The Nexus between R&D, Financial Innovation, and Sustainable Development

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Abstract

The present study examines the connection among financial innovation, research and development expenditure, and carbon dioxide emissions across seven Asian nations, namely Japan, Korea, Singapore, Indonesia, Malaysia, Thailand, and Vietnam. The author examined the years 1996–2021 using information from Global Financial Development and the World Bank Development Indicator. The author's research shows that R&D spending and the financial development lower CO2 emissions in both developed and developing nations. Each country has a variety of estimation results. Furthermore, policies relating to sustainable development are discussed.

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Research background

The relationship between r&d, financial innovation, and economic growth, especially sustainable development, has been a topic of interest for economists and policymakers alike. The importance of these factors in driving economic progress is well recognized. This relationship is crucial for understanding how economies can achieve long-term growth while maintaining environmental and social sustainability.

Financial innovation refers to the improvement in the financial institutions, markets, and instruments that facilitate the efficient allocation of resources. It includes the expansion of banking services, stock markets, and other financial intermediaries. Financial innovation is essential for mobilizing savings, facilitating investments, and promoting economic growth. It provides the necessary capital for businesses to invest in innovative projects and technologies, which can lead to increased productivity and growth. Financial innovation can enhance the effectiveness of R&D investments by providing better access to capital and reducing financial constraints. This, in turn, can lead to higher levels of innovation and productivity growth.

R&D expenditure is a critical driver of innovation and technological advancement. Investments in R&D lead to the development of new products, processes, and services that can enhance productivity and economic growth. R&D activities are often associated with high levels of uncertainty and risk, which makes access to financial resources crucial. Financial innovation can support R&D by providing the necessary funding and reducing the cost of capital for innovative projects.

R&D expenditure has been shown to have a positive impact on economic growth, mainly in high-income and upper-middle-income countries (Saleem, H., Khan, M.B. and Shabbir, M.S., 2020). The development of green technologies through R&D can also help mitigate environmental impacts and promote sustainable growth.

Understanding the relationship between financial innovation, R&D expenditure, and sustainable economic growth is crucial for policymakers aiming to foster long-term economic prosperity. By promoting financial innovation and supporting R&D investments, countries can achieve sustainable growth that benefits both current and future generations.

In the context of OECD countries, the study by Mtar and Belazreg (2021) provides valuable insights into these relationships. Their research, which spans the period from 2001 to 2016, reveals a unidirectional causality from economic growth to financial innovation. Interestingly, they found no evidence of causality from financial innovation to economic growth, between innovation and economic growth, or between financial innovation and innovation. This neutrality hypothesis suggests that the relationships among these variables are complex and potentially influenced by country-specific characteristics. These findings underscore the need for further research to understand the nuanced dynamics among innovation, financial innovation, and economic growth. In particular, the role of government in fostering innovation through legal frameworks and the impact of financial system regulation on economic development warrant further exploration. Moreover, the country-specific nature of these relationships suggests that a one-size-fits-all approach may not be effective, highlighting the need for tailored strategies that take into account the unique circumstances of each country.

This research aims to adjuncts on the work of Mtar and Belazreg (2021) and Shahbaz, M., et al. (2020) by delving deeper into these relationships, with a particular focus on the role of government policy. By doing so, it hopes to contribute to the body of knowledge in this field and provide actionable insights for policymakers towards sustainable development.

Literature review

The intricate interplay between research and development (R&D), financial innovation, and economic growth has been the subject of extensive scholarly investigation. Recent studies on the origins of economic growth have underscored the pivotal role of innovation. A significant part of the growth observed in developed economies, such as those in the OECD, can be attributed to their innovative processes and the scale of their innovations. Tracing back to the influential work of Schumpeter (1934), the literature has consistently highlighted that innovation and technological advancements have become a primary catalyst for economic growth (citations include Solow 1956; Griliches and Mairesse 1984; Romer 1990; Grossman and Helpman 1994; Aghion et al. 2005; Aghion and Howitt 2009). Innovation is seen as a crucial driver of economic growth, with innovative activities forming the backbone of economic productivity and expansion.

