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Decoupling Analysis, Economic Structure on Environmental Pressure in Vietnam During 2008–2018

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ABSTRACT

In this research, we display the trajectories of Vietnam's environmental pressure throughout the years during 2008–2018 and identify the underlying socioeconomic driving factors through input-output and forward-backward linkage analysis. Decoupling index (DI) and input-output analysis (IOA) indicated that mining, the extraction, and use of fossil fuels, as well as energy generation for daily life and manufacturing industries, are the primary contributors to rising environmental pressures (DI; forward and backward linkage values > 1). Vietnam's decoupling performance has four distinct phases. Mineral and fossil fuel depletion; climate change in the short-term and long-term, and water stress indexes (the ratio of total annual freshwater withdrawal to hydrological availability) were high with 456.91%; 55.91%; 54.43%; 41.87%; and 30%, respectively during 2008–2018.

Keywords: decoupling analysis, input-output analysis, Vietnam, forward-backward linkage, economic structure, environmental vulnerability.

INTRODUCTION

Economic structure and market trade are driving economic growth and environmental performance in each country. A relationship between resource consumption, economic structure, and environmental presentation strongly interacts (Huong et al. 2020; Huong and Shah 2021). Currently, many developing countries seem to be choosing the same development pathway as China's leap-frogging economy (Wang et al. 2015; Huong & Shah 2021). Therefore, each country needs to make assessments and adjust decisions in each period such as 5 years, or 10 years to bring the economy to sustainable development (Chiu et al. 2017; Xu et al. 2019). To do this, the indicators evaluate the growth rate; resource consumption; shortage of resources; economic structure; technological status; and environmental impacts, etc…need to be adjusted through their core indicators (Schandl and Turner 2009; Cai et al. 2020). To greatly understand the transitional phenomenon, authors selected Vietnam as a typical developing country to study resource consumption; economic structure; emissions; resource depletion during 2008 - 2018 series data. To fully comprehend the economic massive reforms that must be described inter-regional input-output by integrating the supply-demand relationship in an economy. Essentially, the core IO model frequently incorporates an economic database (Leontief 1974; Drejer 2002; Boqiang and Kui 2017). Whereas improved and aggregated IO models in some industrialized nations include environmental data to create a complete reference demonstrating the link between wealth and the environment (Miller and Blair 1985; Rumiana 2015; Wang et al. 2020). In this research, the authors aim to address some of the important research questions: (a) In a low-income country, how do material consumption, resource depletion, and emissions manifest? (b) How did environmental concerns and economic development in emerging nations interact during 2008–2018?

(c) How did the economic structure of developing countries like Vietnam affect resource consumption and environmental impacts during 2008-2018? (d) How did Vietnam's economic growth impact during 2008–2018 in terms of the vulnerability of Vietnam's society and environment?

MATERIALS, METHODS, AND DATABASE

Decoupling analysis (DI)

To demonstrate the impact of economic expansion on the environment, the decoupling index (DI) is employed. It illustrates the degree to which environmental pressure responds to changes in the unitary gross domestic product (GDP) over a specific period. It is computed by dividing the change in economic growth (ΔGDP) by the proportional percentage change in resource use or environmental pressure (ΔMP). It was calculated using the following comprehensive Eq. (1) (Chen 1990; Boqiang and Liu 2017):

$$\mathrm{DI} = \frac{\Delta MP}{\Delta GDP} \tag{1}$$

For DI analysis, materials were collected from the International Resource Panel. They have 3 groups in biomass (crop residues; crops; grazed biomass and fodder crops; wild catch and harvest, and wood categories), metal ores (ferrous ores, non-ferrous ores categories), and non-metallic minerals (non-metallic minerals in construction dominant and non-metallic minerals in industrial or agricultural dominant categories) (Eurostat 2013, 2017). For the final energy supply by source perspective, it was gathered from the International Energy Agency (IEA) – source World Energy Balances 2022 (International Energy Agency 2022). Coal, oil products, biofuels and waste; hydro, oil, and wind – solar. Which has a small amount of supply since our research did not mention much about the resource (Oracle 2022).

Input-output analysis combined with forward and backward linkage analysis.

The modern input-output analysis approach was built on Leontief's foundational studies. He realized that the input-output model is a formalization of the essential notions established around two centuries ago by the French economist Francois Quesnay (1975) (Leontief 1974; Liang et al. 2017; Yu et al. 2020) which illustrates revenue flows across economic sectors. Besides, backward and forward links are broadly acknowledged notions in the literature on inter-industry linkages, although there is disagreement over how to assess them. Jones looked at the links between forward and backward linkages (Jones 1976). Liang and his team added additional information to produce more exact measurements of the economic value of the important sectors (Lin and Chang 1997; Liang et al. 2017). Drejer presented the comparison and discussion of input-output based on measurements (Drejer 2002; Wang et al. 2020). Miller and Blair offered a detailed explanation of several ways used to compensate for the inadequacies of standard metrics of connections (Miller and Blair 1985). In this study, we adopt the Leontief supply-driven multiplier as a backward-linkage estimate and the Hirschman (1958) supply-driven multiplier as a forward-linkage measure (Miller and Blair 1985; Rumiana 2015).

Method

In the research, we have $N = 35$ primary inputs and definitions. Before Leontief formulation can be performed, we have some major notations used in the study.

