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Enhancing Environmental Sustainability and Green Innovation in Vietnam: Does Foreign Aid Matter?

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ABSTRACT

This study utilizes an extended time-varying autoregression model to examine contemporaneous and lagged linkages between environmental innovation and foreign aid in Vietnam from 1994 to 2022. The R^2 decomposed linkage method is also employed as a robustness check. Our analysis reveals that, prior to 2015, environmental innovation drove foreign aid, facilitating key projects like solar power and waste management improvements. However, from 2015 onward, foreign aid began to overshadow environmental innovation, indicating a growing dependency on external support amidst slower domestic resource development. Furthermore, environmental innovation initially influenced economic growth but later became increasingly responsive to economic expansion. Environmental innovation's interaction with CO_2 emissions and HDI also evolved, showing its critical role in both environmental and human development. These findings suggest that effective policy should balance economic growth with sustained investment in environmental innovations to achieve long-term sustainability.

Keywords: Environmental Innovation, Foreign Aid, Vietnam, The R^2 Decomposed Linkage Method
JEL Classifications: F3, Q43.

1. INTRODUCTION

Recent years have seen a dramatic increase in environmental crises such as degradation and resource scarcity, making pollution control and the sustainable use of resources critical global issues (Liu et al., 2024; Wang and Azam, 2024). With the advent of sustainable development, environmental protection has become a crucial component of economic development throughout the world, including Vietnam (Awosusi et al., 2023; Ha et al., 2021; Van Quang and Thanh, 2023). Researchers believe that the development and diffusion of green technologies are essential to improving energy efficiency, reducing energy consumption, reducing emissions, and realizing sustainable economic and environmental growth. Among the business reasons for engaging in green innovation are to respond to environmental and social challenges as well as to achieve long-term sustainable economic growth (Liu et al., 2024; Wang and Azam, 2024), especially in a rapidly developing economy such as Vietnam. Consequently, the Vietnamese government has issued several policy documents on green innovation to encourage firms to pursue green and sustainable development paths, thereby guiding economic growth from high speed to high quality.

Green innovation faces a double externality problem in comparison to traditional innovation (Liu et al., 2024; Rennings, 2000). According to conventional thinking, environmental regulations impose an unnecessary burden on firms, which makes them invest in unproductive activities in order to reduce environmental pollution, which ultimately reduces their profitability (Bui and To, 2024; Pekovic et al., 2018; Tang, 2023). According to Porter and van der Linde, appropriate environmental standards have the potential to stimulate firms to innovate, offset the costs associated with compliance, and enhance their competitiveness (Porter and van der Linde, 1995). It is commonly referred to as the "Porter hypothesis". Furthermore, (Liu et al., 2024; Yu et al., 2017) note that despite increased costs resulting from environmental regulations, firms are still able to respond effectively to external environmental pressures by implementing green innovation strategies. The implementation of such strategies can also contribute significantly to a firm's sustainable competitive advantage and financial performance over the long term (Jiang et al., 2024; Roh and Yu, 2023; Yan and Yang, 2024). Although there is relatively strong theoretical and empirical evidence of green innovation's environmental benefits, there is controversy as to whether it can enhance firms' financial performance. Moreover, the issue has become more serious in developing nations, which still face challenges in catching up with the innovative level of industrialized countries. They lack research and development initiatives at both commercial and governmental levels and are still emerging as development partners in global development discussions. Critics remain sceptical about developing or developed nations' ability to assist other developing nations in ecological innovation growth due to the dominance of industrialized nations in various spheres of international affairs (Bogliacino et al., 2012).

According to the justifications mentioned above, underdeveloped nations often require more capability in creating green innovation (GI) due to their low technological capabilities. Industrialized nations with access to cutting-edge technology and educational resources are often considered the only experts in GI. Nevertheless, specific academic research indicates that increased assistance could potentially spur the growth of green innovation, provided that the private sector actively participates in humanitarian endeavours (Ha et al., 2022; Thanh et al., 2022). Foreign aid is seen as crucial for the effective growth of GI in emerging nations. Nonetheless, a developing nation like Vietnam does not have a significant ownership stake. Therefore, it is important to consider how foreign aid can promote Vietnam's GI. Vietnam has been both a beneficiary of funding from sophisticated countries and a proactive provider, assisting other least-developed nations with their creative growth. Hence, there is a need for more academic research on the drivers of GI, especially the role of foreign aid in Vietnam.

After the fall of the communist regime, Vietnam underwent significant changes in its economy, politics, and environment. The previous government's disregard for the environment before 1986 left the country with significant environmental challenges. The country's traditional economic policies that prioritized heavy and extractive sectors and intensified agriculture have led to severe pollution and soil degradation. However, the situation has gradually improved due to subsequent economic reforms. Furthermore, it is expected that increased development cooperation will provide more financial and technical support to safeguard biodiversity in Vietnam (Ha et al., 2022). Environmental regulations and standards have been gradually enhanced to demonstrate an eagerness to join international organizations or receive foreign aid. With these changes, the development of innovative technologies is increasingly targeted to reduce energy and material needs and increase the utilization of greener energy sources (Le, 2022). The increasing engagement of donors in environmental assistance transfers inspires us to investigate the following research questions: "What are the interrelations between foreign aid and environmental innovation development in Vietnam?" and "What are the effective policies to promote foreign aid as well as green innovation in Vietnam on the path toward sustainable development?" Data from Vietnam's database between 1994 and 2022 will be utilized.