The EKC phenomenon itself was introduced by the World Bank (1992) and by Grossman and Krueger (1995) as presenting an inverse U-shaped relationship between environmental pressure and income. Grossman and Krueger (1995) showed that low-income countries could learn from the history portrayed by this curve and try to avoid making the same mistakes. Moreover, the quadratic relationship between pollution emissions and income suggests that environmental quality will improve as a result of doing nothing. Overall, many authors have used different measures (Huang et al., 2008; Akbostanci et al., 2009), different types of methods (Halkos and Tsionas, 2001; Luzzati and Orsini, 2009; Inmaculada and Aurelia, 2004; Lise, 2006), and different explanatory variables (Heerink et al., 2001; Cole, 2004; Tamazian et al., 2010; Kristrom and Lundgren, 2005; Galeotti et al., 2006) to estimate air pollution.

Technological advancements and all elements that promote the creation of new knowledge form the foundation of economic development (Aghion and Howitt 2009). Consequently, on a macroeconomic scale, growth is exhibited through the spread of innovation in economic activities, facilitating a dynamic accumulation process of physical, human, and technical capital (Belze and Gauthier, 2000). This process aids in enhancing labor productivity and total factor productivity (TFP), thereby propelling economic growth (Crépon et al. 1998).

The paper by Mtar and Belazreg (2021) delves into the causal relationship between innovation, financial development, and economic growth. The authors employed a panel VAR approach to analyze data from 27 OECD countries over the period 2001–2016. Their findings revealed a unidirectional causality from economic growth to financial development. Furthermore, they confirmed the neutrality hypothesis from financial development to economic growth, as well as between innovation and economic growth and between financial development and innovation. The paper concludes by emphasizing that further regulation of financial systems and the quality of funding are crucial elements for fostering economic development. Mtar and Belazreg (2021) provides a foundation for understanding the complex relationships between innovation, financial development, and economic growth. Building upon this, we can explore the concept of digital inclusive finance and its role in R&D investment and green technology innovation. Digital inclusive finance refers to the use of digital technologies to deliver financial services to individuals and businesses, particularly those who are underserved by traditional financial institutions. It has the potential to drive economic growth by fostering innovation and facilitating access to finance for R&D activities.

In the context of green technology innovation, digital inclusive finance can play a pivotal role. Green technology innovation is an effective means to achieve high-quality economic development (Sun H, Luo Y, Liu J, Bhuiyan MA, 2024). The impact and mechanism of digital financial inclusion on regional green technology innovation are tested using a threshold regression model and the panel fixed effect model, based on China's provincial Panel data from 2011 to 2020(Sun H, Luo Y, Liu J, Bhuiyan MA, 2024). According to the study, there is a direct link between local green technology innovation and digital financial inclusion. This paper highlights the differences in their influence by location and usage depth and underscores the necessity of government engagement to improve these characteristics. Information infrastructure needs to be strengthened, especially in areas with gaps. Greater investment in research and development (R&D) indirectly supports regional green technology innovation since it is impacted by digital financial inclusion. Interestingly, a threshold effect becomes most noticeable when digital financial inclusion rises above a particular threshold. Promoting utilizing digital financial inclusion to lessen regional differences in green technology innovation is important. In conclusion, digital inclusive finance can be a powerful tool for promoting R&D investment and fostering green technology innovation. However, the effectiveness of digital inclusive finance can vary depending on a variety of factors, including the level of financial development, the degree of innovation, and the specific characteristics of each country or region. Therefore, further research is needed to fully understand the potential of digital inclusive finance and to develop strategies for maximizing its benefits.

