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Sustainability spillover effects and partnership between East Asia & Pacific versus North America: interactions of social, environment and economy

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Abstract

The three sustainability pillars of social, environment and economy were initially introduced by the United Nations in 2002, addressing major global sustainability issues including economic problems, income inequality, environmental pollution and social shortcomings. Comparing East Asia & Pacific with North America, there is a growing concern over economic, political and even social competition as a result of recent development and industrialization that is taking place in Asian countries. This might lead to an unhealthy conflict that favors regional independency as opposed to the current globalization and trade facilitation trend. As a result, this study aims to assess the effects of development in three main pillars of sustainability (social, environment and economy) in the East Asia and Pacific on that of North America and vice versa. To estimate this interactive or spillover effects of sustainable development (or sustainability elasticities), our research employs Econometric methodologies including Simultaneous Equations System, Vector AutoRegressive (VAR) and Granger Causality approaches during 1971–2016. The results show that most of the sustainability elasticities are positive between and inside the two regions, supporting the synergetic character of the sustainability spillover effects and confirming constructive role of globalization and openness in the sustainability progress. Based on the results, this research suggests policy-makers to follow cooperative and flow-based governance rather than the placed-based or regional independent thinking that supports integrated sustainable development benefiting not only the two parties but also the overall global sustainability.

Keywords Sustainability · Sustainable development · Spillover effect · Partnership · Peace · Globalization · Openness

JEL Code O19 · O24 · O21 · Q52 · Q56

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1 Introduction

The three pillars of sustainability, initially introduced by the United Nations in 2002 and 2015, respectively, are a comprehensive united manifesto to address the major global sustainability issues including economic problems, income inequality, environmental pollution and social concerns (Allen et al. 2019; Fullman et al. 2017; Hák et al. 2016; Lyytimäki et al. 2020; Nilsson et al. 2016; Nodehi and Taghvaei 2021a; Smith et al. 2018; Taghvaei et al. 2021). The development of such goals is a response to polarization of different regions in the world, often sharing the same issues such as the ever-increasing population, environmental degradation and social issues (Liu et al. 2020).

Depending on the global regions, the condition, development, and issues might vary, yet, in all forms, both the industrialized and un-industrialized regions often experience the same issues such as poverty, social issues and environmental pollution. As such, around 23% of the world mortalities are from the environmental issues (annually 12.6 million deaths) with Asia having the highest reported cases (WHO 2018). In the same way, the top 8 greenhouse gas emitters in 2019 are China, US, Japan, South Korea, Iran, Saudi Arabia, and Canada, located either in Asia & Pacific or in North America (Amin et al. 2020). With both of the continents are competing for economic growth in two distinctive polarization of East and West (especially referring to China and US trade conflict), environmental degradations and economic and trade conflicts are emerging as its result (Xiong and Wu 2021). In this environment, the economic competition between the two regions is likely to exacerbate the environmental pollution and trade obstacles, affecting the global sustainability and the sustainable development goals. These issues are observable in the emergence of growing political conflicts over trade tariffs and market competition in the recent years (Liu et al. 2020). These conflicts inspire the governments to pursue place-based policies with domestic and independent outlook rather than flow-based ones with global perspectives.

To assess this issue, our study aims to evaluate the effects of globalization and openness on sustainable development in the North America versus that of East Asia and Pacific. To do so, this study tries to map the spillover (or interactive) effects, considered as a proxy for globalization and openness, between the two regions. With spillover effect referring to the impact of seemingly unrelated events to a variable (Liu et al. 2018; Sadorsky 2014), a positive (or negative) spillover effect imply synergistic (or trade-off) relationships and beneficial (or detrimental) role of globalization and openness in the sustainability of the two regions, implicitly. This analysis is helpful for policy-makers to develop flow-based (or place-based) governance in case of synergistic (or trade-off) relationship. Synergistic (or trade-off) spillover effects are an evidence for the beneficial (or detrimental) role of globalization and openness in the sustainability of the two competing regions.

2 Global sustainability and spillover effects

Global sustainability refers to the interactions among humans, societies, and the biosphere on global scale that co-exist and function in harmony to enable productive growth, stability and resilience for current and future generations (Brown et al. 1987). In its essence, global sustainability considers an inter-related chain of variables that incorporates socio-economic and environmental interactions to potentially create sustainability solutions (Batabyal and Folmer 2020; Hull and Liu 2018; Liu et al. 2015; Nodehi and Taghvaei 2021b). This, in effect, requires a deeper understanding of interconnected effects of such variables (or spillover effects), that evaluates the effect of a given factor in a flow-based system, as opposed to the most commonly considered holistic approaches. Being rooted in the externalities of processes or activities (Uyar et al. 2021), previous studies have shown the effect of geographical vicinity of different countries on public and non-public sectors (Wang and Wu 2016). In this regard, regional proximity and geographical connectivity have relational effects on the productivity generating synergic effects on other economies which is commonly referred to as 'spatial diffusion with friction' (Geoffrey 2007).

Yet, recent mainstream contributions of growth in literature have shown that such interrelation is heterogeneous across regions or major economies (Basile et al. 2011) and can potentially spill over with different intensities according to geographical distance (spatial friction hypothesis). Such non-linearity (spatial heterogeneity), in effect, can be an indication of global spillover effect from region-to-region and local-to-local scales (Basile 2008; Batabyal and Nijkamp 2017). This, in other words, considers the regional spillover effects to be an inter-dependent component of its origin, local-to-local spillover, and its respective intensity (Basile et al. 2011) With such basis, exogenous variables such as the 3 commonly-known pillars of sustainability (economy, environment and social) (Taghvaei, Arani, Nodehi, et al. 2021), provide an insight on the degree of intensity for spillover effects on different regions (in this study, East Asia & Pacific versus North America). Despite various interpretation of the spillover results in different fields and sectors, it generates the need for specific policy interventions of countries located in the two mentioned competing-regions.

3 Methodology

To estimate the sustainable development spillover effects (or sustainability elasticities) between East Asia & Pacific versus that of North America, this research develops SEY¹ model following (Taghvaei et al. 2021) as a package of Simultaneous Equations System, Vector Autoregressive (VAR) and Granger Causality approaches during 1971–2016.

¹ SEY model stands for Social (S), Environment (E), and Economy (Y) which are the three pillars of sustainability.

According to the assumption of SEY model, development in each sustainability pillar in region “i” is a function of development in the sustainability pillars of region “j”, as in Eq. 1 (Mirshojaieian Hosseini and Kaneko 2012).

$$\begin{aligned} S_i &= f(S_j, E_j, Y_j) \\ E_i &= f(S_j, E_j, Y_j) \\ Y_i &= f(S_j, E_j, Y_j) \end{aligned} \quad (1)$$

where S, E and Y are social, environment and economy pillars of sustainability, respectively. “i” and “j” are East Asia & Pacific and North America.

The SEY model is transformed into Simultaneous Equation System, as follows (Abdouli and Omri 2020; Ben Youssef et al. 2016; Kahouli and Omri 2017; Taghvaei et al. 2016).

$$\begin{aligned} LE_{it} &= \alpha_{0j} + \alpha_{1j}LE_{jt} + \alpha_{2j}CO_{jt}^{-1} + \alpha_{3j}GDP_{jt} + \varepsilon_{1t} \\ CO_{it}^{-1} &= \beta_{0j} + \beta_{1j}LE_{jt} + \beta_{2j}CO_{jt}^{-1} + \beta_{3j}GDP_{jt} + \varepsilon_{2t} \\ GDP_{it} &= \theta_{0j} + \theta_{1j}LE_{jt} + \theta_{2j}CO_{jt}^{-1} + \theta_{3j}GDP_{jt} + \varepsilon_{3t} \end{aligned} \quad (2)$$

where LE is life expectancy measured in year as an index for social pillar of sustainability; CO^{-1} is the inverse of CO_2 emissions per capita in 1/metric tons as a proxy for environmental pillar of sustainability; GDP is Gross Domestic Production per capita in constant 2010 US Dollar as a proxy for economic pillar of sustainability; α_0 , β_0 and θ_0 are intercept; ε is error terms; and t is year.

These simultaneous equations systems, for estimating the coefficients, employ two approaches.

- Limited Information Approach is for estimating the equations one by one as a single regression. This approach covers four distinctive methods: Ordinary Least Squares (OLS); Weighted Ordinary Least Squares (WOLS); 2-Step Least Squares (2SLS); and Weighted 2-Step Least Squares (WSLS).
- Full Information Approach is for estimating the equations altogether. This approach is in four methods: 3-Step Least Squares (3SLS); Seemingly Unrelated Regressions (SUR); Generalized Methods of Moments (GMM); and Full Information Maximum Likelihood (FIML).

The coefficients are the sustainability elasticities (Taghvaei et al., 2019). Since all the variables are in natural logarithm form, α , β and θ are the spillover elasticities of social, environmental and economic sustainability. α_1 , α_2 and α_3 are the social, environment and economy spillover elasticity of social sustainability; β_1 , β_2 and β_3 are those of the environment sustainability; and θ_1 , θ_2 and θ_3 are those of the economic sustainability, respectively.

To unify the resulted elasticities of various methods, this research calculates the arithmetic mean of elasticities resulted from the different methods.

