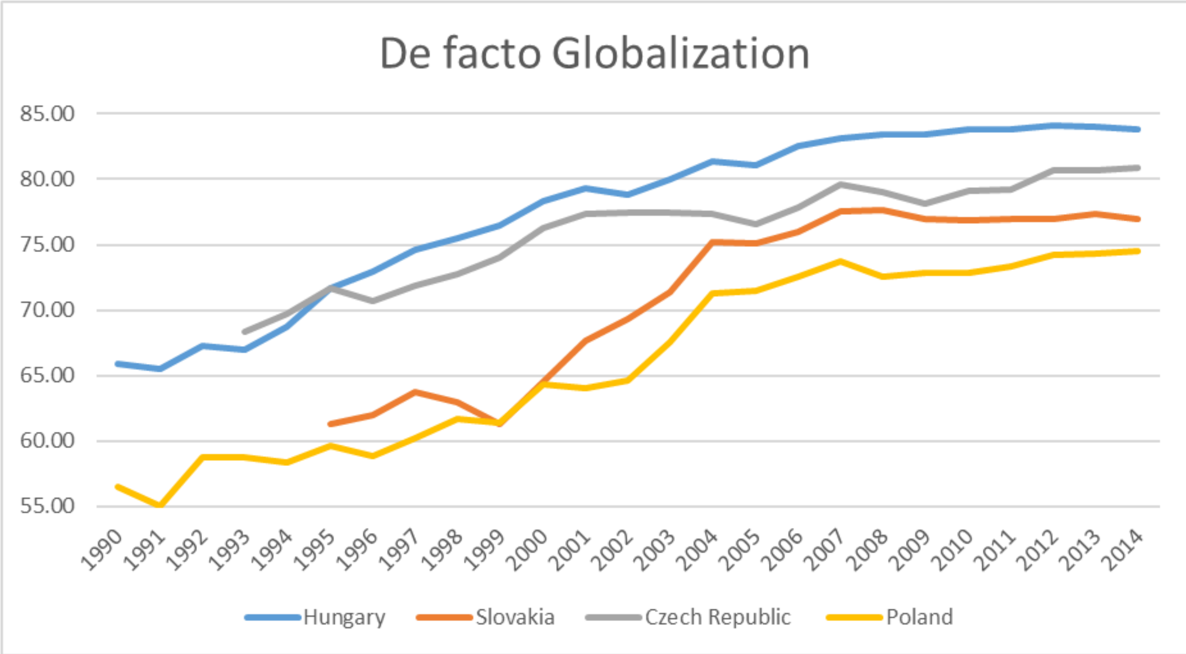
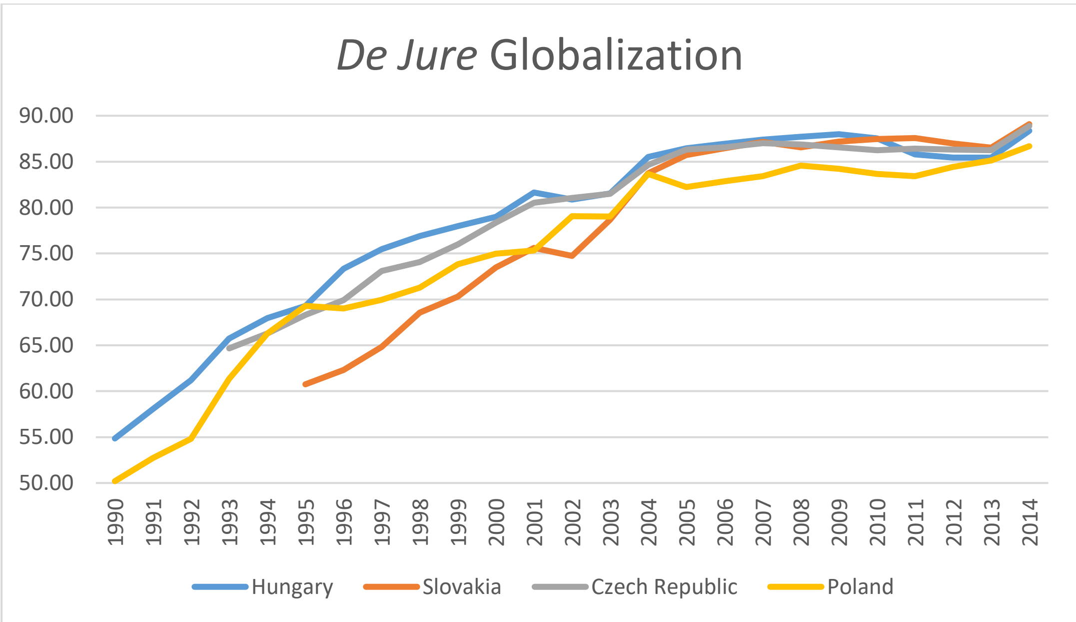