The remainder of our study is organized as follows. The second section provides a comprehensive review of existing research on the correlation between foreign aid and environmental innovation. Section 3 outlines the process of model development, data description, and the empirical and analytical methodologies employed. Section 4 presents the results and discussions. Finally, Section 5 offers conclusions and policy recommendations.

2. LITERATURE REVIEW

2.1. Theoretical Underpinning: A Theory of Social Capital (SCT)

The term "social capital" refers to a collection of resources that have been developed from connections, interactions, and processes between a variety of actors, as defined by (James, 2023). An organization's resource base is comprised of resources that result from the exchange and synthesis of various types of connections, such as organizational and interpersonal networks. The function of social capital is to facilitate the exchange of resources within a social unit, as well as to serve as the foundation for the existence of any organization. Described as the quantity and quality of interpersonal ties within social units, social capital encompasses both formal and informal networks. The use of this technology is widely recognized across all academic disciplines as a means of increasing information dissemination efficiency, reducing redundancy and transaction costs, and fostering collaboration. As a result of these attributes, innovative organizational structures can be developed.

The interplay between a business's capability for green innovation and its R&D strategy constitutes an intricate and interconnected network in the field of "green management" (Bataineh et al., 2024). The development of new products and processes must take into account environmental factors as part of the organization's business strategy. A key aspect of green innovation is the exchange and sharing of information based on environmental criteria. It is imperative that organizations increase their capacity to manage green information in order to comply with strict environmental standards. Social capital enhances the ability of organizations to share information pertinent to green management, resulting in superior innovation performance. In this study, the goal is to explore the interconnectedness between different forms of social capital, as well as how social capital affects knowledge transfer and innovation performance in the field of green management.

Research indicates that strong connections between social actors facilitate information sharing, and structural capital is characterized by the network of interactions among social actors (Alecu et al., 2022; Renzl, 2008; Vonneilich, 2022). Structured capital facilitates resource exchange and the exchange of sustainability-related information through the structural environment mechanism. The ability to comprehend the implications of environmental regulations on the partners of an organization is enhanced when it is endowed with greater structural capital.

Green management requires an understanding of the interplay between the three primary components of social capital. Researchers have found that interpersonal relationships foster relational capital (Debicki et al., 2020; John, 1978; Ramírez-Solis et al., 2022; Vlasic, 2022). Trust connections develop over time as members engage, strengthening mutual trustworthiness. The purpose of green management is to gather, compile, and distribute data and resources from staff, clients, suppliers, and partners. An organization's ability to communicate and share resources is facilitated by its knowledge management systems, information management capabilities, and managerial procedures for environmental management. Relational capital is, therefore, more adeptly developed by businesses with greater structural capital. Shared values also support reliable connections (Kenter et al., 2015; Sitkin and Roth, 1993). The pursuit of common green management objectives fosters trust between businesses and their partners, resulting in a strong network of coworkers, clients, suppliers, and partners. By building cognitive and structural capital, organizations can adapt to global environmental trends and stringent environmental regulations. Businesses producing green products benefit from sharing green information, which facilitates the exchange of environmental needs. The integration of green knowledge into organizational knowledge systems enhances innovation performance, enabling R&D teams to identify and develop detailed plans for green innovation (Abbas and Khan, 2022).

2.2. Foreign Aid and Needs for Environmental Innovations

Depending on humanitarian motivations, aid recipients' needs can be divided into two general categories: Economic needs, which are measured based on economic development indicators such as GDP per capita, and social needs, which can be estimated using a range of socioeconomic indicators, including literacy, life expectancy, neonatal mortality, and calorie intake (Dreher et al., 2024; Harrigan and Wang, 2011). Altruism theory suggests that aid allocation increases as needs increase. Environmental aid often falls into this category, with recipients' environmental needs being determined according to the priorities of the donors. As an example, if a donor is concerned about ensuring that the recipient has access to clean drinking water, they may consider the percentage of renewable freshwater available in the country. An ecological footprint indicator can be utilized to encourage the responsible use of natural resources in less developed countries. In addition, another set of criteria emphasizes the importance of aid allocation, especially with regard to institutional quality and political progress. These indicators include the Global Governance Indicators, the level of civil liberties and political rights, and the type of government. The merit theory suggests that donors may provide additional assistance to recipients with superior institutional performance as a form of reward, including preferences for particular political regimes, such as democracy over autocracy. According to Burnside and Dollar (2000), the quality of institutions in recipient countries has a significant influence on aid effectiveness. There have been criticisms of this study (Burnside and Dollar, 2000), but it has led to the imposition of specific political conditions on foreign aid. The merit argument can also be applied to environmental aid, with donors allocating a greater amount of funds to countries with a higher level of environmental performance.

In spite of this, we are fascinated by environmental explanatory factors' impact on environmental innovation. A novel method has been proposed by (Hicks et al., 2008) to study the environmental consequences of specific aid initiatives. (Roberts et al., 2009) describe this method in detail. Roberts et al. (2009) are interested in understanding the impact of environmental factors on Czech environmental aid. The selection of variables was limited by a second criterion. Only a few nations have access to many environmental indicators (particularly more developed nations). There is a need to include records, particularly for more recent periods. As an incentive, significant assistance is offered to nations that perform better on environmental matters, while the seventh is related to the country's environmental performance (Awewomom et al., 2024). The hypothesized relationship explains the reasoning behind the selection of each variable.