Since the elasticities are comparable with one another, this study calculates their arithmetic mean to give unique elasticity for sustainability as follows.

$(\alpha_1 + \beta_1 + \theta_1)/3 \leftrightarrow$ Social spillover – elasticities of sustainability.

$(\alpha_2 + \beta_2 + \theta_2)/3 \leftrightarrow$ Environment spillover – elasticities of sustainability.

$(\alpha_3 + \beta_3 + \theta_3)/3 \leftrightarrow$ Economic spillover – elasticities of sustainability.

$(\alpha_1 + \alpha_2 + \alpha_3)/3 \leftrightarrow$ Spillover – elasticities of social sustainability.

$(\beta_1 + \beta_2 + \beta_3)/3 \leftrightarrow$ Spillover – elasticities of environmental sustainability.

$(\theta_1 + \theta_2 + \theta_3)/3 \leftrightarrow$ Spillover – elasticities of economic sustainability.

$\sum_{k=1}^3 (\alpha_{kj} + \beta_{kj} + \theta_{kj})/9 \leftrightarrow$ Spillover – elasticities of sustainability for region j.

Only those elasticities are considered in our analysis about the sustainability which show causal relationships, estimated with VAR and Granger causality approach as follows (Boutabba and Ahmad 2017; Ismael et al. 2018; Mamipour et al. 2019; Tan and Lu 2015)

$$\begin{aligned}\Delta LE_{it} &= C_t + \sum_{l=1}^p \alpha_{1l} \Delta LE_{jt-l} + \sum_{l=1}^p \alpha_{2l} \Delta CO_{jt}^{-1} + \sum_{l=1}^p \alpha_{3l} \Delta GDP_{jt} + \varepsilon_{1t} \\ \Delta CO_{it}^{-1} &= C_t + \sum_{l=1}^p \beta_{1l} \Delta LE_{jt-l} + \sum_{l=1}^p \beta_{2l} \Delta CO_{jt}^{-1} + \sum_{l=1}^p \beta_{3l} \Delta GDP_{jt} + \varepsilon_{1t} \quad (3) \\ \Delta GDP_{it} &= C_t + \sum_{l=1}^p \theta_{1l} \Delta LE_{jt-l} + \sum_{l=1}^p \theta_{2l} \Delta CO_{jt}^{-1} + \sum_{l=1}^p \theta_{3l} \Delta GDP_{jt} + \varepsilon_{1t}\end{aligned}$$

where l is lag and p is the optimal lag. It gives impulse response functions, showing how each pillar of sustainability in region “i” responds to the changes in sustainability pillars in region “j”.

Finally, this research considers only those coefficients which not only are statistically significant in the simultaneous equations system, but also reveals significant causal relationship in the Granger Causality and VAR approach. The arithmetic average of the elasticities are the sustainability elasticities.

The SEY model employs simultaneous equations system, Granger causality and VAR approaches to estimate the sustainability elasticities and spatial spillover effects. The positive coefficients imply the synergistic nature of sustainability spillover effects between the two regions of North America and East Asia, while the negative coefficients confirm the trade-off nexus (Štreimikienė and Kačerauskas 2020; Tremblay et al. 2020; Umar et al. 2020; Xu et al. 2020). The

synergistic and trade-off relationships suggest that the effects of globalization and openness are beneficial for or detrimental to the sustainability, respectively.

In addition to the cross-region estimations, this study investigates the interactions of the sustainable development pillars inside each region separately. This shows how development of each pillar in each region affect the development of other pillars in the same region.

To show the reliability of the results, this research goes further to estimate all the above models and equations with alternative proxies and variables for the three pillars of sustainable development. In the second round of estimations, this study considers school enrolment primary (% gross),² inverse of greenhouse gas emissions (in kilo of CO₂ equivalent per capita) and energy use (in kg of oil equivalent per capita) as proxies for the social, environmental and economic pillars of sustainable development. In the equations and models, their symbols are SC, GH⁻¹ and EN, respectively.

All the data are extracted from the World Development Indicators, World Bank, within 1971–2016; and for the alternative variables, the period is 1971–2014 (World Bank, 2021). They are normalized values of the natural logarithm form.³

The data are accessible at the following link (Nodehi et al. 2021).

<https://data.mendeley.com/datasets/xvd7bv6mjb/5>

4 Result

The results show that most of the sustainability elasticities are positive both between and within East Asia & Pacific and North America, supporting the synergetic character of the sustainability spillover effects.

Table A-1 to Table A-6 in the Appendix, and Figure A-1 and Figure A-2 show the results of simultaneous equations system, Granger causality and VAR approaches. According to Table A-1 to Table A-6 in the Appendix, the signs are positive for most of the elasticities with statistically significant causal and long-run relationship, supporting the synergetic character of sustainability spillover effects both between and within North America and Asia even with changing the proxies. Although, this research employs various methods to estimate the SEY model including limited information (OLS, WOLS, 2SLS and WLS) and full information (3SLS, SUR, GMM and FIML), all the methods give the same results. It shows that the results are valid and robust. In the appendix, Figure A-1 and Figure A-2 present the impulse functions of the SEY model. These tables and figures show that the relationship

² “Gross enrollment ratio is the ratio of total enrollment, regardless of age, to the population of the age group that officially corresponds to the level of education shown. Primary education provides children with basic reading, writing, and mathematics skills along with an elementary understanding of such subjects as history, geography, natural science, social science, art, and music.” (World Bank, 2021).

³ The normalization is according to the following equation:

$$\text{Normalized value} = \frac{\text{Current value} - \text{Maximum value}}{\text{Maximum value} - \text{Minimum value}}$$

After normalization, all the variables are put into unit root tests and they are stationary in level, paving the way to run the model without any worry for spurious regression result.

Table 1 Interactive sustainability elasticities between North America and East Asia & Pacific (with the 1st set of proxies: Life expectancy, CO₂ and GDP)

Region j = > Region j		Asia = > America	America = > Asia
<i>Social_j</i>			
Social _j	$LE_j \Rightarrow LE_j$	+ 1.0718***	+ 0.5782***
Environment _j	$CO_j^{-1} \Rightarrow LE_j$	–	–
Economy _j	$GDP_j \Rightarrow LE_j$	–	–
<i>Environment_i</i>			
Social _j	$LE_j \Rightarrow CO_j^{-1}$	–	–
Environment _j	$CO_j^{-1} \Rightarrow CO_j^{-1}$	–	–
Economy _j	$GDP_j \Rightarrow CO_j^{-1}$	+ 0.4588***	–
<i>Economy_j</i>			
Social _j	$LE_j \Rightarrow GDP_j$	+ 0.2873***	– 0.2459***
Environment _j	$CO_j^{-1} \Rightarrow GDP_j$	–	–
Economy _j	$GDP_j \Rightarrow GDP_j$	+ 0.7811***	–
Interactive Sustainability Elasticities		+ 64%	+ 17%***

among the sustainable development pillars are significant with various methods, proxies, variables and regions. It is an evidence for the existence of positive sustainable development spillover effects among the regions.

Table 1 presents only those coefficients of the Table A-1, Table A-2 in the Appendix and Figure A-1 which are statistically significant both in the simultaneous equations systems and in the Granger Causality tests. These are actually the elasticities of sustainable development pillars in East Asia & Pacific and North America. The social development in each region has the most considerable spillover effect on the social development in the other region. This effect is about + 107% from Asia to America and 57% from America to Asia. Although, the social development in Asia has positive effect on the economic development in America (about + 28%), the social development in America has negative effect on economic development in Asia (about – 24%). In addition, the economic development in Asia has spillover effects on both the economic and the environmental development in America, approximately + 78% and + 45% respectively. At the final row of Table 1, the interactive sustainability elasticities are the average the elasticities in the table, showing that sustainability in North America improves 64%, if sustainability in East Asia & Pacific improves 100%. Likewise, sustainability in East Asia & Pacific increases 17%, in case of 100% improvement in the sustainability of North America. Therefore, the spillover effects of sustainability are positive and synergistic between North America and East Asia.