Figure 3: The *de Jure* GI Index for the V4 countries

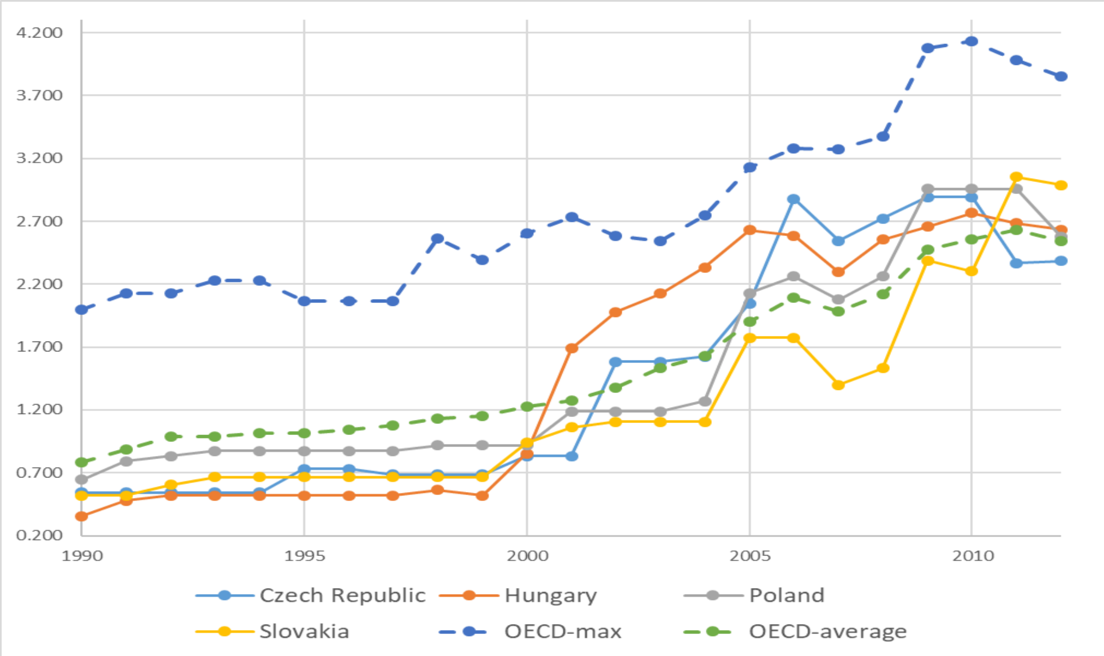


From Figure 2 and Figure 3, it is evident that both GI indices increase over time. The evolution of the *de facto* GI implies that V4 countries retain their relative positions concerning the economic integration. For the examined period, Hungary is the most globalized country while Poland is the least globalized one. On the contrary, the *de jure* GI evolves in a similar way for all the countries, which indicate that the V4 countries follow common policies.

Finally, the paper takes into account the OECD Environmental Policy Stringency Index (EPS). The EPS is defined as the degree to which environmental policies put an explicit or implicit price on polluting or environmentally harmful behaviour. The index ranges from 0 to 6, where high values indicate high policy stringency. The index takes into account 14 environmental policy instruments, primarily related to climate and air pollution (Botta and Koźluk 2014). Data on the EPS were drawn from the OECD web page[3]. The following Figure 4 depicts how the EPS has evolved for the V4 countries. To facilitate the comparison, Figure 2 includes two OECD constructs, namely the average and the maximum for the OECD countries (excluding the V4 countries).

[3] https://stats.oecd.org/Index.aspx?DataSetCode=EPS.

Figure 4: The Evolution of EPS for the V4 countries compared to OECD average and max values (1990-2014)



From Table 4, it seems that policy stringency for the V4 converges, through time, with the average OECD value. Hungary had the stricter environmental policies of all V4 between 2000 and 2005, but since then its other countries have introduced more severe policies. Slovakia, on the other hand, has been fell behind but since 2010 it has the most stringent environmental policy. Although the discrepancies between the maximum OECD value and the individual V4 scores are declining through time, they are significant.