There is evidence that natural disasters negatively impact household well-being (Gunby and Coupé, 2023). The aftermath of a natural disaster can lead to a temporary rise in GDP due to post-disaster recovery; however, it can also stifle long-term economic progress in underdeveloped countries (Daher, 2024). The governments of developing nations (including Vietnam) aim to prevent an essential goal, natural risks, and disasters through official development policies (Ngo and Truong, 2022; Van Quang & Thanh, 2023). The governments of the developing nations are also seeking more foreign aid sources where these advanced economies will be willing to provide environmental knowledge and experience, techniques for reducing energy consumption, promoting the use of renewable energy sources and limiting environmental damage (Opršal and Harmáček, 2019). A nation's pursuit of green innovation is more likely to increase due to this trend.

3. THE ECONOMETRIC MODEL

An elegant and simple way to create a benchmark model is to use the model-free connectedness approach. The null hypothesis in statistics assumes that no effects are taking place, and the applied statistical model rejects or accepts this hypothesis. It is useful to see the model-free connectedness approach as a null hypothesis because it assumes that the lagged variables have no impact on z_t, so the VAR coefficients, B, are zero. In response to this assumption, the associated GFEVD collapses as follows:

$$z_t = u_t \qquad z_t, u_t \sim N(0,\Sigma)$$

$$A_o = I_k \qquad A_0 = 0 \; i = 1, \ldots, p$$

$$O_{i \leftarrow j}^{gen}(H) = \frac{\Sigma_{ij}^2}{\Sigma_{jj}\Sigma_{ii}} = \left(\frac{\Sigma_{ij}}{\sqrt{\Sigma_{jj}\Sigma_{ii}}}\right)^2 = p_{ij}^2 = R_{ij}^2$$

The squared Pearson correlation coefficient, which measures the goodness-of-fit of a bivariate linear regression between variables, is invariant of the forecast horizon, H. Thus, the following equality holds: $R_i i^2 = 1$ and $R_{ij}^2 = R_{ji}^2$.

In the following way, the (scaled) GFEVD can be formulated using the normalization suggested by Diebold and Ylmaz (2012):

$$gSOT_{i\leftarrow j} = \frac{R_{ij}^2}{\sum_{l=1}^{k} R_{ij}^2}$$

In order to be complete, if variable i can be perfectly predicted by all other variables j, then the row sum of variable i would be unity. Thus, the sum of the bivariate R_{ij}^2 does not equal the R_i^2 value of the multivariate linear regression where i is the dependent variable and j is the explanatory variable: $gSOT_{ij}$. On the other hand, $gSOT_{ij}$ illustrates the relative R_i^2 contribution of variable j to variable i if all variables are orthogonal. Considering that $R_{il}^2 = 1$, the supremum value of $\sum_{l=1}^{k} R_{il}^2$, is equal to k.

Two significant findings can be drawn from the model-free connectedness approach. The first benefit of this approach is that it enables us to calculate an upper limit for the TCI, which shows that it does not fall between zero and unity. We also find a relationship between the Pearson correlation coefficient and the PCI, which is important for the minimum connectedness portfolio.

It is now possible to interpret the TCI of (Diebold and Yilmaz, 2012) as the average sum of weighted bivariate variables, where and can be written as follows:

$$TCI = 1 - \frac{1}{k}\sum_{i=1}^{k} gSOT_{i\leftarrow i}$$

$$= 1 - \frac{1}{k}\frac{R_{ii}^2}{\sum_{l=1}^{k} R_{il}^2}$$

It follows that the TCI lies between 0 and $\frac{k-1}{k}$, since R_{ii}^2 = unity and the supremum value of $\sum_{l=1, l\neq i}^{k} R_{il}^2$ = k .

The following diagram illustrates this:

$$TCI = \frac{k}{k} - \frac{1}{k}\sum_{i=1}^{k}\frac{1}{k}$$

$$= \frac{k-1}{k}$$

(Chatziantoniou and Gabauer, 2021) confirmed their Monte Carlo simulation results with this analytical result. The PCI formula can be simplified as follows:

$$PCI_{ij} = 2\left(\frac{gSOT_{i\leftarrow j} + gSOT_{j\leftarrow i}}{gSOT_{i\leftarrow i} + gSOT_{i\leftarrow j} + gSOT_{j\leftarrow i} + gSOT_{j\leftarrow j}}\right)$$

$$= 2\left(\frac{\frac{R_{ij}^2}{\sum_{l=1}^{k} R_{il}^2} + \frac{R_{ji}^2}{\sum_{l=1}^{k} R_{jl}^2}}{\frac{1}{\sum_{l=1}^{k} R_{il}^2} + \frac{R_{ij}^2}{\sum_{l=1}^{k} R_{il}^2} + \frac{R_{ij}^2}{\sum_{l=1}^{k} R_{jl}^2} + \frac{1}{\sum_{l=1}^{k} R_{jl}^2}}\right)$$

$$= 2\left(\frac{R_{ij}^2 \cdot \left(\sum_{l=1}^{k} R_{jl}^2 + \sum_{l=1}^{k} R_{il}^2\right)}{R_{ij}^2 \cdot \left(\sum_{l=1}^{k} R_{jl}^2 + \sum_{l=1}^{k} R_{il}^2\right) + \sum_{l=1}^{k} R_{il}^2 + \sum_{l=1}^{k} R_{jl}^2}\right)$$

$$= \frac{2 \cdot R_{ij}^2}{1 + R_{ij}^2} = \frac{2 \cdot p_{ij}^2}{1 + p_{ij}^2} \quad -1 < p_{ij} < 1,\ 0 \leq R_{ji}^2 \leq 1$$