- a_i – indicates the industrial gross output level of sector *i, i = 1, ..., N*
- a_{ij} – represents the level of the inter-industrial output of industry *i* supplied to industry *j, j = 1,..., N*
- y_{ij} – represents the amount of output industry *i* provides to industry *j* to produce 1 unit of output *j*
- x_{ij} – exhibits the number of main inputs *i* in the industrial *j*
- d_i – shows the final demand in sector *i*

The technical coefficients x_{ij} are defined as Eq. 2 (Cai et al. 2020):

$$x_{ij} = \frac{a_{ij}}{a_j} \tag{2}$$

If each industry produces just enough output to satisfy intermediate and final demand, then our input-output can be expressed by the following from Eq. 3 to Eq. 4 (Cai et al. 2020):

$$\begin{aligned} a_1 &= x_{11}a_1 + x_{12}a_2 + x_{13}a_3 + x_{1n}a_n + d_1 \\ a_2 &= x_{21}a_1 + x_{22}a_2 + x_{23}a_3 + x_{2n}a_n + d_2 \\ a_3 &= x_{31}a_1 + x_{32}a_2 + x_{33}a_3 + x_{3n}a_n + d_3 \end{aligned} \tag{3}$$

$$\cdots\cdots\cdots$$

$$a_N = x_{N1}a_1 + x_{N,2}a_2 + x_{N3}a_3 + x_{NN}a_N + d_N \tag{4}$$

These can be rewritten Eq. 5 (Lin and Chang 1997).

$$\begin{pmatrix} a_1 \\ \dots \\ a_N \end{pmatrix} = \begin{pmatrix} x_{11} & \dots & x_{1N} \\ \dots & \dots & \dots \\ x_{N1} & \dots & x_{NN} \end{pmatrix} \begin{pmatrix} a_1 \\ \dots \\ a_N \end{pmatrix} + \begin{pmatrix} d_1 \\ \dots \\ d_N \end{pmatrix} \quad (5)$$

$$a = Aa + d \leftrightarrow a - Aa = d \leftrightarrow (I - A)a = d$$

Let $a \in R^{1\times 3}5$, $A \in R^{1\times 35}$, and $d \in R^{1\times 35}$ respectively denote the output vector, the technology matrix, and the demand vector where their elements are defined as in Eq. 4, the Leontief equation can be formulated as follows in Eq. 6 (Lin and Chang 1997; Miller and Blair 1985; Fleischer and Freeman 1997).

$$(I - A)a = d \quad (6)$$

where: $(I - A)$ – the Leontief matrix.

Using the Leontief inverse matrix $(I - A)^{-1}$, a can be calculated by Eq. 7 (Liang et al. 2017).

$$A = (I - A)^{-1} d \quad (7)$$

To interpret the entries of the matrix, assume that the final demand for product 1 increases by one unit while the final demand for the other products remains unchanged. Let the change in the final demand vector be represented by delta d (Δd) and measured by Eq. 8 below (Rumiana 2015; Liang et al. 2017; Yu et al. 2020).

$$\Delta d_n = \begin{pmatrix} \Delta d_1 \\ \dots \\ \Delta d_i \\ \dots \\ \Delta d_1 \end{pmatrix} \quad (8)$$

where: $\Delta d_i = 1$, if $i = n$, otherwise $\Delta d_i = 0$.

Corresponding to this change in the final demand, there is a change in the final output Δa. It was expressed in Eq. 9 (Thijs ten Raa 2009; Rumiana 2015).

$$a + \Delta a = (I - A)^{-1}(d + \Delta d) \leftrightarrow \Delta a = (I - A)^{-1}\Delta d \quad (9)$$

The first column of $(I–A)^{-1}$ represents the increase in output of different industries because the final demand of industry 1 increases by one unit, keeping the final demand of industry 1 unchanged. The second column and the rest of the Leontief inverse matrix are interpreted in similarly (Rumiana 2015; Wang et al. 2020).

Backward and forward linkage analysis

Backward linkage (BL) refers to an industry's relationship with lesser industries (industries that consume the products of that industry). Backward estimation is used to estimate the function of an industry as a user of actual products and services as input from the broader economy. Backward linkage is known as the power of dispersion criterion, and it is recognized in conjunction with the scaled coefficients of backward linkage in Eq. 10 (Jones 1976; Drejer 2002).

$$Backward\ linkage = \frac{nBL_j}{\sum BL_j} \quad (10)$$

where: $BL_j = \Sigma_i t_{ij}$, in which t_{ij} is the element of the Leontief matrix, n is the number of sectors in the model.

Forward linkage (FL) refers to an industry's prominence as a supplier of physical goods and services for the entire financial system (Jones 1976; Liang et al. 2017; Wang et al. 2020). This measure is used to quantify the economy's sensitivity to dispersion and is calculated as follows Eq. 11 (Jones 1976; Lin and Chang 1997):

$$Forward\ linkage = \frac{nFL_i}{\sum FL_i} \quad (10)$$

where, $FL_j = \Sigma_i t_{ij}$, in which t_{ij} is the element of the Leontief matrix, n is the number of sectors in the model.

To understand the linkage results, we classify under the Table 1(Yu et al. 2020).

Database for input-output and linkage analysis

The database of input-output tables for Vietnamese economies during 2008–2018 was aggregated by many original data sources related to Social Accounting Matrix (SAM) for Vietnam; Accounting Matrices for Vietnam; the Danish Institute of Agricultural and Fisheries Economics (SJFI); Asian Development Bank; Vietnam National Accounts Statistics; government budget data; Vietnam Living Standard Survey; Common format for Transient Data Exchange (COMTRADE). After measurement and adjustment of these big data, the comprehensive database was shown under an IO database with 35 economic sectors with their specific abbreviations – published by Asian World Bank (Table 2) (World Bank 2016; Asian Development Bank 2018). These categories cover various types of activities in occupied sectors. For instance, agriculture-food sectors/non-agriculture; business-service; education; transportation; health care; engineering and technology; non-trade-related

Table 1. Classification linkage result (Yu et al. 2020)

Backward linkage	Forward linkage		
		Low < 1	High >1
	Low < 1	Generally independent	Dependent on industry demand
	High > 1	Dependent on interindustry supply	General dependent