In addition to the cross-region estimations, this research estimates the spillover effects of sustainable development pillars inside each region, summarized in Table 2 (also see Table A-3 and Table A-4 in the Appendix). This estimation also shows that the spillover effects of sustainability are significantly and mostly positive in a single region. Table 2 presents only those coefficients of the Table A-3, Table A-4 and Figure A-2 in the appendix which are statistically significant both in the simultaneous

Table 2 Interactive sustainability elasticities within North America and East Asia & Pacific (considering the interactions of each region separately) using the 1st set of proxies: Life expectancy, CO₂ and GDP

Region j => Region j		Asia => Asia	America => America
<i>Social_j</i>			
Social _j	$LE_j \Rightarrow LE_j$	-	-
Environment _j	$CO_j^{-1} \Rightarrow LE_j$	-	-
Economy _j	$GDP_j \Rightarrow LE_j$	-	-
<i>Environment_i</i>			
Social _j	$LE_j \Rightarrow CO_j^{-1}$	-	-
Environment _j	$CO_j^{-1} \Rightarrow CO_j^{-1}$	-	-
Economy _j	$GDP_j \Rightarrow CO_j^{-1}$	-	-
<i>Economy_j</i>			
Social _j	$LE_j \Rightarrow GDP_j$	+0.5147***	+0.5680***
Environment _j	$CO_j^{-1} \Rightarrow GDP_j$	-0.0180***	-
Economy _j	$GDP_j \Rightarrow GDP_j$	-	-
Interactive Sustainability Elasticities		+25%	+70%

Table 3 Interactive sustainability elasticities between North America and East Asia & Pacific (with the 2nd set of proxies: School enrolment, Greenhouse gas emissions and Energy consumption)

Region j => Region i		Asia => America	America => Asia
<i>Social_i</i>			
Social _j	$SC_j \Rightarrow SC_i$	-	+0.6836***
Environment _j	$GH_j^{-1} \Rightarrow SC_i$	-	-
Economy _j	$EN_j \Rightarrow SC_i$	-	-
<i>Environment_i</i>			
Social _j	$SC_j \Rightarrow GH_i^{-1}$	+1.4525***	-
Environment _j	$GH_j^{-1} \Rightarrow GH_i^{-1}$	-	-0.1264***
Economy _j	$EN_j \Rightarrow GH_i^{-1}$	-	-
<i>Economy_i</i>			
Social _j	$SC_j \Rightarrow EN_i$	-0.3893***	-
Environment _j	$GH_j^{-1} \Rightarrow EN_i$	-	0.1688***
Economy _j	$EN_j \Rightarrow EN_i$	-	-
Interactive Sustainability Elasticities		+53%	+24%***

equations systems and in the Granger Causality tests. According to the tables, the majority of the resulted coefficients are positive. It confirms the coefficients of the estimated models which are in Table 1, Table A-1, and Table A-2. Thus, this is also an evidence which supports the positive nature of sustainability spillover effects.

To show the robustness of the results, this study replicates all the estimated models with another set of proxies for the pillars of sustainable development, summarized in Table 3 (also see Table A-5 and Table A-6 in the Appendix). The spillover effects of sustainable development show positive and synergetic nature even in case

of changing the proxies. It is also another evidence for the reliability of the model estimations in this research. Based on these results, the nature of the sustainable development pillars is positive and synergetic even in case of altering the variable sets and region interactions.

This research employs various methodologies, models, proxies, variables and regions to enhance the reliability of its results. This study estimates the spillover effects of sustainable development pillars not only between the two regions but also inside each region to show the reliability of the results. Again, for more reliability, this study goes further to estimate the models with another set of proxies to check the findings with alternative variables and proxies. Although, it is possible to employ more and more proxies, variables, models and regions to estimate the spillover effects, space and word limits are a restriction to do all of them in only one single paper. Hence, we leave this task for the future studies. Additionally, each study is to answer its question/s with a limited number of models and variables; and no study has the capacity to cover all the available variables, proxies and models in only one single research. Regarding this analysis, our study supports the synergetic characteristics of sustainable development pillars on the basis of its own estimated models, datasets and proxies which are undoubtedly limited just like all the other studies with their limited models, variables and estimations.

Tables 3, 4 and 5 are a very brief summary of all the 6 tables and 2 figures in the appendix (Table A-1 to A-6 and Figure A-1 and A-2). As a summary, Tables 3, 4 and 5 represent the statistically significant causalities with *average* long-run relationships of sustainable development pillars between and within North America and East Asia & Pacific, considering two sets of proxies. Numbers are the sustainability elasticities (or rather the spillover effects of sustainable development pillars) as the positive ones are synergies and the negative one is trade-off nexus. The *average of the averages* is the interactive sustainability elasticity.

5 Discussion

Findings of this research support the positive role of globalization and openness in the global sustainability. Figure 1 is the graphical translation of Table 1, showing the supporting role of globalization and openness in sustainability of East Asia & Pacific and North America. According to Fig. 1, except one trade-off nexus (-24%), all the bilateral relationships between the two regions are synergetic (or positive), specifically for the social and economic interactions. Thus, according to the results, the sustainability spillover effects are positive, confirming constructive role of globalization and openness in the sustainability progress.

These positive relationships are observable not only in this model but also, in the other alternative models. In addition to the cross-region analysis, our findings confirm that these synergetic relationships exist among the sustainability pillars inside each single region, as shown in Fig. 2. Accordingly, this research claims that such synergetic nexus is noticeable even if the variables and proxies change totally, as shown in Fig. 3. Regarding Fig. 3, most of the spillover effects are positive. Despite some minor negative and trade-off spillover effects, the major interactions are

positive and synergetic. Therefore, the synergetic nexus of sustainability pillars is considerable in various regions, models, proxies and variables.

The considerable influence of spillover effects on sustainability nominates it as the 4th pillar of sustainable development alongside with *social, environment and economy* to introduce a new sustainability perspective, i.e., *Integrated Sustainability*. In contrast with the weak sustainability perspective that values all the sustainable development pillars equally and the strong sustainability that considers environment more important than the other pillars, our newly-defined perspective, *Integrated Sustainability*, considers spillover effect as the most dominant pillar of sustainable development. Through the *Integrated Sustainability* and its spatial synergies, therefore, the globalization and openness are beneficial for sustainable development in the two regions.

6 China as an emerging superpower

The growing concern over unhealthy competition between East Asia versus that of North America is the result of the power transition that has taken place in recent decades, challenging the contemporary global socio-economic stance. In East Asia and Pacific, China, with a population of around 1.4 billion and a GDP of 14.72 trillion (World Bank Group 2021), is a de facto superpower and the major dominating country with the most significant impact on the three pillars of social, economic and environment of the entire region. On this basis, China has become a major rival to the United States whose global dominance has been unchallenged, after the fall of the Soviet Union, for decades. Although the two dominating forces have a considerably different socio-economic stance (e.g., Liberalism versus Socialism), their impact on the regional and global spillover sustainability is equally significant. This, in sustainability terminology, is referred to the effects of synergetic or trade off relationships, resulting in flow-based (and cooperative) or place-based (and independent) governance, respectively.

Effectively, based on the result of this study, despite the variation in the benefits of partnership between the two major superpowers that can have more benefits for one over the other, both parties are found to be positively influenced from collaboration rather than an unhealthy conflicting competition. Yet, the degree to which, such benefits can exist is in direct relationship to the two parties' willingness to adopt cooperative policies that enhance the social, environment and economic sustainability, not only on regional but also on a global scale.

7 Conclusion

This study investigates the spatial spillover effects between North America and East Asia & Pacific to find whether or not globalization and openness are beneficial for the global sustainability. As a result of this research, the regional spillover effects of sustainability are found to be dominantly positive both between and within East Asia & Pacific and North America, showing the beneficial effects of globalization

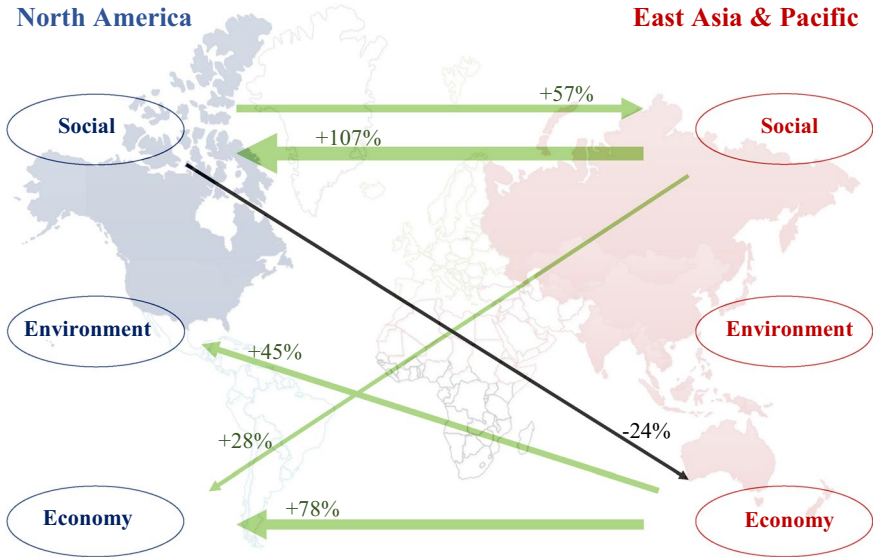


Fig. 1 Estimated spillover effects (or elasticities) of sustainable development pillars between East Asia & Pacific and North America (with 1st set of proxies: Life expectancy, CO₂ and GDP)