4) Methodology

In order to examine the links between the Environmental Terms of Trade, Globalisation and Environmental Policy Stringency, the paper applies two different methodologies. First, the analysis follows a recent proposal by Narayan et al. (2016), which is based on the cross-correlation (CC) to assess the dynamic relationship between two variables.

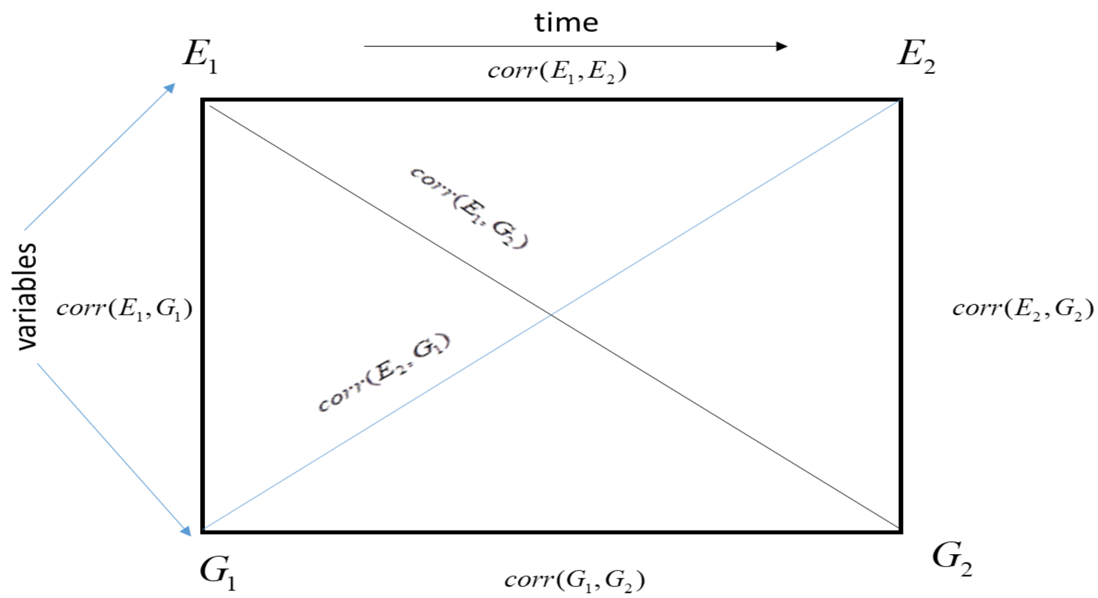
The CC is a common method for estimating the association of two time-variant events over some time intervals, by shifting time (time reversal) and repeatedly calculating the correlation between current values in one vector with the past (or future) values in another vector. Essentially, a sequential match of measurements is selected from each time series, such that both vectors contain the same number of occasions, and then the Pearson correlation is calculated for these two vectors (Boker et al. 2002).

The typical CC coefficient between the proxy of globalisation, G_t and the pollution terms of trade, E_t can be written as (Jammazi and Aloui 2015):

$$CC_{E_tG_t}(k) \equiv corr(E_t, G_{t-k}) = \frac{\sum_{t=1}^{n-k}\left(G_t - \bar{G}\right)\left(E_{t+k} - \bar{E}\right)}{\sqrt{\sum_{t=1}^{n-k}\left(G_t - \bar{G}\right)^2\left(E_{t+k} - \bar{E}\right)^2}} \quad (1)$$

where $t = 1,...,n$ indicates time and k the number of lags. Also, $\bar{G}$ and $\bar{E}$ stand for average values. If $k = 0$ then the $CC_{E_tG_t}(0)$ is the synchronous correlation between the variables (the Pearson correlation coefficient). Otherwise, when $k = 1$ the $CC_{E_tG_t}(1)$ refers to the correlation between G_t and E_{t+1} (lead or future value), while if $k = -2$ the $CC_{E_tG_t}(-2)$ stands for the correlation between G_t and E_{t-2} (lag value). The following Figure 5, drawn from (Locascio 1982), illustrates the rationale of the CC analysis.

Figure 5: The Cross-correlation model (2variables-2periods)



There are six correlation coefficients in Figure 5: two synchronous, $corr(E_1, G_1)$ and $corr(E_2, G_2)$, two auto-correlations $corr(E_1, E_2)$ and, $corr(G_1, G_2)$ and two cross (lagged) correlations $corr(E_1, G_2)$ and $corr(E_2, G_1)$. The likely causality is inferred by comparing the two cross-lagged correlations (Anderson and Kida 1982). Suffice to say that Figure 5 can be very complex if the number of variables and the time steps increase, see Zyphur et al. (2020).