Table 2. The 35 economic sectors for the inter-regional input-output model

Economic sector	ABB	Economic sector	ABB
Agriculture, hunting, forestry, and fishing	c1	Wood and products of wood and cork	c6
Mining and quarrying	c2	Pulp, paper, paper products, printing, and publishing	c7
Food, beverages, and tobacco	c3	Coke, refined petroleum, and nuclear fuel	c8
Textiles and textile products	c4	Chemicals and chemical products	c9
Leather, leather products, and footwear	c5	Rubber and plastics	c10
Wood and products of wood and cork	c6	Other nonmetallic minerals	c11
Pulp, paper, paper products, printing, and publishing	c7	Basic metals and fabricated metal	c12
Coke, refined petroleum, and nuclear fuel	c8	Machinery, nec	c13
Chemicals and chemical products	c9	Electrical and optical equipment	c14
Rubber and plastics	c10	Transport equipment	c15
Manufacturing, nec; recycling	c16	Retail trade, except of motor vehicles and motorcycles; repair of household goods	c21
Electricity, gas, and water supply	c17	Hotels and restaurants	c22
Construction	c18	Inland transport	c23
Sale, maintenance, and repair of motor vehicles and motorcycles; retail sale of fuel	c19	Water transport	c24
Wholesale trade and commission trade, except for motor vehicles and motorcycles	c20	Air transport	c25
Other supporting and auxiliary transport activities; activities of travel agencies	c26	Public administration and defense, compulsory social security	c31
Post and telecommunications	c27	Education	c32
Financial intermediation	c28	Health and social work	c33
Real estate activities	c29	Other community, social, and personal services	c34
Renting of M&Eq and other business activities	c30	Private households with employed persons	c35

(households, enterprises), etc. However, IO tables in Vietnam are insufficiently because of missing environmental data.

Socio-economic-environmental vulnerability

To quantify Vietnam's socioeconomic and environmental vulnerability during 2008 - 2018, several significant indices were gathered and presented in this part. Forest area (% of land area) was gathered from World Bank Data. Renewable share in final energy consumption (Sustainable Development Goals 7.2) which indicator was mentioned in the International Energy Agency (IEA) (Asian Development Bank 2018; United Nations Statistics Division 2021). Potential species loss from land use (micro-PDF*year); climate change long-term and short-term (million tonnes CO_2 eq); blue water consumption (billion m^3 H_2O eq); water stress (billion m^3 H_2O eq); marine eutrophication (million tonnes); fossil fuel depletion (billion tonnes oil eq); mineral depletion (billion tonne Cu eq); human development index; and socio-economic vulnerability indicators were downloaded by using open access data, which download tool was created to assist in the creation of national policy interventions within the context of SCP. The database followed as UN Environment Programme (2022); Sustainable Consumption and Production – Hotspot Analysis Tool (SCP-HAT) database version 2.0. UN Life Cycle Initiative; UN One Planet Network; and UN International Resource Panel (Eurostat 2013, 2017).

RESULT AND DISCUSSION

Decoupling analysis

Our analysis of the weight percentage change revealed that Vietnam used up significant resources during 2008–2018. At the same time, the use of biomass climbed by 268.15%, coal consumption increased by 217.52%, while hydro usage increased by 219.71%, respectively. While this was going on, the study periods 2008–2011, 2011–2014, and 2014–2018 only revealed a minor increase in each selected variable (Figure 1). Non-metallic minerals and biofuel waste, on the other hand, saw minor decreases during 2014–2018 (40.68% and -35%, respectively) (Figure 1). Our finding indicates that freshwater extraction did not alter considerably during the research period. In essence, the use of hydro and fossil fuels (coal, metal ores, and oil) was greatly reduced. Driving environmental parameters such as methane, CO_2, and nitrous oxide emissions were used to examine the environmental pressure. During 2008–2018, there was a 142.89% increase in CO_2 emissions. Methane and nitrous oxide emission data showed relative variations of 2.23% and 35.19% during the period under study.

Vietnam's decoupling analysis results during 2008–2018 can be seen as four intervals (Figure 2). The decoupling index (DI), however, allows us to comprehend how resource use and environmental strain relate to one another based on the decoupling study. Figure 2 displays the relative decoupling of freshwater withdrawal, biomass, land usage, biofuels, and waste index during 2008–2018. Because these decoupling indices were higher than 1, metal ores, coals, and hydro indicators were the key contributors to the rapidly increasing environmental strain in comparison to economic expansion (Figure 2). Only non-metallic minerals, biofuels and waste indicators performed absolute decoupling throughout the study decade, with -0.11 and -0.41, respectively. CO_2, nitrous oxide, and methane emissions are frequently used to symbolize environmental pressure in any economy from an environmental standpoint. For the three study periods in Vietnam (2008–2011, 2014–2018, and 2008–2018), CO_2 emissions remained negatively decoupled (Figure 2). Nitrous oxide and methane emissions in almost examined intervals were the relative decoupling performances.

Forward and backward linkage analysis

Forward linkage result

The relevance and relative interconnection of industrial sectors at the national level might be investigated using IO analysis (Table 3). The heatmap of forward linkage in Vietnam from 2008 to 2018 was displayed on the color scale. Moreover, we can easily understand when the linkage value is higher than 1.5 – meaning which is a key sector. If the linkage value is from 1 to 1.5 – denoting that the factor is strong backward/forward. Furthermore, the linkage value is less than unity – showing the weak linkage.

Deep green signifies sectors that are more than unity (unity is 1 in the heatmap forward linkage) and lighter green until you see a pink hue - signifying that such sectors require fewer and fewer inputs from other industrial sectors. Sectors c1; c3; c6; c7; c8; c15; and c16 have a higher value than unity - indicating that those sectors need less and less inputs from other industrial sectors. Some sectors are noteworthy including c1; c3; c6;

	2008-2011	2011-2014	2014-2018	2008-2018
Freshwater withdrawal	0.00	0.00	0.00	0.00
Methane emisisons	4.70	1.47	-3.77	2.23
CO2 emisison (kt)	32.65	15.96	57.90	142.89
Nitrous oxide emisison	11.08	11.43	9.22	35.19
Biomass	2.89	8.97	3.93	16.52
Metal ores	34.73	49.77	82.45	268.15
Non-metallic minerals	18.51	29.42	-40.68	-9.01
Land use	-0.09	12.92	25.96	42.10
Coal	32.95	27.70	87.03	217.52
natural gas	18.89	20.69	-9.41	29.98
Hydro	57.48	46.23	38.84	219.71
Biofuels and waste	0.02	0.42	-35.00	-34.72
Oil	26.55	13.50	18.27	69.87

Figure 1. Weight percentage changes of resource consumption and environmental indexes in Vietnam during 2008–2018