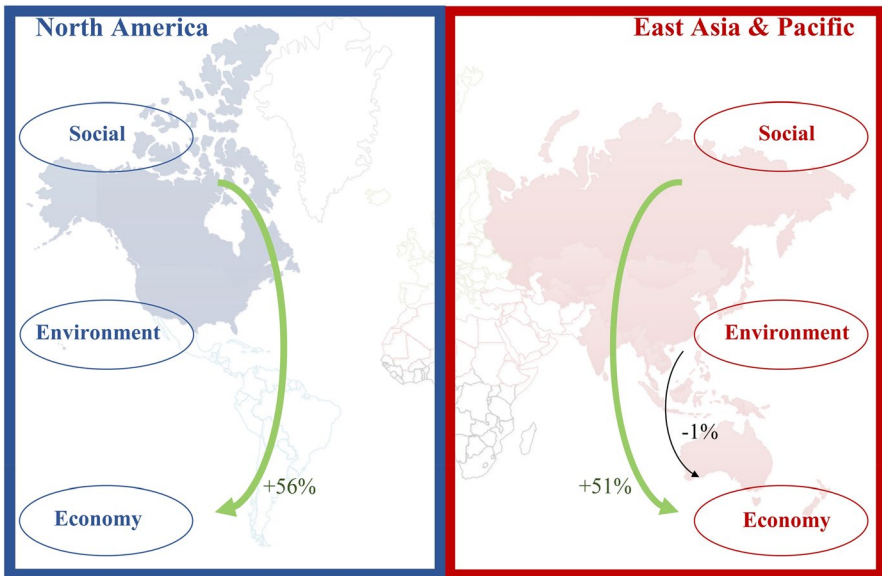


Fig. 2 Estimated spillover effects (or elasticities) of sustainable development pillars within East Asia & Pacific and North America (considering the interactions of each region separately)

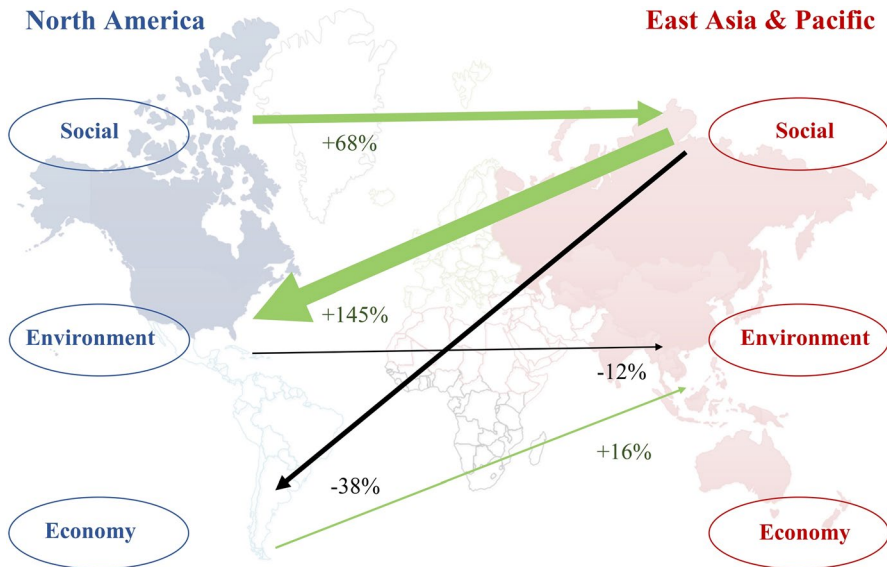


Fig. 3 Estimated spillover effects (or elasticities) of sustainable development pillars between East Asia & Pacific and North America (with the 2nd set of proxies: School enrolment, Greenhouse gas emissions and Energy consumption)

and openness. Based on this, we introduce *Integrated Sustainability* in which sustainability spillover effect is considered as the 4th pillar to the traditional sustainable development pillars (including *social*, *environment* and *economy*). This perspective has the capacity to resolve both the environmental and economic issues in the two regions. *Integrated Sustainability*, implicitly, claims that policy-makers should follow flow-based governance,⁴ establish international unions and agreements and boost the global peace and partnership to foster globalization and openness which can play a key role in global sustainability.

However, the COVID-19 pandemic in 2019 reveals that the globalization process has some shortcomings, needing modifications to its current mode. The globalization of the 20th and early twenty-first century helped this disease spread rapidly and widely via the integrated global trade and tourism. In that respect, these limitations might not be the intrinsic character of globalization, but they make transitory perturbations flourish easier especially in shorter timeframe. A subsequent research can study the trends and qualities of spillover effects after the pandemic to show how this shock changed these synergetic effects. It paves the way for modifying, improving, and optimizing the mode of globalization and openness process. In addition, the other researchers can investigate these relationships among the other regions and countries providing further insight into the degree to which globalization and partnership is effective in global sustainability. While attempting to do so, other alternative proxies for the pillars of sustainable development can be adopted to check how much the claims made in this study are reliable.

⁴ Rather than place-based governance.

Appendix

See Figs. 4 and 5

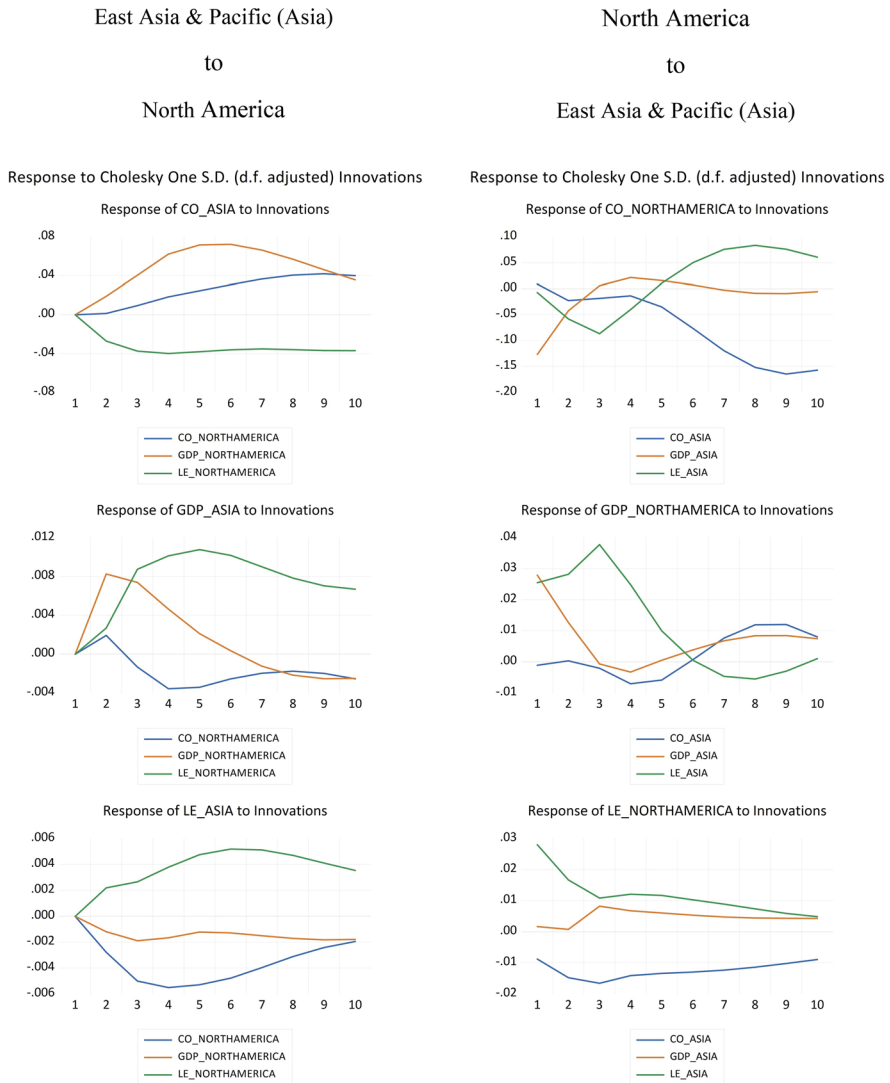


Fig. 4 Impulse functions of sustainable development pillars among the two regions (CO: inverse of per capita CO2 emissions; GDP: per capita GDP; LE: life expectancy)