PCI is related to Pearson correlation coefficients (and R^2) based on this equation. The PCI values range from zero to unity based on this equation. Moreover, this relation also explains why minimal connectivity and minimal correlation portfolio weights (Broadstock et al., 2022) are similar in quantitative terms (Adekoya et al., 2022; Broadstock et al., 2022; Tiwari et al., 2023).

4. RESULTS

4.1. Data Description

Our paper uses yearly time series data to explore environmental innovation in Vietnam, covering technological advancements. It delves into innovation in environment-related technology (EI), Foreign Aid (FA), CO_2 emissions (CO_2), gross domestic product (GDP), and human development index (HDI) from 1994 to 2022. The CO_2 and FA statistics came from the Our World in Statistics database. The EI was supplied by the Organization for Economic Co-operation and Development (OECD). The growth rates of the previously described data series were computed after the data was collected and used in the statistical analysis. Figure 1 illustrates the returns of our indicators. Environmental innovation surged in the early years but experienced a sharp decline around 1995, followed by rapid growth. This trend persisted until 2005, when the fluctuations diminished, leading to a slight positive trend towards the end of the period. It can be attributed to attributed to the economic restructuring and challenges Vietnam faced during the early stages of its "Doi Moi" economic reforms. The subsequent rapid growth might be linked to increased governmental and international support for sustainable development initiatives (Baum, 2020). Conversely, foreign aid exhibited modest growth rate fluctuations in the initial phase. However, from 2010 onwards, the amplitude of these fluctuations increased significantly, culminating in a sharp drop towards the end of the period. It may be due to changing international donor priorities and Vietnam's transition from a low-income to a lower-middle-income country, which affected eligibility for certain types of aid (Bony-Cisternes, 2019). GDP generally showed positive growth rates throughout the period, with a few near-zero slowdowns around 1995, 2015, and 2020. This can be linked to specific economic and external shocks, such as the lingering effects of the "Doi moi" reforms, the global financial crisis, and the COVID-19 pandemic, respectively. The peak in GDP growth between 2005 and 2010 aligns with Vietnam's economic boom due to robust domestic and foreign investment (The World Bank In Viet Nam, 2024). CO_2 emissions recorded zero growth around 2000 and negative growth in 2013 and from 2020 to 2022. It might be due to the implementation of early environmental protection policies and environmental regulations and the impact of the COVID-19 pandemic, which reduced industrial activity and emissions (Climate Transparency, 2020). Despite experiencing negative growth rates in 1996 and 2021, HDI generally maintained positive growth rates. However, this positive trend continuously declined from 1996 to 2021, after which it rocketed upwards significantly. It could be linked to economic challenges and health crises affecting education and living standards. The significant upward trend post-2021 might be due to renewed governmental efforts towards improving healthcare and education and recovery from the COVID-19 pandemic (UNDP, 2022).

Table 1 provides a comprehensive overview, revealing positive mean returns across Table 1 provides a comprehensive overview, revealing positive mean returns across all series except foreign aid. From 2014, foreign aid decreased significantly. All series are non-normal distribution patterns (Jarque and Bera, 1980) except CO_2 emissions and HDI. Only CO_2 emissions are stationary, as indicated by the ERS unit root test (Elliott et al., 1996). Additionally, complications arise because the weighted portmanteau test (Fisher and Gallagher, 2012) reveals autocorrelation affecting the sole returns in only environmental innovation and economic growth. These findings validate our methodology and provide compelling evidence supporting the adoption of a novel decomposed connectedness approach to investigate the nexus of environmental innovation and foreign aid[1].

Due to the nonstationarity of all variables, it is necessary to check for cointegration in order to determine the appropriate model specification. For testing cointegration, we use a multivariate VAR-based trace test and a maximal eigenvalue test developed by (Johansen, 1991; Johansen and Juselius, 1990). Additionally, we use (Kripfganz and Schneider, 2020) critical values to assess the robustness of the Johansen tests using the bounds test approach

1 In addition, the Ljung–Box test statistics for the standard residuals reject the null hypothesis of no serial correlation in all series at 1 and 5 lags. Engle's ARCH-LM tests confirm the significance of the ARCH effects in all included series under consideration.