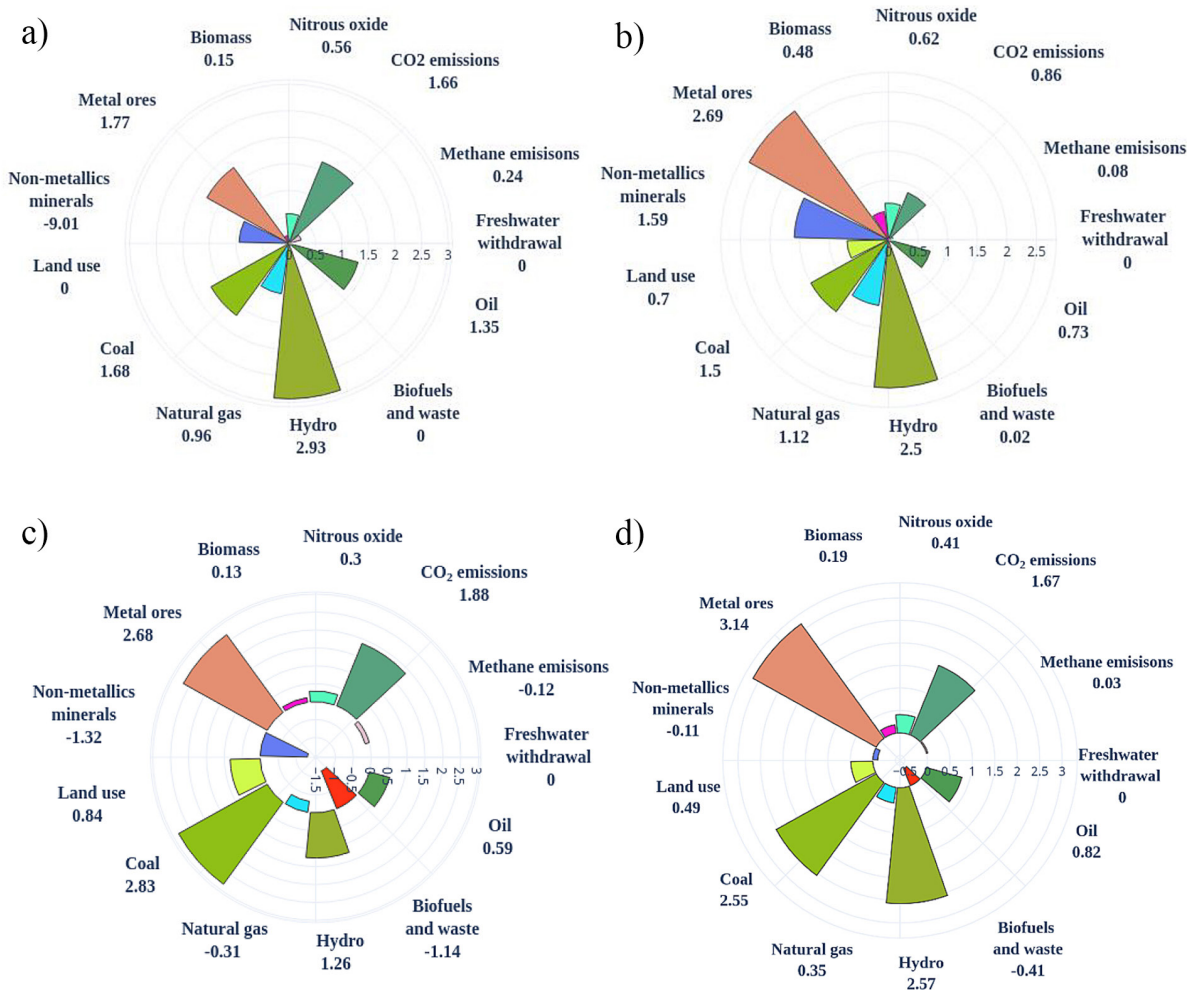

Figure 2. The environmental degradation of Vietnam's economic expansion during 2008–2018. (a) 2008–2011; (b) 2011–2014; (c) 2014–2018; and (d) 2008–2018. Each pie's length corresponds to a particular environmental pressure's decoupling index value. Economic growth and environmental pressure are negatively decoupled when the decoupling index exceeds 1, relatively decoupled when it is between 0 and 1, and absolutely decoupled when it is below 0

c7; c8; c15; c16 have a greater value than unity – denoting that to produce one unit product of these sectors requires high inputs from other sectors. The heatmap categorizes the following groups as having low forward linkage values: c2; c4; c5; from c19 to c22; and from c28 to c35. These sectors have lower input needs from relevant activities and have just a minor influence (a unit decrease in the input will lead to a below-average impact decreases in the economic association).

Backward linkage result

Backward linkage results depicted the performance of backward linkages (Table 4). Sectors c1; c2; c3; c7; c8; c9; c12, and c20 have higher forward linkage values than the unity, indicating that a one-unit drop in eventual demand for the sector *i* would result in an above-average rise in economic activity. Sector c1 has the greatest forward linkage value (2.08 in 2008 and 1.67 in 2018). The second largest sector is coke, refined petroleum, and nuclear fuel (c8), which slightly decreased from 2.38 (in 2008) to 2.08 (in 2018), indicating a tremendous gain in impact throughout this time. Socioeconomic indicators such as public administration and defense; compulsory social security; education; health and social work; other communal, social, and personal services; and private homes with employed people have somewhat widened the gap between its own forward linkage value and unity. This means that these sectors have little sway over economic activity and require less input from other linked activities. However, the forward linkage-oriented results show that these sectors have a poor relationship with other sectors.