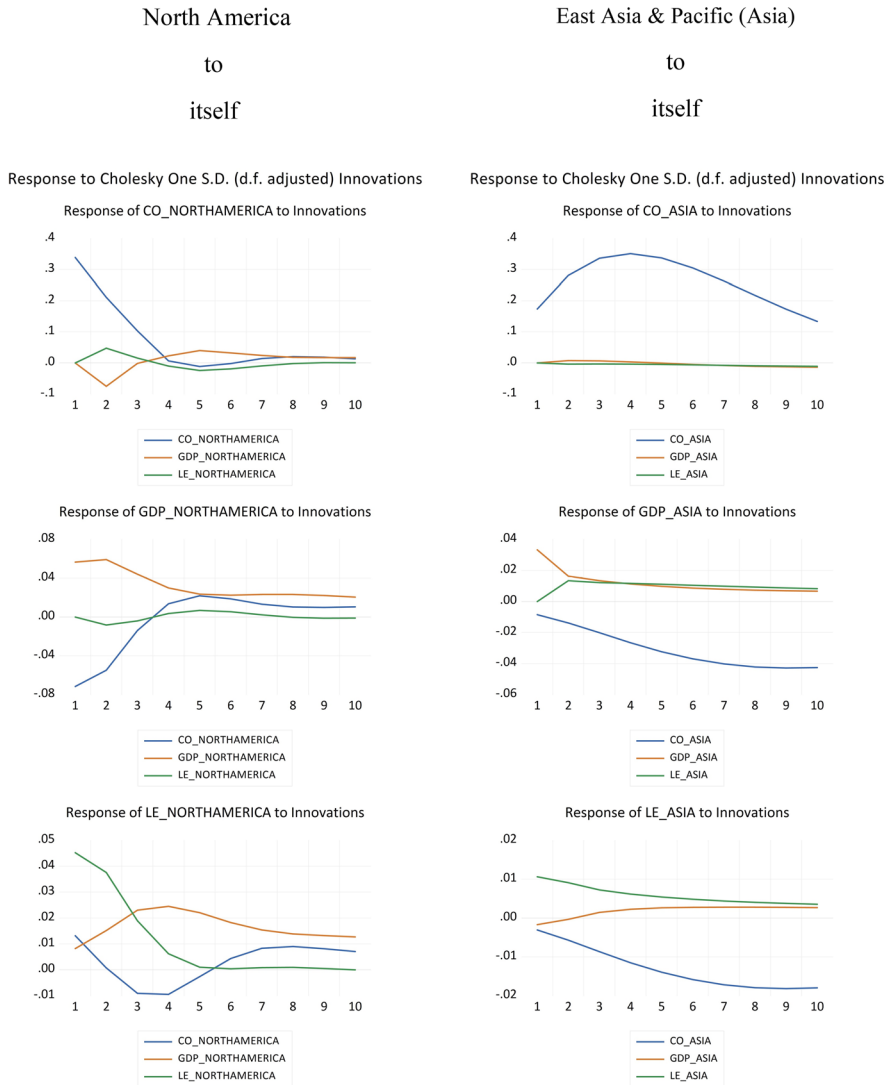


Fig. 5 Impulse functions of sustainable development pillars within the two regions (CO: inverse of per capita CO2 emissions; GDP: per capita GDP; LE: life expectancy)

See Tables 4, 5, 6, 7, 8 and 9

Table 4 Estimated relationships and causality directions of sustainable development pillars from North America to East Asia and Pacific via simultaneous equations system and Granger causality test

	East Asia & Pacific (Asia) \leftrightarrow North America (N. America)						Full information approach (single equation)						Granger Causality		
	Limited information approach (single equation)			Full information approach (single equation)			Full information approach (single equation)						Granger Causality		
	OLS	WOLS	2SLS	WLS	3SLS	SUR	GMM	FIML							
<i>LE equation_{Asia}</i>															
C	0.8752*** (0.00)***	0.8752*** (0.00)***	0.8752*** (0.00)***	0.8752*** (0.00)***	0.8752*** (0.00)***	0.8752*** (0.00)***	0.8752*** (0.00)***	0.8752*** (0.02)***	0.8752*** (0.00)***	0.8752*** (0.00)***	0.8752*** (0.00)***	0.8752*** (0.02)***	0.8752*** (0.00)***	–	Optimal lag=5
LE _{N. America}	0.5782*** (0.00)***	0.5782*** (0.00)***	0.5782*** (0.00)***	0.5782*** (0.00)***	0.5782*** (0.00)***	0.5782*** (0.00)***	0.5782*** (0.00)***	0.5782*** (0.00)***	0.5782*** (0.00)***	0.5782*** (0.00)***	0.5782*** (0.00)***	0.5782*** (0.00)***	0.5782*** (0.00)***	LE \Rightarrow LE*** (0.01)	
CO ⁻¹ _{N. America}	-0.0791*** (0.03)***	-0.0791*** (0.02)***	-0.0791*** (0.03)***	-0.0791*** (0.03)***	-0.0791*** (0.02)***	-0.0791*** (0.02)***	-0.0791*** (0.02)***	-0.0791*** (0.02)***	-0.0791*** (0.02)***	-0.0791*** (0.02)***	-0.0791*** (0.20)***	-0.0791*** (0.57)***	-0.0791*** (0.57)***	CO ⁻¹ \Rightarrow LE*** (0.40)	
GDP _{N. America}	0.2987*** (0.00)***	0.2987*** (0.00)***	0.2987*** (0.00)***	0.2987*** (0.00)***	0.2987*** (0.00)***	0.2987*** (0.00)***	0.2987*** (0.00)***	0.2987*** (0.00)***	0.2987*** (0.00)***	0.2987*** (0.00)***	0.2987*** (0.00)***	0.2987*** (0.17)***	0.2987*** (0.17)***	GDP \Rightarrow LE*** (0.19)	
<i>CO equation_{Asia}</i>															
C	7.2736*** (0.00)***	7.2736*** (0.00)***	7.2736*** (0.00)***	7.2736*** (0.00)***	7.2736*** (0.00)***	7.2736*** (0.00)***	7.2736*** (0.00)***	7.2736*** (0.00)***	7.2736*** (0.00)***	7.2736*** (0.00)***	7.2736*** (0.00)***	7.2736*** (0.10)***	7.2736*** (0.10)***	–	
LE _{N. America}	1.0575*** (0.00)***	1.0575*** (0.00)***	1.0575*** (0.00)***	1.0575*** (0.00)***	1.0575*** (0.00)***	1.0575*** (0.00)***	1.0575*** (0.00)***	1.0575*** (0.00)***	1.0575*** (0.00)***	1.0575*** (0.00)***	1.0575*** (0.01)***	1.0575*** (0.74)***	1.0575*** (0.74)***	LE \Rightarrow CO ⁻¹ *** (0.61)	
CO ⁻¹ _{N. America}	-0.7722*** (0.00)***	-0.7722*** (0.00)***	-0.7722*** (0.00)***	-0.7722*** (0.00)***	-0.7722*** (0.00)***	-0.7722*** (0.00)***	-0.7722*** (0.00)***	-0.7722*** (0.00)***	-0.7722*** (0.00)***	-0.7722*** (0.00)***	-0.7722*** (0.02)***	-0.7722*** (0.62)***	-0.7722*** (0.62)***	CO ⁻¹ \Rightarrow CO ⁻¹ *** (0.93)	
GDP _{N. America}	-1.4762*** (0.00)***	-1.4762*** (0.00)***	-1.4762*** (0.00)***	-1.4762*** (0.00)***	-1.4762*** (0.00)***	-1.4762*** (0.00)***	-1.4762*** (0.00)***	-1.4762*** (0.00)***	-1.4762*** (0.00)***	-1.4762*** (0.00)***	-1.4762*** (0.00)***	-1.4762*** (0.32)***	-1.4762*** (0.32)***	GDP \Rightarrow CO ⁻¹ *** (0.81)	
<i>GDP equation_{Asia}</i>															
C	-0.9669*** (0.00)***	-0.9669*** (0.00)***	-0.9669*** (0.00)***	-0.9669*** (0.00)***	-0.9669*** (0.00)***	-0.9669*** (0.00)***	-0.9669*** (0.00)***	-0.9669*** (0.00)***	-0.9669*** (0.00)***	-0.9669*** (0.00)***	-0.9669*** (0.00)***	-0.9669*** (0.05)***	-0.9669*** (0.05)***	–	
LE _{N. America}	-0.2459*** (0.00)***	-0.2459*** (0.00)***	-0.2459*** (0.00)***	-0.2459*** (0.00)***	-0.2459*** (0.00)***	-0.2459*** (0.00)***	-0.2459*** (0.00)***	-0.2459*** (0.00)***	-0.2459*** (0.00)***	-0.2459*** (0.00)***	-0.2459*** (0.00)***	-0.2459*** (0.50)***	-0.2459*** (0.50)***	LE \Rightarrow GDP*** (0.01)	

Table 4 (continued)

		Limited information approach (single equation)					Full information approach (single equation)					Granger	
		OLS	WOLS	2SLS	WLS	3SLS	SUR	GMM	FIML	Causality			
CO^{-1}	$N_{America}$	0.2497*** (0.00)***	0.2497*** (0.00)***	0.2497*** (0.00)***	0.2497*** (0.00)***	0.2497*** (0.00)***	0.2497*** (0.00)***	0.2497*** (0.00)***	0.2497*** (0.20)***	$CO^{-1} \Rightarrow GDP$ *** (0.21)			
GDP	$N_{America}$	1.1734*** (0.00)***	1.1734*** (0.00)***	1.1734*** (0.00)***	1.1734*** (0.00)***	1.1734*** (0.00)***	1.1734*** (0.00)***	1.1734*** (0.00)***	1.1734*** (0.00)***	$GDP \Rightarrow GDP$ *** (0.77)			

Table 5 Estimated relationships and causality directions of sustainable development pillars from East Asia and Pacific to North America via simultaneous equations system and Granger causality test