The paper by Vincent O'Connell, Naser Abu Ghazaleh, Yasean Tahat, and Garvan Whelan(2022) explores the interrelationship between R&D investment, financial leverage, and a firm's R&D innovation success. The study uses a sample of UK and EU firms and predicts that changes in one-year-ahead R&D investment are negatively associated with changes in financial leverage in the current period. Crucially, the authors also predict that this negative association is positively moderated by the extent to which firms are successful in generating commercially viable and technically feasible innovations from their R&D work. The authors draw on extant theory to predict a negative relationship between changes in one-period-ahead R&D investment and current-period financial leverage changes. They argue that success with R&D innovations reduces the risk associated with R&D investment from the perspective of both management and the providers of debt finance. While the relationship between R&D investment and current financial leverage is generally negative, the authors suggest that this relationship can be positively moderated by the firm's success in R&D innovation. This means that when a firm has a high level of success in generating commercially viable and technically feasible innovations, the negative impact of R&D investment on financial leverage is reduced. In other words, successful R&D innovation can mitigate the risk associated with R&D investment The study contributes to the existing literature by demonstrating that R&D innovation success influences how firms finance their subsequent investments in R&D. It also shows that accounting disclosures have the potential to play an important role in open innovation networks.

Numerous studies lend credence to Schumpeter's (1912) proposition that banks foster innovative endeavors (citations include King and Levine 1993; Levine 1997; Rajan and Zingales 1998; Allen and Gale, 1999; Morales, 2003; Cabral and Mata, 2003; Aghion et al. 2005; Hyytinen and Toivanen, 2005; Acemoglu and Robinson, 2006; Zang and Kim 2007). These authors argue that banks stimulate technological innovation by channeling resources towards entrepreneurs who present the most promising new opportunities, such as novel products and production techniques. This implies that by modifying the process of resource allocation, a country's financial sector can positively impact innovation-related activities. They do this by offering crucial financial services, like information acquisition and risk management, which decrease transaction costs, mitigate risk, and consequently, promote investment in innovative entrepreneurial activities in the long term (Levine 1997).

The paper by Shahbaz, M., et.al. 2020 had empirical results lead us to conclude on the presence of long run association among the underlying variables. Specifically, the EKC hypothesis is validated for the UK, which implies that in the short run economic growth damages the environment, and beyond the threshold level it improves environmental quality. The post-global financial crisis period, however, showed less support to this notion. It implies that in the current climate, the ecological consequences of economic growth should be given an utmost priority in the policy-making to achieve a sustainable natural environment. Based on the theoretical and empirical discussions, Shahbaz, M.,et.al., (2020) model the general carbon emissions function, considering economic growth, financial development, energy consumption, and R&D expenditures as determinants of environmental quality using historical data for the UK economy spanning well over 147 years from 1870 to 2017. Employing the bootstrapping bounds testing approach to examine short- and long-run relationships, the analysis is based on historical data from 1870 to 2017. The results suggest the existence of cointegration between CO2 emissions and its determinants. Financial development and energy consumption lead to environmental degradation, but R&D expenditures help to reduce CO2 emissions. The estimated environmental effects of economic growth support the EKC hypothesis. While a U-shaped relationship is found between financial development and CO2 emissions, the nexus between R&D expenditures and CO2 emissions is analogues to the EKC. In the context of the efforts to tackle climate change, the findings suggest policy prescriptions by using financial development and R&D expenditures as the key tools to meet the emissions target.

The study by Shahbaz,M. et.al. (2013) investigated the dynamic relationship between economic growth, energy consumption, financial development, trade openness and CO2 emissions in case of Indonesian economy over the period of 1975Q–2011Q4. For this purpose, the writers applied the ARDL bounds testing approach to cointegration to examine the cointegration among the variables in the presence of structural breaks in series for long run. The VECM Granger causality is applied to test the direction of causal relationship between the variables and robustness of causality analysis was tested by using innovative accounting approach (IAA). The results indicated that the variables are cointegrated for long run relationship in the presence of structural breaks in the series. The empirical evidence showed that energy consumption increases carbon emissions and economic growth is a major contributor to CO2 emissions. Financial development condenses carbon emissions and inverted-U shaped relationship is also confirmed between financial development and carbon emissions. This validates the contribution of financial sector to improve the quality of environment. Trade openness also declines energy pollutants. The causality analysis exposed the bidirectional causality between energy consumption and carbon emissions. Economic growth and carbon emissions are interrelated. Feedback hypothesis is validated between CO2 emissions and trade openness. Energy consumption and economic growth Granger cause each other. Financial development Granger causes energy consumption, energy pollutants, economic growth and trade openness. The results imply that carbon emissions can be reduced at the cost of economic growth or energy efficient technologies should be encouraged to enhance domestic production with the help of financial sector and import environment friendly technology from advanced countries. Financial development Granger causes energy consumption which reveals that adoption of energy conservation policy would not adversely affect economic growth. Again, financial sector must fix its focus on the allocation of funds to those firms which adopt environment friendly technologies and encourage the firms to use more energy efficient technology for production purpose and hence to save environment from degradation.