Table 3. The heatmap of normalized forward linkage in Vietnam from 2008 to 2018

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
c1	1.14	1.10	1.16	1.11	1.13	1.10	1.08	1.09	1.07	1.12	1.07
c2	0.93	0.96	0.93	0.89	0.90	0.97	0.93	0.88	0.92	0.88	0.92
c3	1.39	1.34	1.48	1.41	1.45	1.40	1.39	1.43	1.38	1.41	1.37
c4	0.86	1.11	0.85	0.95	0.92	0.81	0.92	1.09	0.90	1.05	0.89
c5	0.91	1.08	0.89	0.89	0.99	0.85	0.85	1.07	0.85	1.07	0.83
c6	1.49	1.22	1.43	1.48	1.50	1.44	1.47	1.46	1.46	1.43	1.46
c7	1.27	1.20	1.22	1.27	1.30	1.28	1.28	1.27	1.28	1.24	1.27
c8	1.21	0.81	1.15	1.09	1.13	1.25	1.32	1.13	1.37	1.44	1.40
c9	1.07	1.25	1.07	1.07	1.06	1.10	1.11	1.04	1.10	1.09	1.10
c10	1.05	1.20	1.08	1.08	1.08	1.09	1.06	1.06	1.05	1.03	1.04
c11	1.05	1.04	1.06	1.04	1.06	1.14	1.13	1.08	1.17	1.17	1.19
c12	1.01	0.93	1.03	1.01	0.96	1.01	0.93	0.97	0.92	0.89	0.90
c13	0.99	0.99	1.00	0.98	0.91	0.90	0.87	0.95	0.87	0.84	0.86
c14	1.09	0.99	1.10	0.99	0.87	0.83	0.83	1.04	0.82	0.87	0.81
c15	1.14	1.33	1.14	1.17	1.16	1.11	1.01	1.18	1.01	1.00	1.00
c16	1.21	1.35	1.25	1.28	1.29	1.25	1.24	1.27	1.24	1.22	1.23
c17	0.87	0.76	0.79	0.77	0.76	0.79	0.81	0.77	0.81	0.83	0.81
c18	1.03	1.15	1.06	1.07	1.06	1.08	1.03	1.06	1.03	1.02	1.02
c19	0.90	0.84	0.91	0.91	0.90	0.91	0.90	0.90	0.91	0.89	0.91
c20	0.89	0.77	0.84	0.87	0.87	0.88	0.89	0.85	0.90	0.89	0.92
c21	0.61	0.57	0.61	0.62	0.61	0.61	0.62	0.59	0.63	0.65	0.63
c22	1.11	1.05	1.13	1.09	1.12	1.11	1.10	1.11	1.10	1.11	1.10
c23	1.03	1.06	1.02	1.00	1.01	1.03	1.03	0.96	1.02	0.97	1.02
c24	1.13	1.10	1.10	1.11	1.13	1.14	1.15	1.03	1.14	1.03	1.15
c25	0.90	1.05	1.02	1.03	1.04	1.05	1.06	0.96	1.04	0.95	1.05
c26	0.95	1.01	0.98	1.03	1.05	1.05	1.08	0.99	1.06	1.00	1.07
c27	1.07	1.17	1.11	1.07	1.02	1.01	1.01	1.07	1.00	1.01	1.00
c28	0.98	0.92	0.85	0.90	0.91	0.91	0.92	0.87	0.93	0.93	0.94
c29	0.80	0.75	0.80	0.83	0.83	0.83	0.83	0.81	0.84	0.84	0.85
c30	0.95	0.97	0.91	0.95	0.95	0.95	0.96	0.93	0.96	0.94	0.97
c31	0.84	0.79	0.78	0.80	0.80	0.80	0.81	0.78	0.82	0.80	0.81
c32	0.77	0.73	0.72	0.74	0.74	0.74	0.75	0.73	0.76	0.77	0.76
c33	0.83	0.87	0.92	0.90	0.88	0.95	1.00	0.99	1.00	0.98	0.99
c34	0.83	0.90	0.91	0.94	0.93	0.93	0.95	0.93	0.95	0.93	0.95
c35	0.71	0.64	0.67	0.67	0.67	0.67	0.68	0.65	0.69	0.70	0.69

Note: the unity is 1.

The entire picture of the linkage result

Examine the forward, backward, and total links shown in Figure 3 and Figure 4. In 2009, the densities of forward and backward link values dilated, with no clusters developing near the junction (1, 1). However, following this year, the performance has altered. The dots indicate industries, and they have moved closer together. Overall, several sectors have a high forward linkage value over the whole time series, such as c1; c3; c6; c7; c8; c9; c12; c28, indicating that other sectors must offer more inputs to develop these industrial sectors. As illustrated in Figure 4, the total linkage value of each sector during 2008–2018 reveals that the vital function and economic structure of driving sectors have moderately altered in over two decades. Vietnam retains agriculture as a strength for economic growth, but harnessing energy and non-renewable resources are viewed as two essential techniques for reviving the economy following