		Limited information approach (single equation)					Full information approach (single equation)					Granger Causality		
		OLS	WOLS	2SLS	WSLS	3SLS	SUR	GMM	FIML					
<i>North America (N. America) ⇌ East Asia & Pacific (Asia)</i>														
<i>LE equation_{N. America}</i>														
C	-0.7594*** (0.00)***	-0.7594*** (0.00)***	-0.7594*** (0.00)***	-0.7594*** (0.00)***	-0.7594*** (0.00)***	-0.7594*** (0.00)***	-0.7594*** (0.00)***	-0.7594*** (0.00)***	-0.7594*** (0.00)***	-0.7594*** (0.00)***	-0.7594*** (0.00)***	-0.7594*** (0.00)***	-	Optimal lag=5
LE _{Asia}	1.0718*** (0.00)***	1.0718*** (0.00)***	1.0718*** (0.00)***	1.0718*** (0.00)***	1.0718*** (0.00)***	1.0718*** (0.00)***	1.0718*** (0.00)***	1.0718*** (0.00)***	1.0718*** (0.00)***	1.0718*** (0.00)***	1.0718*** (0.00)***	1.0718*** (0.00)***	LE ⇒ LE*** (0.21)	
CO ⁻¹ _{Asia}	0.0227*** (0.62)***	0.0227*** (0.60)***	0.0227*** (0.62)***	0.0227*** (0.60)***	0.0227*** (0.60)***	0.0227*** (0.60)***	0.0227*** (0.60)***	0.0227*** (0.60)***	0.0227*** (0.60)***	0.0227*** (0.60)***	0.0227*** (0.60)***	0.0227*** (0.60)***	CO ⁻¹ ⇒ LE*** (0.95)	
GDP _{Asia}	0.1030*** (0.37)***	0.1030*** (0.34)***	0.1030*** (0.37)***	0.1030*** (0.34)***	0.1030*** (0.34)***	0.1030*** (0.34)***	0.1030*** (0.34)***	0.1030*** (0.34)***	0.1030*** (0.34)***	0.1030*** (0.34)***	0.1030*** (0.34)***	0.1030*** (0.34)***	GDP ⇒ LE*** (0.70)	
<i>CO equation_{N. America}</i>														
C	2.5214*** (0.00)***	2.5214*** (0.00)***	2.5214*** (0.00)***	2.5214*** (0.00)***	2.5214*** (0.00)***	2.5214*** (0.00)***	2.5214*** (0.00)***	2.5214*** (0.00)***	2.5214*** (0.00)***	2.5214*** (0.00)***	2.5214*** (0.00)***	2.5214*** (0.00)***	-	
LE _{Asia}	-0.0328*** (0.91)***	-0.0328*** (0.90)***	-0.0328*** (0.91)***	-0.0328*** (0.90)***	-0.0328*** (0.90)***	-0.0328*** (0.90)***	-0.0328*** (0.90)***	-0.0328*** (0.90)***	-0.0328*** (0.90)***	-0.0328*** (0.90)***	-0.0328*** (0.90)***	-0.0328*** (0.90)***	LE ⇒ CO ⁻¹ *** (0.35)	
CO ⁻¹ _{Asia}	-0.1270*** (0.27)***	-0.1270*** (0.25)***	-0.1270*** (0.27)***	-0.1270*** (0.25)***	-0.1270*** (0.25)***	-0.1270*** (0.25)***	-0.1270*** (0.25)***	-0.1270*** (0.25)***	-0.1270*** (0.25)***	-0.1270*** (0.25)***	-0.1270*** (0.25)***	-0.1270*** (0.25)***	CO ⁻¹ ⇒ CO ⁻¹ *** (0.42)	
GDP _{Asia}	0.4588*** (0.11)***	0.4588*** (0.10)***	0.4588*** (0.11)***	0.4588*** (0.10)***	0.4588*** (0.10)***	0.4588*** (0.10)***	0.4588*** (0.10)***	0.4588*** (0.10)***	0.4588*** (0.10)***	0.4588*** (0.10)***	0.4588*** (0.10)***	0.4588*** (0.10)***	GDP ⇒ CO ⁻¹ *** (0.07)	
<i>GDP equation_{N. America}</i>														
C	-0.2964*** (0.01)***	-0.2964*** (0.01)***	-0.2964*** (0.01)***	-0.2964*** (0.01)***	-0.2964*** (0.01)***	-0.2964*** (0.01)***	-0.2964*** (0.01)***	-0.2964*** (0.01)***	-0.2964*** (0.01)***	-0.2964*** (0.01)***	-0.2964*** (0.01)***	-0.2964*** (0.01)***	-	
LE _{Asia}	0.2873*** (0.00)***	0.2873*** (0.00)***	0.2873*** (0.00)***	0.2873*** (0.00)***	0.2873*** (0.00)***	0.2873*** (0.00)***	0.2873*** (0.00)***	0.2873*** (0.00)***	0.2873*** (0.00)***	0.2873*** (0.00)***	0.2873*** (0.00)***	0.2873*** (0.00)***	LE ⇒ GDP*** (0.00)	

Table 5 (continued)

	North America (N. America) \Leftarrow East Asia & Pacific (Asia)										
	Limited information approach (single equation)					Full information approach (single equation)					Granger Causality
	OLS	WOLS	2SLS	WLSLS	3SLS	SUR	GMM	FIML			
CO^{-1} Asia	0.0897*** (0.00)***	0.0897*** (0.00)***	0.0897*** (0.00)***	0.0897*** (0.00)***	0.0897*** (0.00)***	0.0897*** (0.00)***	0.0897*** (0.00)***	0.0897*** (0.45)***	0.0897*** (0.92)	$CO^{-1} \Rightarrow GDP$ ***	
GDP Asia	0.7811*** (0.00)***	0.7811*** (0.00)***	0.7811*** (0.00)***	0.7811*** (0.00)***	0.7811*** (0.00)***	0.7811*** (0.00)***	0.7811*** (0.00)***	0.7811*** (0.00)***	0.7811*** (0.01)	$GDP \Rightarrow GDP$ ***	

Table 6 Estimated relationships and causality directions of sustainable development pillars in North America via simultaneous equations system and Granger causality test North America (N. America)

	Limited information approach (single equation)				Full information approach (single equation)				Granger Causality
	OLS	WOLS	2SLS	WLS	3SLS	SUR	GMM	FIML	
	Optimal lag=5								
<i>LE equation</i> N. America									
C	0.7484*** (0.00)***	0.7484*** (0.00)***	0.8092*** (0.00)***	0.8092*** (0.00)***	0.8092*** (0.00)***	0.6936*** (0.00)***	0.8092*** (0.00)***	0.8835*** (0.12)***	–
LE N. America ⁽⁻¹⁾	0.7624*** (0.00)***	0.7624*** (0.00)***	0.8875*** (0.00)***	0.8875*** (0.00)***	0.8875*** (0.00)***	0.7020*** (0.00)***	0.8875*** (0.00)***	0.8406*** (0.32)***	LE ⇒ LE*** (0.01)
CO ⁻¹ N. America	-0.0211*** (0.56)***	-0.0211*** (0.55)***	-0.0707*** (0.08)***	-0.0707*** (0.07)***	-0.0707*** (0.07)***	-0.0338*** (0.33)***	-0.0707*** (0.35)***	-0.2871*** (0.68)***	CO ⁻¹ ⇒ LE*** (0.40)
GDP N. America	0.0889*** (0.07)***	0.0889*** (0.06)***	0.0096*** (0.86)***	0.0096*** (0.85)***	0.0096*** (0.85)***	0.1776*** (0.00)***	0.0096*** (0.89)***	0.2204*** (0.36)***	GDP ⇒ LE*** (0.19)
<i>CO equation</i> Asia									
C	-0.0774*** (0.81)***	-0.0774*** (0.80)***	-0.9234*** (0.12)***	-0.9234*** (0.11)***	-0.9234*** (0.11)***	-0.1290*** (0.68)***	-0.9234*** (0.07)***	7.0604*** (0.97)***	–
LE N. America	0.7583*** (0.00)***	0.7583*** (0.00)***	0.7673*** (0.01)***	0.7673*** (0.01)***	0.7673*** (0.01)***	0.5799*** (0.00)***	0.7673*** (0.01)***	0.6350*** (0.65)***	LE ⇒ CO ⁻¹ *** (0.61)
CO ⁻¹ N. America ⁽⁻¹⁾	0.5338*** (0.00)***	0.5338*** (0.00)***	1.5368*** (0.00)***	1.5368*** (0.00)***	1.5368*** (0.00)***	0.6043*** (0.00)***	1.5368*** (0.00)***	0.4971*** (0.47)***	CO ⁻¹ ⇒ CO ⁻¹ *** (0.93)
GDP N. America	-0.3380*** (0.08)***	-0.3380*** (0.07)***	-1.0448*** (0.00)***	-1.0448*** (0.00)***	-1.0448*** (0.00)***	-0.2010*** (0.28)***	-1.0448*** (0.07)***	-0.1786*** (0.82)***	GDP ⇒ CO ⁻¹ *** (0.81)
<i>GDP equation</i> Asia									
C	1.0782*** (0.00)***	1.0782*** (0.00)***	1.3082*** (0.00)***	1.3082*** (0.00)***	1.3082*** (0.00)***	0.9070*** (0.00)***	1.3082*** (0.00)***	0.8789*** (0.67)***	–
LE N. America	-0.3980*** (0.00)***	-0.3980*** (0.00)***	-0.7096*** (0.00)***	-0.7096*** (0.00)***	-0.7096*** (0.00)***	-0.3130*** (0.00)***	-0.7096*** (0.00)***	-0.5966*** (0.64)***	LE ⇒ GDP*** (0.01)
CO ⁻¹ N. America	0.0516*** (0.28)***	0.0516*** (0.28)***	0.0595*** (0.26)***	0.0595*** (0.24)***	0.0595*** (0.24)***	0.0936*** (0.03)***	0.0595*** (0.46)***	0.3826*** (0.52)***	CO ⁻¹ ⇒ GDP*** (0.21)

Table 6 (continued)