Following Narayan et al. (2016) a positive lag cross-correlations, $CC_{E_tG_t}(k<0)>0$, in conjunction with negative future cross-correlations, $CC_{E_tG_t}(k>0)<0$, provide evidence of a Kuznets type relationship. Likewise, the case of $CC_{E_tG_t}(k<0)<0$ and $CC_{E_tG_t}(k>0)>0$ indicates a reverse Kuznets type link. Shahbaz et al. (2019) use this procedure to examine the link between globalisation and energy consumption.

In turn, Granger causality test (GCT) complements the cross-correlation analysis, as it is often applied in the scholarly literature (Kong and Feng 2019) (Kuiper and Ryan 2018). The GCT was proposed by Granger (1969) and since then, it is routinely discussed in the relevant textbook (see for example Hamilton (1994)). Following Agung (2009), a bivariate vector autoregressive (VAR) model (without exogenous variables) can illustrate the rationale of a GCT test:

$$E_t = a_0 + \sum_i^p a_i E_{t-i} + \sum_i^p \beta_i G_{t-i} + \varepsilon_{1t} \qquad (2)$$

$$G_t = \delta_0 + \sum_i^p \gamma_i G_{t-i} + \sum_i^p \delta_i E_{t-i} + \varepsilon_{2t} \qquad (3)$$

where ε_{1t} and ε_{2t} are the error terms, $a_0, a_i, \beta_i, \delta_0, \gamma_i, \delta_i$ are the model's parameters , p represents the optimal lag length and t stands for the time. The optimal lag length is chosen on basis of the Akaike Information Criterion (AIC) (Hsiao 1979). The variable E is said to (Granger) cause the variable G , if G can be better predicted using the lagged values of both variables E and G , as opposed to using only the history of G . The null hypothesis states that E does not Granger-cause G . In order to test whether variable E (Granger) causes variable G, the following hypothesis has to be tested $H_0 : \delta_1 = \delta_2 = ... = \delta_p = 0$ & $H_1 = Otherwise$. Likewise, testing if variable G (Granger) causes variable E, the following hypothesis has to be tested $H_0 : \beta_1 = \beta_2 = ... = \beta_p = 0$ & $H_1 = Otherwise$.

5) Results and discussion

This section presents the results of the empirical analysis. The following Table 1 shows the results for the cross-correlations analysis between ETT and *de-facto* GI.. To avoid spurious correlations all data series were de-trended using the Hodrick-Prescott filter. Minitab® has automatically chosen the appropriate number of lags.

Table 1: Cross-correlation results between ETT and *de facto* GI

Lag/leads	Poland	Hungary	Czech Republic	Slovakia
-15	0.261	0.289		
-14	0.184	0.214	0.337	0.479*
-13	0.090	0.128	0.314	0.393
-12	-0.012	0.036	0.275	0.310
-11	-0.116	-0.060	0.222	0.295
-10	-0.216	-0.158	0.157	0.267
-9	-0.310	-0.254	0.086	0.118
-8	-0.397*	-0.347	0.008	-0.015
-7	-0.476*	-0.434*	-0.084	-0.136
-6	-0.543*	-0.514*	-0.193	-0.265
-5	-0.594*	-0.586*	-0.315	-0.411
-4	-0.630*	-0.651*	-0.447*	-0.569*
-3	-0.655*	-0.707*	-0.580*	-0.677*
-2	-0.671*	-0.754*	-0.709*	-0.749*
-1	-0.684*	-0.794*	-0.839*	-0.796*
0	**-0.691***	**-0.825***	**-0.980***	**-0.821***
1	-0.488*	-0.651*	-0.820*	-0.597*
2	-0.309	-0.484*	-0.659*	-0.388
3	-0.160	-0.328	-0.512*	-0.240
4	-0.042	-0.185	-0.387	-0.087
5	0.052	-0.055	-0.280	0.005
6	0.122	0.058	-0.180	0.084
7	0.171	0.154	-0.073	0.188
8	0.204	0.232	0.040	0.284
9	0.225	0.291	0.144	0.320
10	0.236	0.333	0.228	0.341
11	0.241	0.357	0.290	0.347
12	0.243	0.364	0.327	0.334
13	0.244	0.357	0.350	0.299
14	0.245	0.338	0.362	0.239
15	0.243	0.308		