The study by Saleem, et.al. (2020) seeks to examine the policy scheme of Asian countries and their efforts to achieve sustainable environmental practices in terms of green growth, green financing, and CO2emission reduction programs. This study investigates the role of GDP growth, sources of energy consumption, and other plausible hypothetical factors in CO2 emissions using evidence from selected Asian countries over the period of 1980–2015. The FMOLS results for the full panel set indicate the presence of the EKC hypothesis, where the impact of GDP growth and the square of GDP growth on CO2 emission is positive and negative, respectively, in the Asian region in this study. The inverted U-shaped relationship between CO2 emission, energy consumption, economic growth, and other control variables were confirmed by the findings of the FMOLS test in the context of high-income, upper middle-income, and full panel of Asian economies. The FMOLS findings for lower middle-income economies did not support the existence of the EKC hypothesis. Renewable energy as a substitute of non-renewable energy was found to be significant, and the elasticity of CO2 emission with respect to renewable energy consumption (in the upper and lower middle income and panel of full FOMLS) was negative. The contribution of renewable energy use on CO2 emission in upper middle-income economies was higher as compared to other selected Asian economies.

The study by Kihombo, S. et.al. (2021) aims to determine the relationships among financial development, R&D, energy intensity, income level, and CO2 emissions for a panel of selected WAME (West Asia and Middle East) countries from 1990 to 2017. The findings disclose that financial development in the WAME countries causes high environmental deterioration due to investment in energy intensive projects. The energy intensity causes high CO2 emissions; however, R&D brings innovative methods and efficient energy sources in these regions which enhance environmental quality. The results also reveal the presence of a two-way causal link among emissions (CO2) and FD, R&D and emissions, income level and emissions, energy intensity and income level, R&D and income level, energy intensity and income square, R&D and energy intensity, and energy intensity and FD. More importantly, this study reports that when GDP level reaches beyond a certain level, environmental degradation mitigates. Thus, the findings validate the EKC phenomenon. The findings validated the environmental Kuznets curve (EKC) phenomenon for the WAME economies considering R&D and financial development. These empirical findings propose a number of policy implications that can support authorities or policymakers in selected economies to tackle the adverse environmental impacts of income and energy intensity. First, the financial sector is causing environmental deterioration which calls for imposing strict regulations on the lending of the financial sector. It should be made sure that this sector evaluates projects carefully and determines their environmental feasibility before lending money. Policies should be designed to reduce formalities required for providing financial support to green energy projects. Boosting research and development will bring innovative technology and its efficient utilization. The moral behind uplifting R&D investment is to bring new innovative production methods and advanced industrial technology. Hence, selected WAME countries must increase R&D level to support economic development (as there is causal association between R&D and GDP) and reduce CO2 emissions.

Recognizing the importance of innovation and financial sector development to environmental quality, several countries have embarked on identifying ways to improve environmental quality. However, studies on the tripartite linkages among innovation, financial development and pollution relationships have produced mixed findings. Ibrahim, M. et.al. 2021 conduct study on 27 selected industrialized countries to examine the relationships among innovation, financial development and pollution proxied by ecological footprint and CO2 emissions. Findings based on their estimations show that, while increases in innovation reduce environmental pollution with huge effects on ecological footprint relative to CO2 emissions, the writers observe threshold effects of innovation and U–shaped in particular, suggesting that, beyond the estimated threshold levels of innovation, higher innovation exacerbates environmental degradation. Further results also reveal that, while well–developed financial development is associated with environmental degradation, improved innovation dampens the degradation effect of financial development. This evidence holds irrespective of the measure of environmental pollution. Results from their panel causality tests reveal a feedback causal relation between innovation and ecological footprint, and a one-way causal link from CO2 emissions to innovations. However, financial development and environmental degradation evolve independently although there are substantial differences at the individual country levels in terms of the causal nexuses in innovation, financial development and pollution.