Table 4. The heatmap of backward linkage result in Vietnam from 2008 to 2018

Sector	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
c1	2.08	1.84	2.09	2.17	2.14	1.98	2.00	2.00	1.88	1.79	1.67
c2	1.40	1.16	1.70	1.54	1.67	2.16	2.21	1.60	2.02	1.92	1.85
c3	1.10	1.19	1.37	1.15	1.25	1.17	1.08	1.24	1.07	1.05	0.97
c4	0.85	1.17	0.73	0.88	0.84	0.68	0.80	1.04	0.76	0.74	0.72
c5	0.74	0.79	0.70	0.68	0.76	0.65	0.64	0.78	0.65	0.69	0.67
c6	1.15	1.05	1.00	1.04	1.07	1.02	1.03	1.07	1.05	1.06	1.03
c7	1.26	1.33	1.20	1.23	1.25	1.22	1.22	1.21	1.23	1.21	1.19
c8	2.38	2.09	1.85	1.83	1.86	1.89	1.90	1.76	1.95	1.91	2.08
c9	1.30	1.54	1.34	1.41	1.32	1.34	1.36	1.42	1.34	1.34	1.40
c10	0.99	1.22	1.02	0.99	1.04	1.06	0.97	1.08	0.96	0.94	0.97
c11	0.88	0.93	0.81	0.82	0.86	0.87	0.83	0.83	0.82	0.85	0.86
c12	1.73	1.61	1.67	1.60	1.43	1.56	1.26	1.69	1.26	1.10	1.15
c13	0.74	0.78	0.69	0.84	0.78	0.77	0.80	0.86	0.88	0.87	0.85
c14	1.40	1.56	1.29	1.02	0.75	0.63	0.71	1.23	0.69	0.68	0.67
c15	0.71	0.71	0.77	0.79	0.81	0.77	0.72	0.81	0.77	0.83	0.83
c16	0.67	0.86	0.82	0.82	0.81	0.80	0.80	0.86	0.81	0.82	0.79
c17	1.04	0.95	1.03	1.02	1.02	1.05	1.08	1.08	1.13	1.14	1.13
c18	0.75	0.71	0.76	0.79	0.81	0.80	0.80	0.82	0.92	1.03	1.46
c19	0.71	0.64	0.68	0.69	0.68	0.69	0.70	0.66	0.71	0.72	0.71
c20	1.66	1.70	1.41	1.46	1.53	1.56	1.60	1.46	1.62	1.65	1.64
c21	0.61	0.57	0.61	0.62	0.61	0.61	0.62	0.59	0.63	0.65	0.63
c22	0.76	0.69	0.75	0.79	0.81	0.81	0.82	0.72	0.83	0.85	0.82
c23	0.87	0.76	0.81	0.83	0.83	0.83	0.83	0.77	0.82	0.85	0.82
c24	0.68	0.65	0.71	0.72	0.72	0.72	0.73	0.68	0.73	0.74	0.73
c25	0.64	0.63	0.69	0.70	0.70	0.70	0.71	0.65	0.71	0.73	0.71
c26	0.94	0.95	1.08	1.13	1.20	1.20	1.22	0.98	1.17	1.12	1.17
c27	0.82	0.82	0.86	0.83	0.83	0.83	0.84	0.79	0.84	0.87	0.83
c28	1.17	1.27	1.33	1.34	1.36	1.35	1.36	1.27	1.37	1.37	1.33
c29	0.83	0.80	0.86	0.89	0.88	0.88	0.89	0.83	0.88	0.88	0.85
c30	1.01	1.08	1.15	1.17	1.18	1.18	1.20	1.11	1.19	1.19	1.14
c31	0.61	0.57	0.62	0.62	0.62	0.62	0.63	0.60	0.64	0.65	0.64
c32	0.63	0.60	0.64	0.65	0.64	0.65	0.66	0.62	0.67	0.69	0.67
c33	0.61	0.58	0.62	0.63	0.62	0.62	0.63	0.60	0.64	0.66	0.65
c34	0.68	0.65	0.71	0.72	0.72	0.72	0.73	0.69	0.74	0.76	0.74
c35	0.62	0.57	0.61	0.62	0.61	0.61	0.62	0.59	0.63	0.65	0.64

Note: Table 3 and Table 4, when the value starts from 0 to 0.99, the color scale shows from dark red to light yellow, respectively. When the value is greater than 1, the color scale increases from light yellow to dark blue.

the extended conflicts. Meanwhile, nations that excel in socioeconomic technology tend to swiftly transform the economic structure by boosting the effect and influence of service-related industries trade in the balance. However, we have not seen significant changes in Vietnam's economic structure until 2018. And the circumstance will continue for many years until the country faces depleted resources and negative environmental effects.

Socio-economic and environmental vulnerability

Figure 5 depicts the socioeconomic and environmental picture in Vietnam during 2008–2018 using the metrics that were examined in this section. According to the human development index at the same time, the living standard grew somewhat during that time by 7.7% (from 0.65