*-statistical significant at 5%

There are some notable differences within the V4 countries as emerge from Table 1. The synchronous correlations provide evidence that an increase in *de-facto* globalisation results in a decline in the ETT. Consequently, it is possible that *de-facto* globalisation is likely to bring environmental gains for the V4 countries. The strength of such an association between ETT and *de-facto* GI can be traced on the values of zero-order correlation ($k = 0$, or synchronous correlation). For the Czech Republic, Hungary and Slovakia this link is very strong, while for Poland the link is strong. A notable difference between the V4 countries is that Poland and Hungary display considerable more statistical significant lags compared to the Czech Republic and Slovakia.

The static nature of the estimates in Table 1 does not provide any guidance concerning the future links between the examined variables (Narayan et al. 2016). The search for the likely dynamic relationship requires the aggregation of these estimates. Table 2 does that, by presenting the sum of correlations and the average correlations from Table 1.

Table 2: Sum and average CC results between ETT and *de facto* GI.

		Poland	Hungary	Czech Republic	Slovakia
lag	sum	-0.875	-4.592	-3.918	-0.875
	average	-0.062	-0.306	-0.135	-0.062
lead	sum	-0.166	1.088	-1.169	-0.166
	average	-0.012	0.073	-0.084	-0.012

Consistency is the first thing that we need to examine in Table 2. As Narayan et al. (2016) argue, consistency requires that the sum of correlations and the average correlation should have the same sign. This is true for both lags and leads in both correlations, which means that the changes in *de facto* globalisation induce a consistent pattern of changes in the pollution terms of trade in all countries. Since $CC_{E_tG_t}\left(k<0\right)<0$ is negative and, $CC_{E_tG_t}\left(k>0\right)>0$ is positive, it means that the *de facto* globalisation has reduced the ETT in the past for Hungary but will increase them in the future. That means that (*de-facto*) globalisation will bring environmental losses to Hungary in the future. By stark contrast, for Poland, the Czech Republic and Slovakia the *de facto* globalisation has reduced the ETT and will do the same in the future. Likewise, the following Table 3 presents the results for the cross-correlations analysis between ETT and de-jure GI.

Table 3: Cross-correlation results between ETT and *de jure* GI

Lag/leads	Poland	Hungary	Czech Republic	Slovakia
-15	0.229	0.295		
-14	0.186	0.225	0.366	0.350
-13	0.134	0.145	0.368	0.368
-12	0.077	0.057	0.348	0.374
-11	0.014	-0.036	0.303	0.362
-10	-0.052	-0.131	0.234	0.323
-9	-0.121	-0.226	0.150	0.254
-8	-0.191	-0.319	0.054	0.155
-7	-0.263	-0.408*	-0.053	0.031
-6	-0.334	-0.491*	-0.170	-0.106
-5	-0.407*	-0.569*	-0.297	-0.251
-4	-0.487*	-0.639*	-0.432*	-0.401
-3	-0.579*	-0.703*	-0.572*	-0.557*
-2	-0.681*	-0.759*	-0.711*	-0.711*
-1	-0.788*	-0.807*	-0.851*	-0.864*
0	**-0.896***	**-0.848***	**-0.994***	**-0.975***
1	-0.664*	-0.674*	-0.836*	-0.812*
2	-0.451*	-0.508*	-0.689*	-0.679*
3	-0.271	-0.351	-0.551*	-0.558*
4	-0.126	-0.205	-0.429*	-0.428*
5	-0.012	-0.074	-0.322	-0.284
6	0.072	0.042	-0.216	-0.139
7	0.127	0.142	-0.102	0.002
8	0.161	0.223	0.021	0.137
9	0.179	0.286	0.137	0.258
10	0.187	0.330	0.234	0.353
11	0.191	0.357	0.305	0.415
12	0.197	0.366	0.343	0.439
13	0.207	0.361	0.363	0.428
14	0.224	0.342	0.370	0.394
15	0.241	0.314		

*-statistical significant at 5%

The results presented in Table 3 are quite similar to those in Table 2. Here, the difference is that zero-order correlations indicate a very strong association between ETT and *de-jure* GI for all the V4 countries. Table 4 illustrates that the results are consistent for all countries since the averages and the sums have the same sign for both lags and leads.