Data and Empirical Methodology

The author primarily used data from the World Bank Development Indicator and Global Financial Development. The author adjusted the Cointegrating Regression FMOLS from the Saleem, H., Khan, M.B. and Shabbir, M.S., (2020), Kihombo, S. et.al. (2021) and Lee, J.M., Chen, K.H. and Cho, C.H., (2015) model. The author selected samples from several nations, including Japan, Korea, Singapore, Malaysia, Vietnam, Indonesia, and Thailand, and the sample data covered the years 1996–2021. The following equation was used by the author:

$Ct= f(Yt, Yt^2, Rt, Ft)$
$dCt= d\,Yt+ d\,Yt^2 +dRt+ dFt+ ei$

where, Ct, Yt, Yt^2, Rt, Ft, and ei are carbon emissions per capita, GDP per capita, square of GDP per capita, R&D expenditures(%gdp), liquid liabilities (%gdp), and domestic private credit(%gdp) as the proxy for financial innovation adjusted based on Qamruzzaman, M., Jianguo, W., (2017), Qamruzzaman, M.,et.al. (2021), Pradhan, R., et.al. (2018) and the residual term.

Ratio of liquid liabilities to GDP; Liquid liabilities are also known as broad money, or M3. They are the sum of currency and deposits in the central bank (M0), plus transferable deposits and electronic currency (M1), plus time and savings deposits, foreign currency transferable deposits, certificates of deposit, and securities repurchase agreements (M2), plus travelers checks, foreign currency time deposits, commercial paper, and shares of mutual funds or market funds held by residents.

Results and Discussions

All Countries

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(RD)	-0.00381	0.241629	-0.01575	0.9875
D(LL)	-0.00238	0.003154	-0.75378	0.4523
D(FDI)	0.002656	7.64E-03	0.347535	0.7287
D(PRIVATE_CREDIT)	-0.00146	0.004114	-0.35576	0.7226
D(GDP2)	-3.61E-09	1.22E-09	-2.95565	0.0037**
D(GDP_PER_CAP)	4.34E-04	1.07E-04	4.047175	0.0001**

Selected Countries

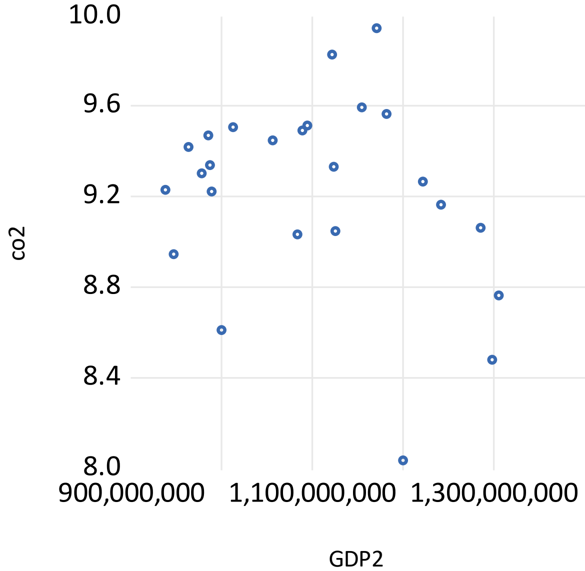
Countries	Variable	Coefficient	Std. Error	t-Statistic	Prob.
JAPAN	D(RD)	0.295855	0.598931	0.493972	0.628
	D(LL)	0.021535	8.52E-03	2.526546	0.0224**
	D(FDI)	1.258607	0.183009	6.877307	0.00**
	D(PRIVATE_CREDIT)	-3.99E-02	1.40E-02	-2.83931	0.0118**
	D(GDP2)	6.21E-08	2.47E-08	2.514852	0.023**
	D(GDP_PER_CAP)	-3.84E-03	1.65E-03	-2.32569	0.0335**