Figure 1: The growth of the included series

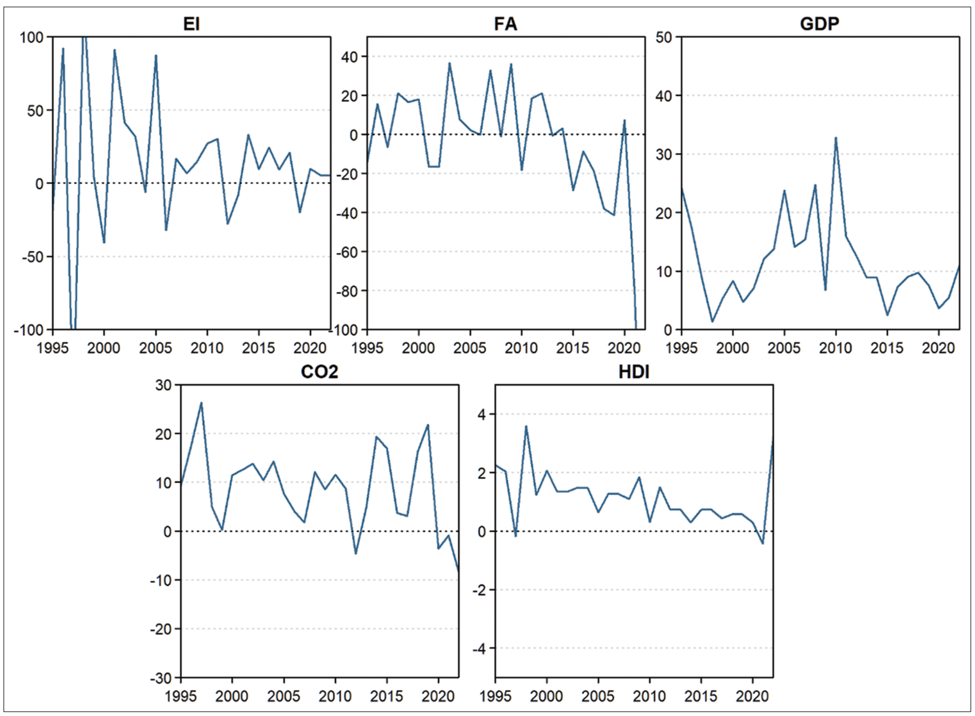


Table 1: Summary statistics

Statistics	EI	FA	GDP	CO2	HDI
Mean	13.545	−10.383	11.510***	8.713***	1.158***
	(0.169)	(0.292)	(0.000)	(0.000)	(0.000)
Variance	2577.12	2616.939	55.961	68.212	0.837
Skewness	−0.639	−3.212***	1.146***	−0.031	0.828**
	(0.120)	(0.000)	(0.010)	(0.937)	(0.050)
Ex.Kurtosis	2.954***	11.685***	0.864	−0.427	0.727
	(0.008)	(0.000)	(0.150)	(0.896)	(0.187)
JB	12.085***	207.446***	6.996**	0.217	3.817
	(0.002)	(0.000)	(0.030)	(0.897)	(0.148)
ERS	−1.315	−0.322	−1.556	−1.758*	−0.027
	(0.205)	(0.751)	(0.137)	(0.096)	(0.979)
Q (20)	18.926**	7.034	15.967*	11.836	8.410
	(0.027)	(0.820)	(0.086)	(0.323)	(0.681)
Q2 (20)	12.252	0.545	12.431	11.755	4.873
	(0.288)	(1.000)	(0.274)	(0.331)	(0.961)

based on the autoregressive distributed autoregressive (ARDL) of (Pesaran et al., 2001). We determine the lag order of the VAR using lag-length tests such as the LR test statistics, the Akaike information criterion, and the Schwarz information criterion in order to test for cointegration. Our lag length is determined using the Akaike information criterion since our sample is relatively small, and the Akaike information criterion performs better in small samples. By using the Akaike information criterion, which is used in the cointegration test, and the estimation of the TVP-VAR model, the order of the VAR is determined to be four.

4.2. Average Connectedness Results

From 1994 to 2019, Table 2 provides an overview of the average findings for the linkages between various components in the framework. The diagonal elements account for each variable's volatility generated by its own shocks, but the off-diagonal elements total their contributions to the volatility of other variables (FROM) and vice versa (TO). Each row in Table 2 describes how one variable affects the forecast error variance of another, whereas the columns show the impact of a given variable category on each of the others independently.

Across the entire observation period, the average TCI value stands at 31.17%, indicating that fluctuations within this network can elucidate 31.17% of the variation in the considered variables. However, idiosyncratic effects account for around 69% of the system's error variance. The final row of Table 2 sheds insight into the impact of each variable, revealing that, on average, environmental innovation and foreign aid have little influence in transferring the consequences and volatility of shocks to other variables in the system. Consequently, CO_2 emissions, GDP, and HDI serve as net recipients of corresponding shocks, with GDP being the most significant shock recipient. This finding aligns with existing research, such as Quy (2016), which explored the relationship between foreign aid and economic growth in Vietnam and found a negative impact on economic growth due to corruption and policy inconsistencies.

4.3. Total Dynamic Connectedness

It's worth emphasizing that the summarized average results provided earlier offer only a surface-level glimpse into the connections among the variables under consideration within the system. To achieve a deeper comprehension of the way crises influence the interactions among variables in a network, adopting a dynamic analytical framework becomes crucial. This framework must adapt to the constantly evolving nature of the Total Connectedness Index (TCI) and accurately depict the changing roles of variables within the network. Specifically, it's essential to monitor transitions in a

Table 2: Averaged joint connectedness

Variables	EI	FA	CO_2	GDP	HDI	FROM
EI	73.36	1.66	6.32	0.43	18.22	26.64
FA	2.63	65.41	8.52	1.72	21.72	34.59
CO_2	8.85	8.95	76.92	2.45	2.83	23.08
GDP	3.25	8.66	2.90	83.20	1.99	16.80
HDI	30.97	18.34	4.41	1.05	45.23	54.77
TO	45.70	37.61	22.15	5.65	44.75	TCI
NET	19.06	3.02	−0.92	−11.15	−10.01	31.17