	Limited information approach (single equation)				Full information approach (single equation)				Granger Causality
	OLS	WOLS	2SLS	WLS	3SLS	SUR	GMM	FIML	
GDP _{N. America} ⁽⁻¹⁾	1.1108*** (0.00) ***	1.1108*** (0.00) ***	1.3773*** (0.00) ***	1.3773*** (0.00) ***	1.3773*** (0.00) ***	1.0260*** (0.00) ***	1.3773*** (0.00) ***	1.0638*** (0.05) ***	$GDP \Rightarrow GDP$ *** (0.77)

Table 7 Estimated relationships and causality directions of sustainable development pillars in East Asia and Pacific on each other via simultaneous equations system and Granger causality test

	East Asia & Pacific (Asia)										Granger Causality
	Limited information approach (single equation)					Full information approach (single equation)					
	OLS	WOLS	2SLS	WLSLS	3SLS	SUR	GMM	FIML			
<i>LE equation_{Asia}</i>											
C	1.4116*** (0.00)***	1.4116*** (0.00)***	1.4249*** (0.00)***	1.4249*** (0.00)***	1.4249*** (0.00)***	1.4284*** (0.00)***	1.4249*** (0.00)***	1.4249*** (0.13)***	1.4249*** (0.13)***	–	
LE (-1) _{Asia}	0.4290*** (0.00)***	0.4290*** (0.00)***	0.4369*** (0.00)***	0.4369*** (0.00)***	0.4369*** (0.00)***	0.4493*** (0.00)***	0.4369*** (0.00)***	0.4369*** (0.00)***	0.4369*** (0.00)***	–	
CO ⁻¹ _{Asia}	0.0091*** (0.37)***	0.0091*** (0.35)***	0.0060*** (0.57)***	0.0060*** (0.56)***	0.0060*** (0.56)***	0.0031*** (0.37)***	0.0060*** (0.39)***	0.0060*** (0.97)***	0.0060*** (0.97)***	CO ⁻¹ ⇒ LE*** (0.78)	
GDP _{Asia}	0.2669*** (0.00)***	0.2669*** (0.00)***	0.2565*** (0.00)***	0.2565*** (0.00)***	0.2565*** (0.00)***	0.2437*** (0.00)***	0.2565*** (0.00)***	0.2565*** (0.08)***	0.2565*** (0.08)***	GDP ⇒ LE*** (0.43)	
<i>CO equation_{Asia}</i>											
C	0.0032*** (0.99)***	0.0032*** (0.99)***	0.0124*** (0.97)***	0.0124*** (0.97)***	0.0124*** (0.97)***	-0.0151*** (0.99)***	0.0124*** (0.96)***	0.0124*** (0.99)***	0.0124*** (0.99)***	–	
LE _{Asia}	0.1341*** (0.48)***	0.1341*** (0.46)***	0.1092*** (0.58)***	0.1092*** (0.56)***	0.1092*** (0.56)***	0.1430*** (0.48)***	0.1092*** (0.13)***	0.1092*** (0.98)***	0.1092*** (0.98)***	LE ⇒ CO ⁻¹ *** (0.10)	
CO ⁻¹ (-1) _{Asia}	0.9661*** (0.00)***	0.9661*** (0.00)***	0.9715*** (0.00)***	0.9715*** (0.00)***	0.9715*** (0.00)***	0.9658*** (0.00)***	0.9715*** (0.00)***	0.9715*** (0.00)***	0.9715*** (0.00)***	–	
GDP _{Asia}	-0.1548*** (0.26)***	-0.1548*** (0.24)***	-0.1330*** (0.36)***	-0.1330*** (0.33)***	-0.1330*** (0.33)***	-0.1597*** (0.26)***	-0.1330*** (0.12)***	-0.1330*** (0.97)***	-0.1330*** (0.97)***	GDP ⇒ CO ⁻¹ *** (0.45)	
<i>GDP equation_{Asia}</i>											
C	1.3009*** (0.00)***	1.3009*** (0.00)***	1.9096*** (0.00)***	1.9096*** (0.00)***	1.9096*** (0.00)***	1.4987*** (0.00)***	1.9096*** (0.00)***	1.9096*** (0.80)***	1.9096*** (0.80)***	–	
LE _{Asia}	-0.2994*** (0.02)***	-0.2994*** (0.01)***	-0.6485*** (0.00)***	-0.6485*** (0.00)***	-0.6485*** (0.00)***	-0.4101*** (0.02)***	-0.6485*** (0.00)***	-0.6485*** (0.85)***	-0.6485*** (0.85)***	LE ⇒ GDP*** (0.00)	

Table 7 (continued)

	Limited information approach (single equation)				Full information approach (single equation)				Granger Causality
	OLS	WOLS	2SLS	WSLS	3SLS	SUR	GMM	FIML	
CO^{-1}_{Asia}	-0.0358*** (0.08) ***	-0.0358*** (0.07) ***	-0.0060*** (0.80) ***	-0.0060*** (0.79) ***	-0.0060*** (0.79) ***	-0.0270*** (0.08) ***	-0.0060*** (0.64) ***	-0.0060*** (0.98) ***	$CO^{-1} \Rightarrow GDP$ *** (0.03)
$GDP(-1)_{Asia}$	1.0348*** (0.00) ***	1.0348*** (0.00) ***	1.2500*** (0.00) ***	1.2500*** (0.00) ***	1.2500*** (0.00) ***	1.1023*** (0.00) ***	1.2500*** (0.00) ***	1.2500*** (0.51) ***	-

^a According to Schwarz information criteria

Table 8 Alternative variables for relationships and causality directions of sustainable development pillars from North America to East Asia and Pacific via simultaneous equations system and Granger causality test

		Limited information approach (single equation)				Full information approach (single equation)				Granger	
		OLS	WOLS	2SLS	WSLS	3SLS	SUR	GMM	FIML	Causality	
<i>SC equation_{Asia}</i>											
C	8.7263*** (0.00)***	8.7263*** (0.00)***	8.7263*** (0.00)***	8.7263*** (0.00)***	8.7263*** (0.00)***	8.7263*** (0.00)***	8.7263*** (0.00)***	8.7263*** (0.00)***	8.7263*** (0.00)***	8.7263*** (0.00)***	Optimal lag = 6
SC _{N.America}	0.6486*** (0.00)***	0.6486*** (0.00)***	0.6486*** (0.00)***	0.6486*** (0.00)***	0.6486*** (0.00)***	0.6486*** (0.00)***	0.6486*** (0.00)***	0.6486*** (0.00)***	0.6486*** (0.00)***	0.6486*** (0.00)***	SC ⇒ SC*** (0.17)
GH ⁻¹ _{N.America}	0.5808*** (0.00)***	0.5808*** (0.00)***	0.5808*** (0.00)***	0.5808*** (0.00)***	0.5808*** (0.00)***	0.5808*** (0.00)***	0.5808*** (0.00)***	0.5808*** (0.00)***	0.5808*** (0.00)***	0.5808*** (0.00)***	GH ⁻¹ ⇒ SC*** (0.23)
EN _{N.America}	-0.5422*** (0.00)***	-0.5422*** (0.00)***	-0.5422*** (0.00)***	-0.5422*** (0.00)***	-0.5422*** (0.00)***	-0.5422*** (0.00)***	-0.5422*** (0.00)***	-0.5422*** (0.00)***	-0.5422*** (0.00)***	-0.5422*** (0.00)***	EN ⇒ SC*** (0.75)
<i>GH equation_{Asia}</i>											
C	-7.5907*** (0.27)***	-7.5907*** (0.25)***	-7.5907*** (0.27)***	-7.5907*** (0.25)***	-7.5907*** (0.25)***	-7.5907*** (0.25)***	-7.5907*** (0.25)***	-7.5907*** (0.25)***	-7.5907*** (0.25)***	-7.5907*** (0.25)***	-
SC _{N.America}	1.4525*** (0.00)***	1.4525*** (0.00)***	1.4525*** (0.00)***	1.4525*** (0.00)***	1.4525*** (0.00)***	1.4525*** (0.00)***	1.4525*** (0.00)***	1.4525*** (0.00)***	1.4525*** (0.00)***	1.4525*** (0.00)***	SC ⇒ GH ⁻¹ *** (0.03)
GH ⁻¹ _{N.America}	-2.1681*** (0.00)***	-2.1681*** (0.00)***	-2.1681*** (0.00)***	-2.1681*** (0.00)***	-2.1681*** (0.00)***	-2.1681*** (0.00)***	-2.1681*** (0.00)***	-2.1681*** (0.00)***	-2.1681*** (0.00)***	-2.1681*** (0.00)***	GH ⁻¹ ⇒ GH ⁻¹ *** (0.71)
EN _{N.America}	0.0886*** (0.89)***	0.0886*** (0.89)***	0.0886*** (0.89)***	0.0886*** (0.89)***	0.0886*** (0.89)***	0.0886*** (0.89)***	0.0886*** (0.89)***	0.0886*** (0.89)***	0.0886*** (0.89)***	0.0886*** (0.89)***	EN ⇒ GH ⁻¹ *** (0.67)
<i>EN equation_{Asia}</i>											
C	-42.6882*** (0.00)***	-42.6882*** (0.00)***	-42.6882*** (0.00)***	-42.6882*** (0.00)***	-42.6882*** (0.00)***	-42.6882*** (0.00)***	-42.6882*** (0.00)***	-42.6882*** (0.00)***	-42.6882*** (0.00)***	-42.6882*** (0.00)***	-
SC _{N.America}	-0.3893*** (0.38)***	-0.3893*** (0.35)***	-0.3893*** (0.38)***	-0.3893*** (0.35)***	-0.3893*** (0.35)***	-0.3893*** (0.35)***	-0.3893*** (0.35)***	-0.3893*** (0.35)***	-0.3893*** (0.35)***	-0.3893*** (0.35)***	SC ⇒ EN*** (0.90)