Table 4: Sum and average CC results between ETT and de jure GI

		Poland	Hungary	Czech Republic	Slovakia
lag	sum	-3.263	-4.365	-1.263	-0.673
	average	-0.218	-0.291	-0.090	-0.048
lead	sum	0.263	0.951	-1.372	-0.475
	average	0.018	0.063	-0.098	-0.034

For Hungary and Poland the *de-jure* globalisation has reduced the environmental terms of trade in the past but will increase them in the future, since $CC_{E_tG_t}(k<0)<0$ is negative and, $CC_{E_tG_t}(k>0)>0$ is positive. In other words, the *de-jure* globalisation will bring environmental losses to these countries in the future. By contrast, the *de-jure* globalisation seems to have been environmentally beneficial (and will be in the future) for the Czech Republic and Slovakia since $CC_{E_tG_t}(k<0)<0$ and, $CC_{E_tG_t}(k>0)<0$ are negative.

The last issue to examine is the likely link between ETT and policy stringency, which is displayed in the following table.

Table 5: Cross-correlation results between ETT and EPS

Lag/leads	Poland	Hungary	Czech Republic	Slovakia
-14	0.118	0.429	0.471*	0.479*
-13	-0.064	0.369	0.517*	0.393
-12	-0.198	0.291	0.459*	0.310
-11	-0.288	0.185	0.352	0.295
-10	-0.382	-0.002	0.246	0.267
-9	-0.438*	-0.203	0.148	0.118
-8	-0.463*	-0.372	-0.035	-0.015
-7	-0.479*	-0.517*	-0.202	-0.136
-6	-0.488*	-0.632*	-0.367	-0.265
-5	-0.497*	-0.718*	-0.510*	-0.411
-4	-0.505*	-0.774*	-0.627*	-0.569*
-3	-0.508*	-0.803*	-0.712*	-0.677*
-2	-0.514*	-0.806*	-0.777*	-0.749*
-1	-0.515*	-0.790*	-0.841*	-0.796*
0	**-0.524***	**-0.768***	**-0.882***	**-0.821***
1	-0.359	-0.592*	-0.735*	-0.597*
2	-0.202	-0.423*	-0.581*	-0.388
3	-0.066	-0.262	-0.401	-0.240
4	0.046	-0.115	-0.236	-0.087
5	0.122	0.013	-0.094	0.005
6	0.177	0.121	0.030	0.084
7	0.219	0.214	0.170	0.188
8	0.244	0.287	0.262	0.284
9	0.241	0.335	0.325	0.320
10	0.233	0.363	0.372	0.341
11	0.222	0.373	0.404	0.347
12	0.211	0.364	0.378	0.334
13	0.196	0.335	0.345	0.299
14	0.184	0.296	0.300	0.239

*-statistical significant at 5%

Looking at the values of the zero-order correlations, the likely association between ETT and EPS is very strong for Hungary, the Czech Republic and Slovakia, while such a link is moderate for Poland. The negative sign indicates that, as the environmental policy becomes stringer, the ETT declines, meaning that trade brings environmental benefits.

Table 6: Sum and average CC results between ETT and EPS

		Poland	Hungary	Czech Republic	Slovakia
lag	sum	-5.22	-4.343	-1.880	-1.756
	average	-0.37	-0.310	-0.134	-0.125
lead	sum	1.47	1.309	0.540	1.128
	average	0.10	0.093	0.039	0.081

The results in Table 6 are again consistent. Since $CC_{E_tG_t}\left(k<0\right)<0$ is negative and, $CC_{E_tG_t}\left(k>0\right)>0$ is positive, for all the V4 countries the environmental stringency will bring environmental losses in the future. The latter is an indication that the PHH "pollution haven hypothesis" is valid for the V4 countries. However, such an observation needs some careful interpretation. It does not imply a stricter environmental policy will bring about environmental losses. Comparing the long run averages in the EPS's values for the OECD (see Figure 4), it is evident that while environmental policy is getting stricter for all OECD countries though time, this is a heterogeneous phenomenon. Despite the fact that environmental policy stringency seem to converge for the V4 countries, it lags behind the stricter OECD countries. In other words, it is the relative strictness of environmental policies that drive the PHH and not the evolution of the environmental policy within a country.