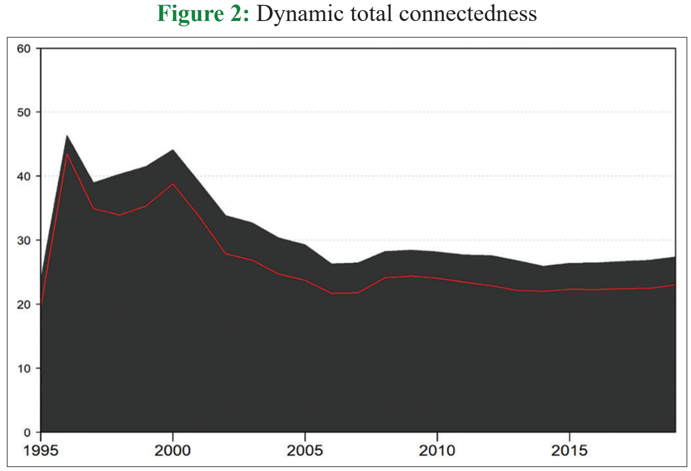
variable's behaviour, transitioning from being a net transmitter of shocks to a net receiver and vice versa. This paper initiates this exploration by scrutinizing the time-varying assessments of total connectedness, elucidating the temporal fluctuations in the TCI, as illustrated in Figure 2. The observed variations in TCI values throughout the sample period are significant. There was an upward trajectory in the early years, peaking at approximately 46% in 1996. Notably, higher TCI values signify robust contagions between the various variables. For instance, Vietnam experienced a notable surge in foreign aid and investment in 1995, with the cumulative total of approved licenses for direct foreign investment soaring to $16 billion in July 1995 despite only $5 billion being effectively invested. Nevertheless, foreign aid and investment remained pivotal drivers of Vietnam's economic expansion during that timeframe. Subsequently, TCI values experienced a slight dip to around 39% in 1997 before rebounding to 43% in 2000. Ultimately, TCI levels fell to 27% in 2006, with ongoing swings around this level.

4.4. Net Total Directional Connectedness

As displayed in Figure 3, we can discern the specific roles each variable assumes within the network over time. Essentially, this figure illustrates whether any variable in the network predominantly transmits or receives shocks throughout the sample period. Values below zero notably imply a net receiver, while those above zero indicate a net transmitter of shocks into the system. In terms of net total connectivity, our findings show that sustainable development regularly acts as ripple shocks's net transmitter. This suggests that fostering development in environmental innovation creates favorable conditions for attracting foreign aid, as it is the recipient of shocks during those periods. For instance, the establishment of eco-industrial parks in Vietnam has facilitated the attraction of foreign direct investment and promoted sustainable growth. Vietnam's government data showcases the establishment of 326 industrial and processing zones across 94,000 hectares since 1991. Over 16,000 projects have been launched within these zones, accumulating a total registered capital that exceeds 180 billion USD.

A similar pattern may be observed in GDP, which is typically a net receiver of shocks, with a handful of exceptions. Foreign aid, on the other hand, gradually adopts both functions from anet transmitting role to a net receiving role. Specifically, foreign aid functioned as a net transmitter of shocks from 1995 to around 2004, peaking in 2000. This

Figure 2: Dynamic total connectedness



can be attributed to Vietnam's potential market size and abundant labor force, making it an appealing destination for foreign investment during the 2000s. Furthermore, as depicted in Figure 3, there was a period from 1995 to 2005 where CO_2 emissions functioned as recipients of net shocks, transitioning thereafter to become net shock sources starting from 2005. Notably, the peak in shock reception occurred in 1996. Interestingly, during this temporal span, HDI emerged as the primary conduit for transmitting shocks to the system, suggesting an interconnectedness between these two variables throughout the 1990s.

4.5. Net Pairwise Dynamic Connectedness

Figures 4 and 5 display the net pairwise dynamic connectedness in our designed system. As previously mentioned, positive values indicate variables that predominantly receive shocks within the network. The pairwise analysis reaffirms earlier findings and offers a comprehensive view of the transmission of uncertainty spillover shocks across this particular network.

In essence, it is notable that environmental innovation serves as the primary transmitter of shocks to all variables in the system. Specifically, environmental innovation transmits shocks to foreign aid, albeit to a lesser extent, with its peak observed in 1997. This underscores the enduring impact of environmental innovation on foreign aid volatility. For instance, Vietnam has initiated a $11.3 million project funded by the U.S. Agency for International Development (USAID) aimed at addressing environmental pollution. This project involves various measures, such as reducing plastic waste and promoting a circular economy