KOREA	D(RD)	0.602338	0.551125	1.092925	0.2906
	D(LL)	-7.61E-04	4.99E-03	-0.15266	0.8806
	D(FDI)	-0.05844	0.178549	-0.32732	0.7477
	D(PRIVATE_CREDIT)	-1.69E-02	8.98E-03	-1.88332	0.078*
	D(GDP2)	-9.24E-09	7.85E-09	-1.17719	0.2563
	D(GDP_PER_CAP)	1.08E-03	3.08E-04	3.514839	0.0029**
SINGAPORE	D(RD)	-0.11591	0.436507	-0.26553	0.794
	D(LL)	-0.03608	0.010733	-3.36144	0.004**
	D(FDI)	8.61E-02	0.009626	8.944435	0.00**
	D(PRIVATE_CREDIT)	3.97E-02	1.09E-02	3.628175	0.0023**
	D(GDP2)	-4.64E-09	2.02E-09	-2.29158	0.0358**
	D(GDP_PER_CAP)	1.99E-05	1.99E-04	0.100358	0.9213
INDONESIA	D(RD)	-1.55653	0.525843	-2.96007	0.0119**
	D(LL)	0.002531	0.005577	0.453776	0.6581
	D(FDI)	-0.00999	0.011125	-0.89795	0.3869
	D(PRIVATE_CREDIT)	-1.88E-02	8.76E-03	-2.14831	0.0528*
	D(GDP2)	1.30E-07	1.17E-07	1.109493	0.289
	D(GDP_PER_CAP)	1.39E-04	9.21E-04	0.150685	0.8827
MALAYSIA	D(RD)	-0.41286	0.373294	-1.10598	0.2904
	D(LL)	-0.00739	0.011242	-0.65722	0.5234
	D(FDI)	0.000856	0.029849	0.02867	0.9776
	D(PRIVATE_CREDIT)	4.33E-03	1.42E-02	0.305649	0.7651
	D(GDP2)	-2.08E-07	6.48E-08	-3.2057	0.0076**
	D(GDP_PER_CAP)	4.48E-03	1.41E-03	3.168954	0.0081**
THAILAND	D(RD)	-0.32175	0.149362	-2.15414	0.0506*
	D(LL)	0.001377	0.002538	0.542395	0.5967
	D(FDI)	0.012443	0.007727	1.610243	0.1313
	D(PRIVATE_CREDIT)	4.84E-03	3.01E-03	1.607261	0.132
	D(GDP2)	-6.80E-08	3.82E-08	-1.78114	0.0983*
	D(GDP_PER_CAP)	1.22E-03	4.37E-04	2.792749	0.0152**
VIETNAM	D(RD)	-1.11114	0.49708	-2.23534	0.0452**
	D(LL)	0.000558	0.003195	0.174574	0.8643
	D(FDI)	-0.00687	0.014558	-0.47219	0.6453
	D(PRIVATE_CREDIT)	2.46E-03	3.01E-03	0.817182	0.4298
	D(GDP2)	3.63E-07	2.39E-07	1.517866	0.1549
	D(GDP_PER_CAP)	-2.55E-05	1.91E-03	-0.01338	0.9895