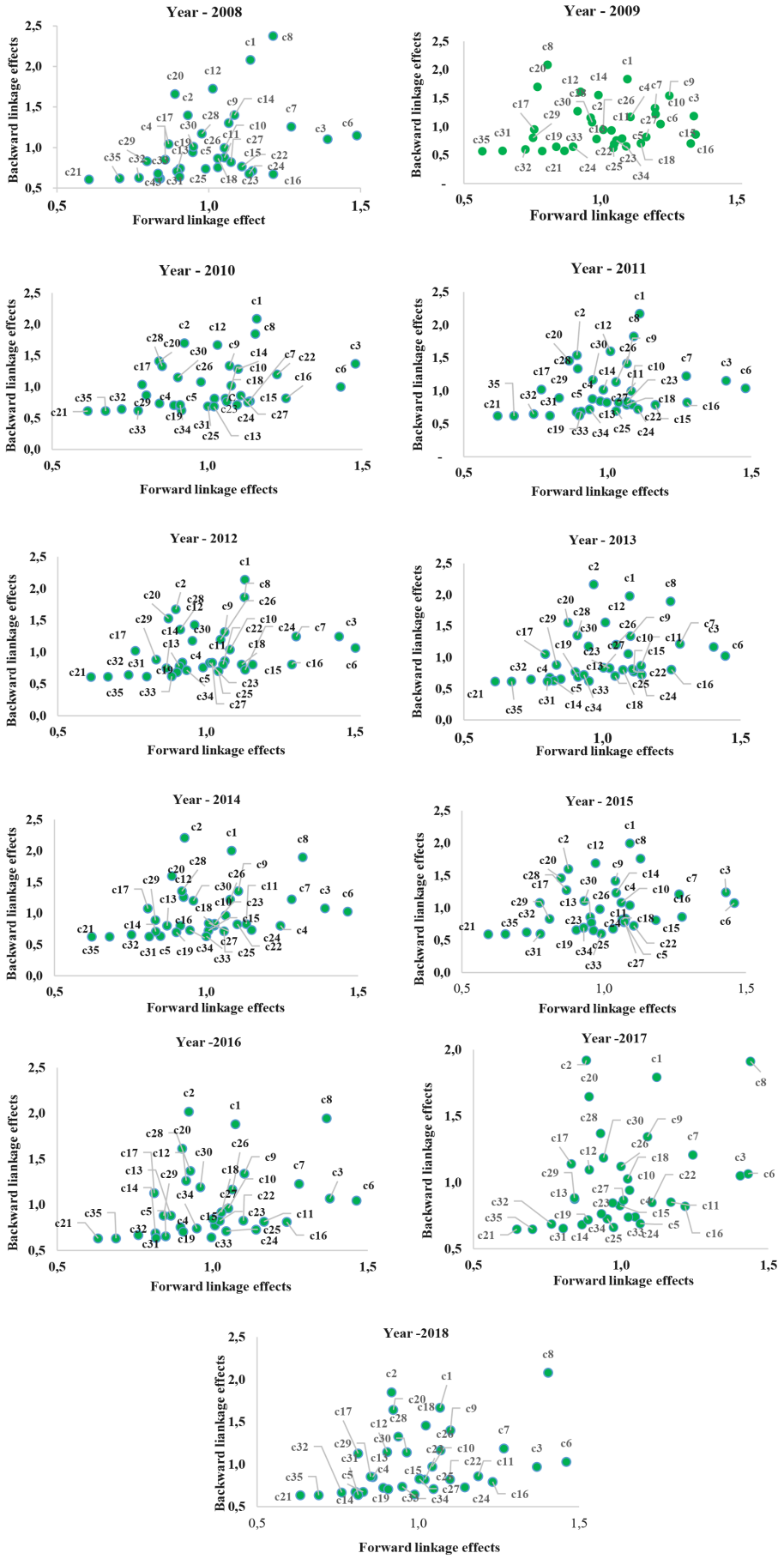

Figure 3. Forward and backward linkages in Vietnam from 2008 to 2018

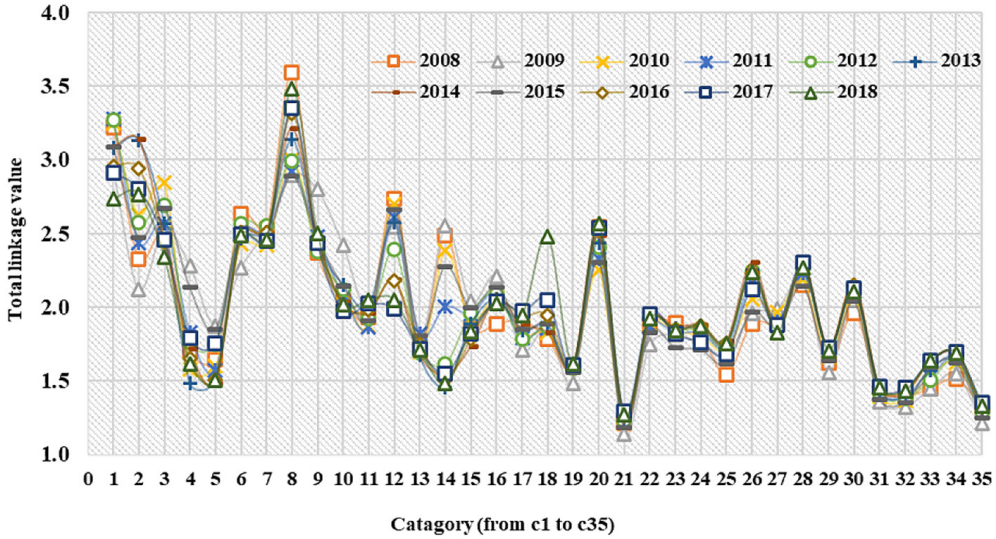

Figure 4. Total linkage value for each indicator during 2008–2018

to 0.7). During the study period, socio-economic vulnerability decreased by -10.53% (from 3.8 to 3.4) (Figure 5a). Consumption of blue water decreased by -16.69% from 6.97 billion m^3 of water in 2008 to 5.8 billion m^3 of water in 2018.

During 2008–2018, the forest area (% of land area) only improved by 10.53% from 41.8 to 46.2 (Figure 5b) indicating the Vietnamese government's efforts to preserve the environment. Additionally, the renewable energy contribution in final energy consumption (SDG 7.2) increased quickly by 70.49%. Hydroelectricity significantly outran this renewable energy. Furthermore, land use was increased 11.38%, there was a recorded increase in short-term and long-term climate change of 41.87% and 54.43%, respectively. Significantly, the indices for water tress, marine eutrophication, fossil fuel depletion, and mineral depletion were 30%, 39.88%, 55.97%, and 456.91%, respectively (Figure 5c and Figure 5d).

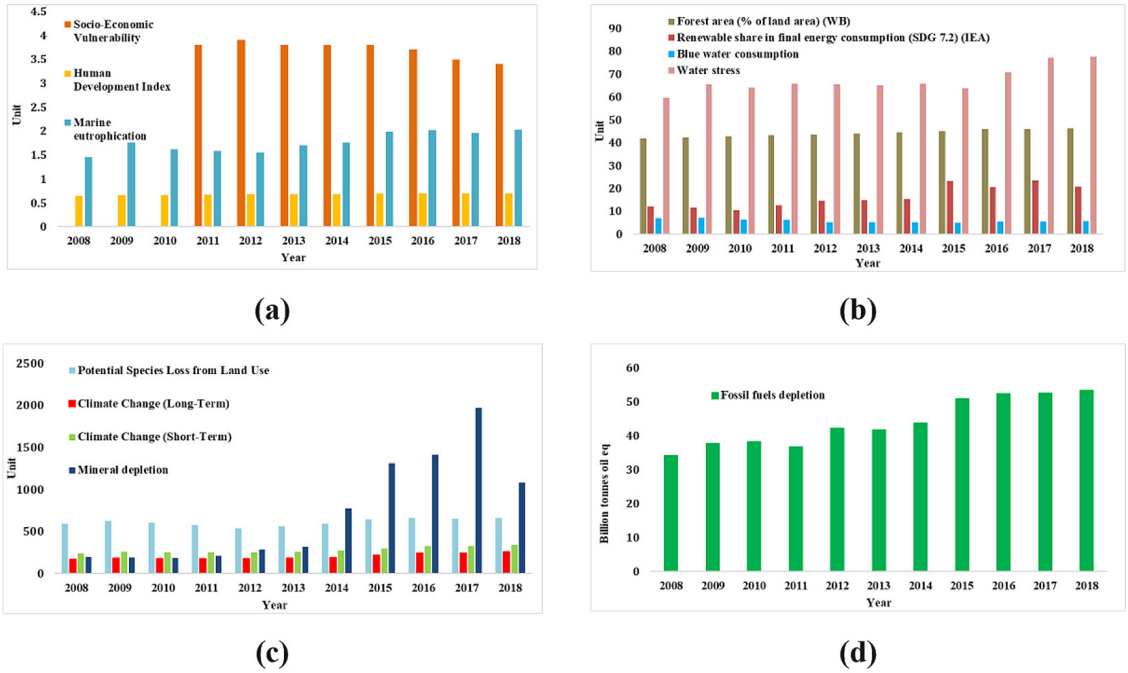

Figure 5. Vulnerable indicators for socio-economic and environment in Vietnam during 2008–2018 (Source: National Assembly of Vietnam 2016; Asian Development Bank 2018; Ministry of Industry and Trade of Vietnam 2018; United Nations Statistics Division 2021)