Figure 3: Dynamic net total directional connectedness

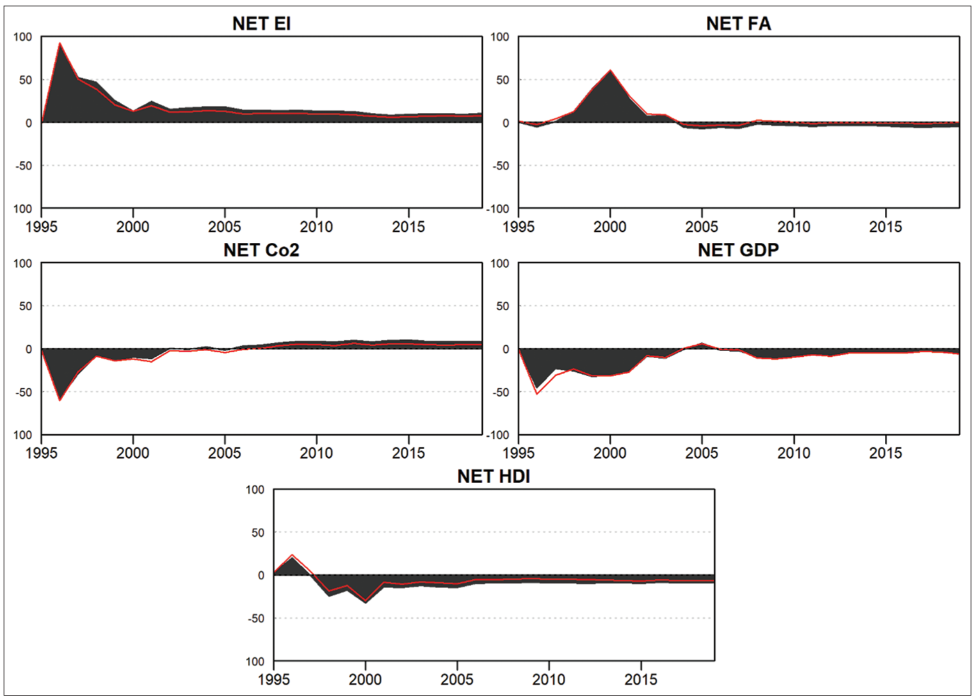


Figure 4: Dynamic interplay between the volatility of other indicators and environmental innovation's pairwise directional connectedness

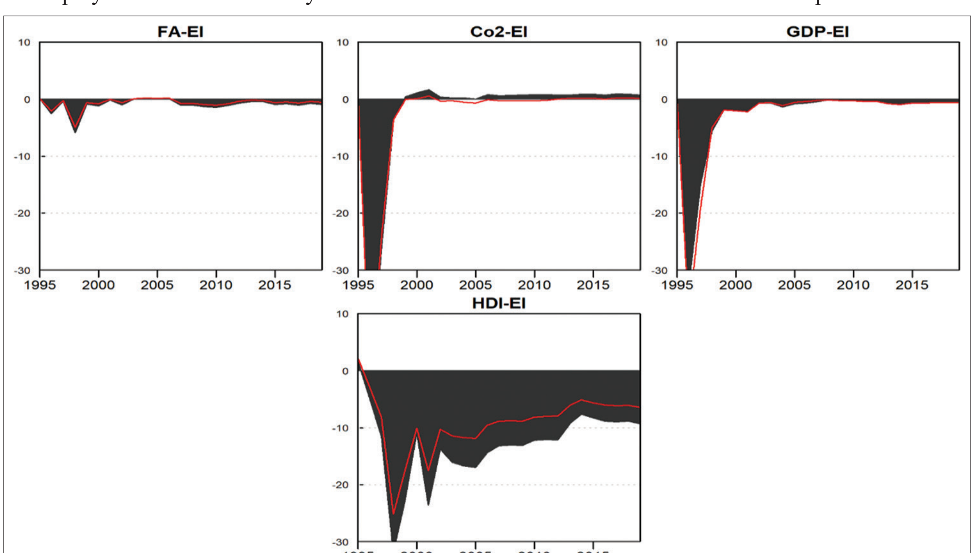
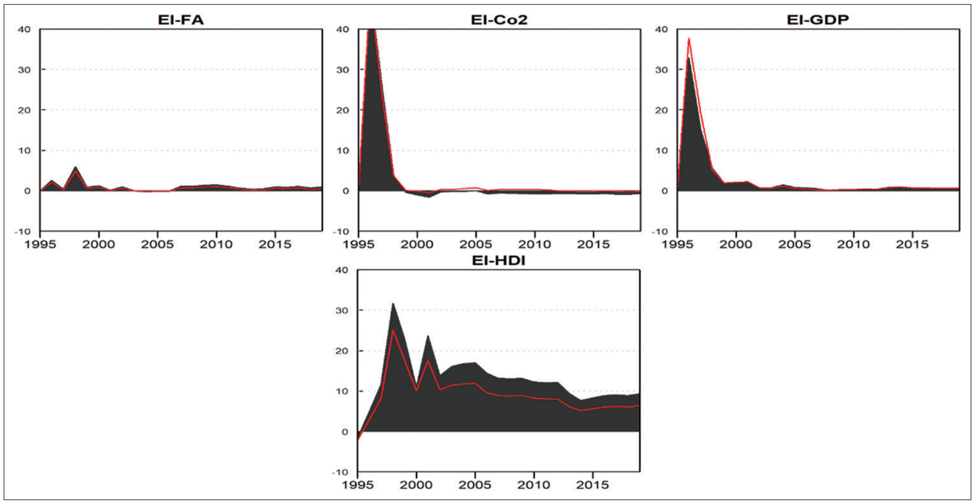


Figure 5: Dynamic fluctuations in environmental innovation's pairwise directional connectedness with volatility across various indicators



model. Economic globalization has both direct and indirect impacts on environmental degradation through advancements in environmental technologies. Additionally, environmental degradation influences the distribution of foreign aid within a nation. Consequently, the demand for environmental innovations escalates with economic globalization, a trend observed in Vietnam. To combat environmental degradation, the government invests in green technologies, leading to a surge in environmental innovations. Moreover, both CO_2 emissions and GDP primarily received shocks from environmental innovation around 1996.