Additionally, the paper applies the GCT to examine the causality structure of the data. Since GCT requires the stationarity of the data, we used the augmented Dickey–Fuller (ADF) (Dickey and Fuller 1979), and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) (Kwiatkowski et al. 1992) tests. The ADF test checks the null hypothesis that a time series is I(1), which means that the process contains a unit root and therefore is non-stationary, against the alternative hypothesis that the process is stationary. KPSS test, on the other hand, tests the null hypothesis that a time series is stationary (I(0)) against the hypothesis that the process is not stationary. Taking into account the properties of the analysed series, ADF and KPSS tests are carried out by including a constant for ETT and by including a constant and trend for *de-facto* GI, *de-jure* GI and EPS. Table A1 in the Appendix presents the results of the ADF unit root test and the KPSS stationarity test.

The combination of ADF and KPSS tests suggest that the analysed time series are integrated of order 1 (I(1)). We obtain the stationary processes by applying the first difference of the log values of the original series. The Granger causality test require a vector autoregressive model (VAR) to be fitted to the variables. The optimal lag length for the VAR model is chosen based on the estimated Akaike Information Criterion (AIC). The maximum lag length is set to 4. The results for lag length tests are given in Table A2 in the Appendix. Table 7 presents the estimated Wald test statistics, which is asymptotically chi-square distributed with *p* degrees of freedom. The degrees of freedom are calculated based on the selected lag order in VAR models (see Table A2). The first column in Table 7 lists the dependent variable while the second column lists the proposed predictor variable for a given VAR.

Table 7: The Results of the Granger causality tests

dependent variable (Y)	predictor variable (X)	Czech Republic	Hungary	Poland	Slovakia
ETT	de facto GI	0,34	12,86**	7,94*	4,41
de facto GI	ETT	4,61**	7,09	6,56	2,74
ETT	de jure GI	0,28	2,20	10,97**	12,34***
de jure GI	ETT	0,04	3,4	2,51	5,94
ETT	EPS	10,41***	2,15	0,45	2,07
EPS	ETT	0,43	0,42	0,36	13,51***

Null hypothesis H0: X does not Granger-cause Y.
Note. *** H0 is rejected at 1%, ** at 5%, and *at 10% significance level.

Although the GCT may examine the bi-directional causality structure in the data, the paper's purposes restrict our attention to whether (lag) variations in the GI-DF, GI-DJ and EPS may explain the heterogeneity of ETT. So, concerning GI-DF, from Table 7 we observe that the null hypothesis is rejected for Hungary and Poland. In other words, there is a causality link between the *de facto* GI and ETT $GI-DF \rightarrow ETT$. By contrast, the null hypothesis, concerning the GI-DJ, is rejected for Poland and Slovakia, which indicates that for these countries we have a causality of the form $GI-DJ \rightarrow ETT$. Finally, concerning the environmental policy stringency (EPS), only for the Czech Republic the null hypothesis is rejected, indicating $EPS \rightarrow ETT$.

The following Table 8 summarizes the major results from GCT and CC analyses in order to recapitulate the main insights provided.

Table 8: Summary results

	Czech Republic	Hungary	Poland	Slovakia
1) Association (Zero Order Correlation)				
de facto GI	very strong	strong	moderate	strong
de jure GI	very strong	strong	strong	very strong
EPS	strong	strong	moderate	strong
2) Causality (Granger Causality Test)				
de facto GI		V	V	
de jure GI			V	V
EPS	V			
3) Dynamic Links (Cross Correlation Analysis)				
de facto GI	-	+	-	-
de jure GI	+	+	-	-
EPS	+	+	+	+

The first three lines present the synchronous correlation coefficients among the de *facto* GI, *de jure* GI, and EPS with the ETT. In all cases, there is clear negative association among globalisation indices and environmental policy stringency with the environmental terms of trade. That means that an increase in globalisation, either *de facto* or *de jure*, and in the environmental policy stringency are likely to bring environmental benefits in all countries.

Then, we examine the causality links with the help of GCT. From the next three lines in Table 8, we observe that *de facto* GI determines the ETT in the cases of Hungary and Poland, while the *de jure* GI affects the ETT of Poland and Slovakia. Gräbner et al. (2021) also found that *de facto* and *de jure* globalisation might diverge. A possible explanation might be the existing level of a country's globalisation. As Leal and Marques (2019) argue that in high globalized countries the *de jure* GI dominates the *de facto* GI and vice versa for the low globalized countries. On the contrary, strict environmental policies seem to bring environmental gains, through changes in ETT, only in the case of the Czech Republic.