Table 8 (continued)

	Limited information approach (single equation)				Full information approach (single equation)				Granger Causality
	OLS	WOLS	2SLS	WLS	3SLS	SUR	GMM	FIML	
$GH^{-1} N_{\text{America}}$	-4.6506*** (0.00)***	-4.6506*** (0.00)***	-4.6506*** (0.00)***	-4.6506*** (0.00)***	-4.6506*** (0.00)***	-4.6506*** (0.00)***	-4.6506*** (0.00)***	-4.6506*** (0.00)***	$GH^{-1} \Rightarrow EN$ *** (0.82)
$EN N_{\text{America}}$	3.8059*** (0.00)***	3.8059*** (0.00)***	3.8059*** (0.00)***	3.8059*** (0.00)***	3.8059*** (0.00)***	3.8059*** (0.00)***	3.8059*** (0.00)***	3.8059*** (0.00)***	$EN \Rightarrow EN$ *** (0.41)

Table 9 Alternative variables for relationships and causality directions of sustainable development pillars from East Asia and Pacific to North America via simultaneous equations system and Granger causality test

		Limited information approach (single equation)						Full information approach (single equation)						Granger	
		OLS	WOLS	2SLS	WSLS	3SLS	SUR	GMM	FIML	Causality					
<i>SC equation</i> _{N. America}														Optimal lag = 6	
C	-0.2254*** (0.72) ***	-0.2254*** (0.71) ***	-0.2254*** (0.72) ***	-0.2254*** (0.71) ***	-0.2254*** (0.71) ***	-0.2254*** (0.71) ***	-0.2254*** (0.71) ***	-0.2254*** (0.73) ***	-0.2254*** (0.93) ***	-	-	-	-	-	-
SC _{Asia}	0.6836*** (0.00) ***	0.6836*** (0.00) ***	0.6836*** (0.00) ***	0.6836*** (0.00) ***	0.6836*** (0.00) ***	0.6836*** (0.00) ***	0.6836*** (0.00) ***	0.6836*** (0.00) ***	0.6836*** (0.19) ***	SC ⇒ SC*** (0.02)	SC ⇒ SC*** (0.02)	SC ⇒ SC*** (0.02)	SC ⇒ SC*** (0.02)	SC ⇒ SC*** (0.02)	SC ⇒ SC*** (0.02)
GH ⁻¹ _{Asia}	-0.0806*** (0.02) ***	-0.0806*** (0.01) ***	-0.0806*** (0.02) ***	-0.0806*** (0.01) ***	-0.0806*** (0.01) ***	-0.0806*** (0.01) ***	-0.0806*** (0.01) ***	-0.0806*** (0.15) ***	-0.0806*** (0.16) ***	GH ⁻¹ ⇒ SC*** (0.48)	GH ⁻¹ ⇒ SC*** (0.48)	GH ⁻¹ ⇒ SC*** (0.48)	GH ⁻¹ ⇒ SC*** (0.48)	GH ⁻¹ ⇒ SC*** (0.48)	GH ⁻¹ ⇒ SC*** (0.48)
EN _{Asia}	0.1704*** (0.00) ***	0.1704*** (0.00) ***	0.1704*** (0.00) ***	0.1704*** (0.00) ***	0.1704*** (0.00) ***	0.1704*** (0.00) ***	0.1704*** (0.00) ***	0.1704*** (0.00) ***	0.1704*** (0.00) ***	EN ⇒ SC*** (0.16)	EN ⇒ SC*** (0.16)	EN ⇒ SC*** (0.16)	EN ⇒ SC*** (0.16)	EN ⇒ SC*** (0.16)	EN ⇒ SC*** (0.16)
<i>GH equation</i> _{N. America}															
C	-0.5143*** (0.55) ***	-0.5143*** (0.54) ***	-0.5143*** (0.55) ***	-0.5143*** (0.54) ***	-0.5143*** (0.54) ***	-0.5143*** (0.54) ***	-0.5143*** (0.54) ***	-0.5143*** (0.65) ***	-0.5143*** (0.57) ***	-	-	-	-	-	-
SC _{Asia}	-0.4866*** (0.00) ***	-0.4866*** (0.00) ***	-0.4866*** (0.00) ***	-0.4866*** (0.00) ***	-0.4866*** (0.00) ***	-0.4866*** (0.00) ***	-0.4866*** (0.00) ***	-0.4866*** (0.03) ***	-0.4866*** (0.01) ***	SC ⇒ GH ⁻¹ *** (0.77)	SC ⇒ GH ⁻¹ *** (0.77)	SC ⇒ GH ⁻¹ *** (0.77)	SC ⇒ GH ⁻¹ *** (0.77)	SC ⇒ GH ⁻¹ *** (0.77)	SC ⇒ GH ⁻¹ *** (0.77)
GH ⁻¹ _{Asia}	-0.1264*** (0.00) ***	-0.1264*** (0.00) ***	-0.1264*** (0.00) ***	-0.1264*** (0.00) ***	-0.1264*** (0.00) ***	-0.1264*** (0.00) ***	-0.1264*** (0.00) ***	-0.1264*** (0.06) ***	-0.1264*** (0.16) ***	GH ⁻¹ ⇒ GH ⁻¹ *** (0.02)	GH ⁻¹ ⇒ GH ⁻¹ *** (0.02)	GH ⁻¹ ⇒ GH ⁻¹ *** (0.02)	GH ⁻¹ ⇒ GH ⁻¹ *** (0.02)	GH ⁻¹ ⇒ GH ⁻¹ *** (0.02)	GH ⁻¹ ⇒ GH ⁻¹ *** (0.02)
EN _{Asia}	-0.2331*** (0.00) ***	-0.2331*** (0.00) ***	-0.2331*** (0.00) ***	-0.2331*** (0.00) ***	-0.2331*** (0.00) ***	-0.2331*** (0.00) ***	-0.2331*** (0.00) ***	-0.2331*** (0.00) ***	-0.2331*** (0.00) ***	EN ⇒ GH ⁻¹ *** (0.18)	EN ⇒ GH ⁻¹ *** (0.18)	EN ⇒ GH ⁻¹ *** (0.18)	EN ⇒ GH ⁻¹ *** (0.18)	EN ⇒ GH ⁻¹ *** (0.18)	EN ⇒ GH ⁻¹ *** (0.18)
<i>EN equation</i> _{N. America}															
C	9.4186*** (0.00) ***	9.4186*** (0.00) ***	9.4186*** (0.00) ***	9.4186*** (0.00) ***	9.4186*** (0.00) ***	9.4186*** (0.00) ***	9.4186*** (0.00) ***	9.4186*** (0.00) ***	9.4186*** (0.00) ***	-	-	-	-	-	-
SC _{Asia}	0.2830*** (0.05) ***	0.2830*** (0.04) ***	0.2830*** (0.05) ***	0.2830*** (0.04) ***	0.2830*** (0.04) ***	0.2830*** (0.04) ***	0.2830*** (0.04) ***	0.2830*** (0.13) ***	0.2830*** (0.12) ***	SC ⇒ EN*** (0.48)	SC ⇒ EN*** (0.48)	SC ⇒ EN*** (0.48)	SC ⇒ EN*** (0.48)	SC ⇒ EN*** (0.48)	SC ⇒ EN*** (0.48)

Table 9 (continued)

		Limited information approach (single equation)					Full information approach (single equation)					Granger Causality	
		OLS	WOLS	2SLS	WSLS	3SLS	SUR	GMM	FIML				
GH^{-1} Asia		0.1688*** (0.00)***	0.1688*** (0.00)***	0.1688*** (0.00)***	0.1688*** (0.00)***	0.1688*** (0.00)***	0.1688*** (0.00)***	0.1688*** (0.00)***	0.1688*** (0.03)***	$GH^{-1} \Rightarrow EN$ *** (0.01)			
		0.0073*** (0.78)***	0.0073*** (0.77)***	0.0073*** (0.78)***	0.0073*** (0.77)***	0.0073*** (0.77)***	0.0073*** (0.77)***	0.0073*** (0.85)***	0.0073*** (0.85)***	$EN \Rightarrow GH$ *** (0.44)			

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Data availability The data and the software files employed in this study are in the following link (Nodehi and Taghvaei 2021a, b). <https://data.mendeley.com/datasets/xvd7bv6mjb/5>

Code availability The work file of EViews software is available at the following link <https://data.mendeley.com/datasets/xvd7bv6mjb/5>

Declarations

Conflicts of interest The authors declare that they have no conflict of interest.

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