5. DISCUSSION

Our findings regarding the nexus between foreign aid and innovation in developing countries are consistent with (Hidayat and Virgianita, 2019; Mahalik et al., 2020; Opršal and Harmáček, 2019; Pradhana et al., 2023), which highlight the responsiveness of foreign aid to environmental performance and needs for innovation. Nevertheless, previous studies have focused primarily on one-sided effects instead of the dynamic interconnections between the effects. In the case of Vietnam, we demonstrate how foreign aid, environmental innovation, and environmental issues are dynamically connected through novel econometric techniques. We highlight a few instances that may explain these results. Vietnam has demonstrated a dedication to environmental conservation and biodiversity through its initiatives in environmental and ecological health. During this period, numerous significant milestones have been achieved, including the establishment and expansion of protected areas, reflecting early efforts dating back to 1986. A commitment to environmental sustainability was made in 2014 to increase conservation coverage to 7% of its land area by 2020. The resilience of Vietnam was demonstrated by devising an action plan for addressing waste from various sectors in the wake of the COVID-19 pandemic in 2020. As a result of this initiative, the environment will be protected, and worldwide health will be improved. A crucial platform for discussing the challenges and strategies associated with transitioning to a low-carbon energy framework was provided by the 3rd Annual Vietnam Energy and Power Development Summit in 2022. During this summit, Vietnam demonstrated its commitment to aligning its energy sector with sustainable and environmentally friendly practices. Moreover, improving the nation's ability to produce more complex commodities contributes greatly to its economic development. According to research from the World Bank and the London School of Economics, high-tech investments have contributed significantly to Vietnam's economic development, allowing it to move into segments of the value chain with higher added value.

In Vietnam, environmental shifts coincided with the emergence of sustainable development and its widespread acceptance. At the Earth Summit, also known as the 1992 United Nations Conference on Environment and Development, in 1987, not only did the debate over environmental sustainability affect worldwide environmental issues, but also financing for environmental goals through foreign assistance. According to the Sustainable Development Goals, environmental issues should be gradually integrated into the global development agenda. The Ministry of Science, Technology, and Environment published the National Environmental Protection Strategy 2001-2010 in 2000, and the Vietnam Environmental Action Program 2001-2010 of the Department of Environment in 2000 created the first legal frameworks for environmental innovation. Vietnam's determination to implement environmental innovation is reflected in many policies such as the National Action Program on "Sustainable Consumption and Production" (Decision 76/QD-TTg dated 11/01/2016), "Law on Environmental Protection" (Law) No 55/2014/QH13). The state's policy is to promote the application of high-tech, environmentally friendly technologies, ensure resource efficiency, develop green and renewable energy sources, strengthen waste reduction, reuse, and recycling, create eco-friendly businesses and products, and lower GHG emissions to support green growth. Eco-friendly goods and services must be produced and used by organizations, businesses, families, and individuals. In Vietnam, due to the significant demand for pollution control technology and environmental technology in the context of ongoing economic expansion, the environmental sector has a typical yearly expansion rate of over 15%.

6. CONCLUDING REMARKS AND POLICY RECOMMENDATIONS

Employing the R^2 decomposed linkage method, the primary objective of our study is to elucidate associations, with a specific focus on distinguishing between contemporaneous and lagged linkages. This novel methodology is applied to scrutinize the transmission of returns among environmental innovation (EI), foreign aid (FA), CO_2 emissions (CO_2), GDP, and human development index (HDI) in Vietnam from 1994 to 2022. Our analysis shows that before 2015, environmental innovation was a key driver of foreign aid, supporting important initiatives such as solar energy projects and advancements in waste management. From 2015 onwards, however, foreign aid began to take precedence over environmental innovation, reflecting a rising reliance on external assistance as domestic resource development lagged. Additionally, while environmental innovation initially spurred economic growth, it later became more reactive to economic expansion. The relationship between environmental innovation, CO_2 emissions, and HDI also changed over time, underscoring its vital contribution to both environmental and human development.

Based on the spillover effects between the variables and the interconnections between the variables, our conclusions have significant policy implications for governments and investors. When politicians have precise information about the main relationships between these indicators, they can formulate the most appropriate policies. Additionally, they seek to minimize the risks that are posed by these signs as well as the dangers that are propagated through the network. As a result of our research, we have found significant links between foreign aid and environmental innovation, underlining the potential risks and underlining the potential of inadequate or excessive investment opportunities in these areas. As unforeseen events and shocks become increasingly interconnected, we draw attention to their increasing interdependency. Foreign aid and environmental innovation are closely related, and as a result, in order to maximize the effectiveness of foreign aid, authorities should encourage environmental innovations and utilize them effectively. Furthermore, our research provides information on how to promote the growth of international aid and the environmental sector. Based on the findings, it can be shown that a shock to one standard indication can affect the entire network. As a result of the findings of this study, policy can be improved in the area of public welfare. In order to maximize the effectiveness of foreign aid and environmental innovation, it is necessary to use the insightful analysis that there are uncertainties involved with both. Consequently, authorities take these factors into account when creating measures designed to improve the social welfare of vulnerable populations.

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