Finally, using the insights from the cross-correlation analysis, the issue whether globalisation is going to bring environmental benefits is indeterminate. For example, *de facto* GI seems to induce environmental improvements in the Czech Republic, Poland, and Slovakia, while *de jure* GI brings environmental benefits to Poland and Slovakia but deteriorates the environment of the Czech Republic and Hungary. At last, strict environmental policies will bring environmental losses for all the V4 countries. Obviously, this very peculiar result, which echoes the rationale of the PHH. As Figure 3 depicts, while V4 countries have introduced strict environmental policies with increasing pace since 2000, the relative stringency of these policies evolve around the average OECD strictness. That means that other countries apply considerably more stringent policies. Thus, the hypothesis of a PHH cannot be excluded.

6) Conclusions

This paper examines whether globalisation and environmental policy stringency affects the environmental terms of trade. To our best knowledge, this is the first time that an analysis examines the dynamic links between environmental terms of trade and globalisation, as well as policy stringency. The article, using cross correlation and Granger causality tests, derives a set of results that the *de jure* and the *de facto* globalisation measures have different environmental impacts. The policy implications of such an observation are profound. Globalisation may be good or bad for the environment depending on how much globalized a country is and what measures it uses (*de jure* vs *de facto*). Put it in another way, against the conventional wisdom that blames globalisation for undermining sustainable development, the evidence is mixed.

In addition, while all the V4 countries have introduced stricter environmental policies, especially since 2000, the policies' relative strength fell behind compared to OECD countries. As a result, the pollution heaven hypothesis cannot be excluded. Again the policy implication is clear, if you want to accomplish (local) environmental gains through trade, you have to introduce more stringent environmental policies, and precisely stricter than the average prevailing ones.

At last, few words about the limitations of this study are necessary. It should be stressed that the results derived by the Granger causality test are conditional to sample size; hence, the limited period of this analysis may have produced biased results. Further analysis is needed to address this issue.

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APENDIX

Table A1: The ADF and KPSS stationarity tests

ADF test[1]				
indicators	Czech Republic	Hungary	Poland	Slovakia
level				
ETT	-2,46	-1,79	-2,75*	-1,39
de facto GI	-2,12	0,05	-1,86	-0,56
de jure GI	-1,12	-1,01	-,94	-0,84
EPS	-3,07	-2,21	-1,87	-2,32
first difference				
ETT	-8,07***	-5,51***	5,02***	-5,16***
de facto GI	-4,33**	-3,92**	-6,03***	-4,57**
de jure GI	-3,20	-4,55***	-4,84***	-3,54*
EPS	-4,22**	-2,83	-3,55*	-5,25***
KPSS test[2]				
indicators	Czech Republic	Hungary	Poland	Slovakia
level				
ETT	0,58**	0,21	0,47**	0,67**
de facto GI	0,18**	0,20**	0,10	0,13*
de jure GI	0,17**	0,19**	0,18**	0,16**
EPS	0,11*	0,09	0,15**	0,17**
first difference				
ETT	0,18	0,19	0,35*	0,50**
de facto GI	0,16**	0,13**	0,11	0,11
de jure GI	0,10	0,09	0,06	0,13*
EPS	0,14*	0,13*	0,14*	0,39**

[1] ADF test null hypothesis H_0: there is a unit root for the series. The series is non-stationary.
[2] KPSS test null hypothesis H_0: the series is stationary.
Note. *** H_0 is rejected at the 1%, **5%, and *10% significance level.

Table A2. VAR lag order selection

lag order			1	2	3	4
GLDF, ETT	Czech Republic	AIC	-7,71*	-7,43	-7,17	-7,66
	Hungary	AIC	-7,33	-7,57	-7,54	-7,96*
	Poland	AIC	-6,91	-6,57	-6,82	-7,27*
	Slovakia	AIC	1,69	1,52	1,63	0,99*
GLDJ, ETT	Czech Republic	AIC	-7,13*	-6,79	-6,46	-6,34
	Hungary	AIC	-6,27	-6,51*	-6,46	-6,23
	Poland	AIC	-6,93	-7,20	-7,22*	-6,89
	Slovakia	AIC	-6,49	-6,76	-7,31*	-7,05
EPS, ETT	Czech Republic	AIC	-1,40	-1,78*	-1,40	-1,35
	Hungary	AIC	-1,74	-2,60*	-2,46	-2,21
	Poland	AIC	-2,64*	-2,49	-2,61	-2,61
	Slovakia	AIC	-1,40	-2,24	-2,63	-3,60*

Note. *indicates lag order selected by the Akaike Information Criterion (AIC).