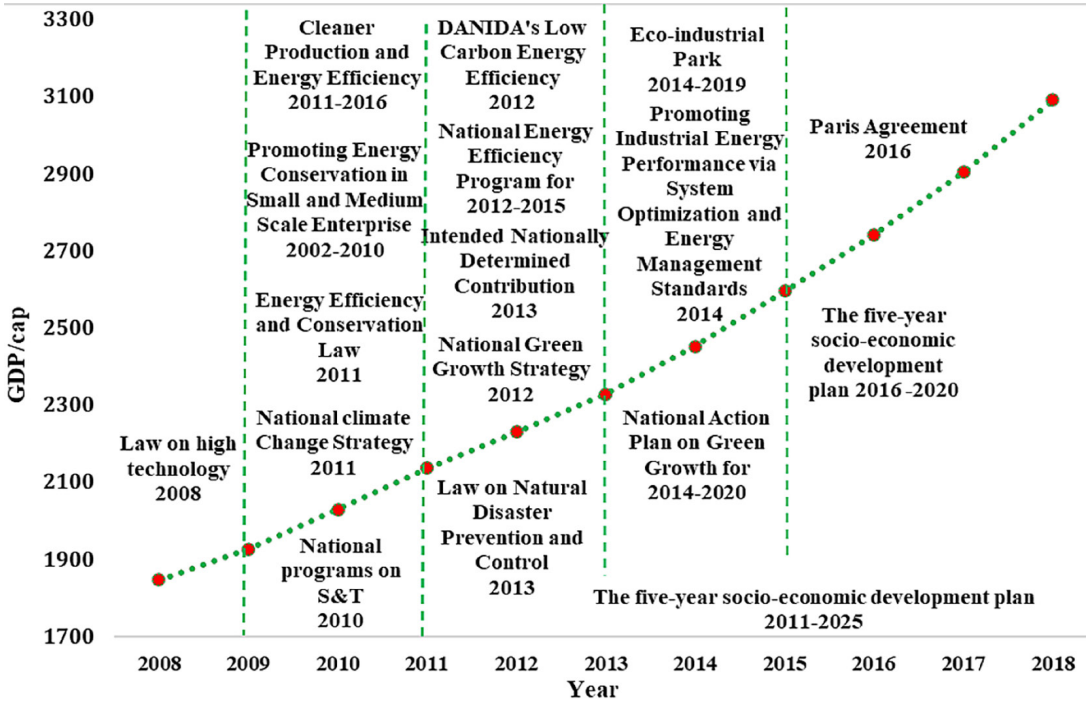

Figure 6. Economic – environmental strategies in Vietnam during 2008–2018 (Source: Vo et al. 2015; Masina 2006; Ministry of Industry and Trade of Vietnam 2018; Huong et al. 2020)

Policy implication

The GDP in Vietnam increased by 6.5% during the first half of 2008. The government's 2008 annual rate of growth target was currently 7%, which was lower than the 8.5%–9% aim declared at the start of the year and lower than the 8.5% growth attained the previous year. The demand for resources – materials and waste emissions will both go up with the expected GDP increase. Aware of this situation, the Government of Vietnam has launched a lot of economic development policies accompanied by efficient consumption of resources - energy. Figure 6 shows that many energy-efficient and sustainable development programs are proposed and implemented continuously (Vo et al. 2015; National Assembly of Vietnam 2016).

The 5-year development policies are still maintained and proved to be quite effective (Figure 6). This is evidenced by the marked improvement in GDP growth rate and per capita income. However, the problems of natural resources – the environment have not been commensurate with the dramatic change in the economy. During 2008–2011, GDP percentage change was reported at 19.6% with agricultural, hunting, forestry, and fishing indicator; food, beverages, and tobacco; basic metals and fabricated metals, and wholesale trade and commission trade, except for motor vehicles and motorcycles sectors were dominant Vietnamese' economic. Meanwhile, the emission is representative of CO_2 emissions were lifted by 32.6% percentage change during this time. During 2011–2014, the trend did not change much compared to 2008–2011. Overall, sustainable development policies have not yet significantly improved pollution and the imbalance between resources and economic development.

CONCLUSIONS

The picture of economic structure and environmental issues and policies in the transition period of Vietnam after the post-recession period of the world economy is outlined through some main results as follows. Material flow and decoupling analysis results show that Vietnam has made remarkable changes after the world economic crisis in 2008 with a strong GDP growth of 85.4% (From $1.58 billion in 2008 to $2.74 billion in 2018). However, it also led to the consumption of mineral resources and the level of environmental degradation increased with 268.15% metal ores increased; 217.5% coal; 219.7% hydro; 69.9% oil consumption; and 142.9% CO_2 emissions, respectively during 2008–2018. Via input-output and forward-backward linkage analysis in Vietnam

during the period revealed that has been impacted by agriculture and associated sectors, with high overall costs. The sector drives economic growth and interacts with other sectors both directly and indirectly, as revealed by backward and forward linkage research. Mining and quarrying sectors; coke-refined petroleum-nuclear fuel sectors; and wholesale commerce sectors cannot be overlooked for industrialization, modernization, and commercialization. For a long time, these variables have dominated the Vietnamese economy. This is also clear, as most countries throughout the world rely heavily on these fundamental characteristics. Besides that, input-output and linkage analyses show that the Vietnamese government has not improved sectors that involve society and service, such as sectors: c31; c32; c32); c33; c34); c34; and c35. These elements are critical in shifting an economy's thinking.

In addition, through the analysis of the basic indicators of the assessment of the improvement of the quality of life and social improvement, and the assessment of environmental pressures in this period, the living standards and incomes of the Vietnamese people are assessed (human development index increased 7.69%). Besides, social issues are also controlled and maintained stable (Socio-economic vulnerability dropped – 10.52%). These are achievements from decisions in the economy and development of the country. However, indicators of energy and resource security have been alarming about the possibility of depletion shortly.

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