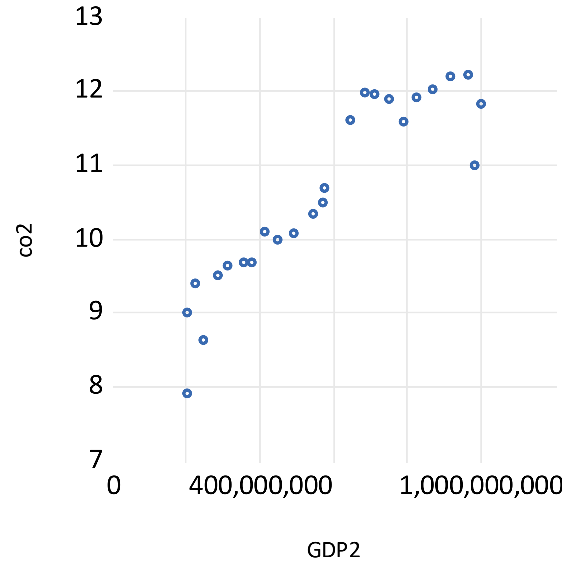
** sig at .05,* sig at.1

Graphic Kuznet EKC

JAPAN



KOREA



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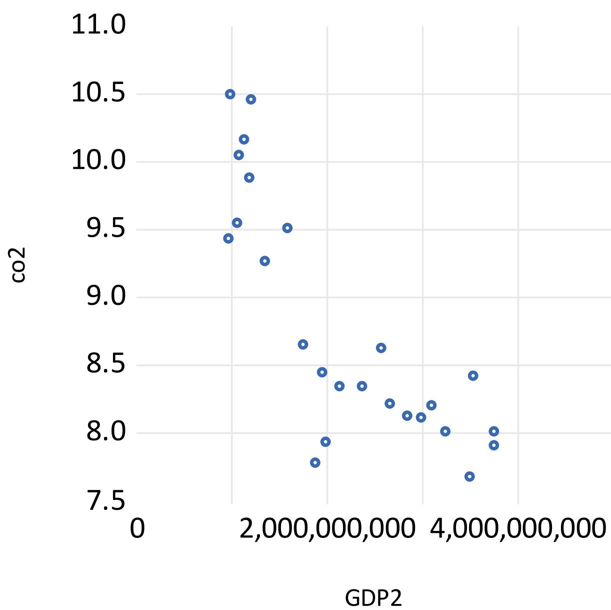

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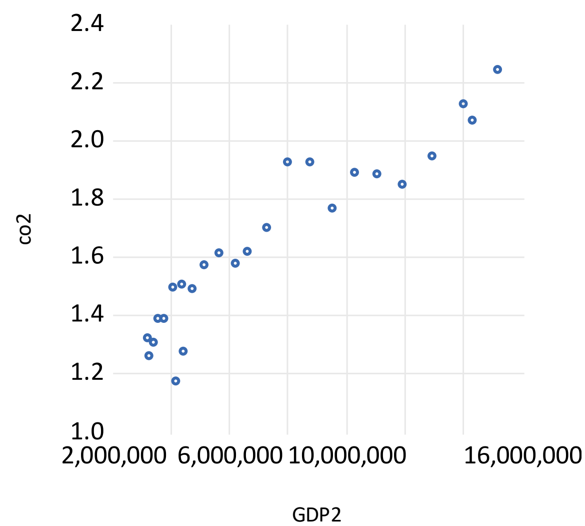
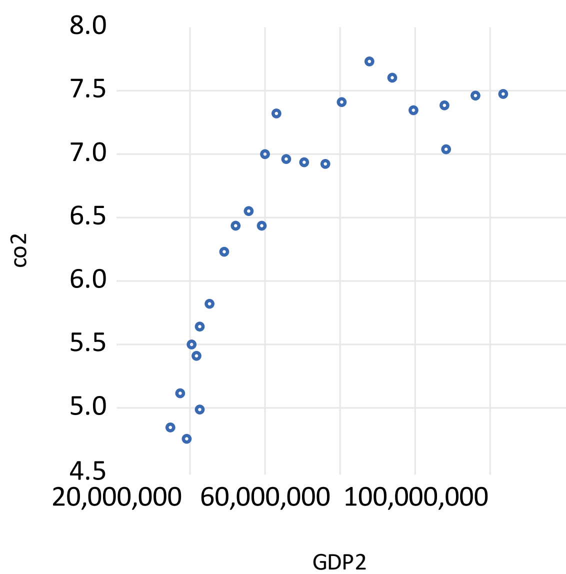
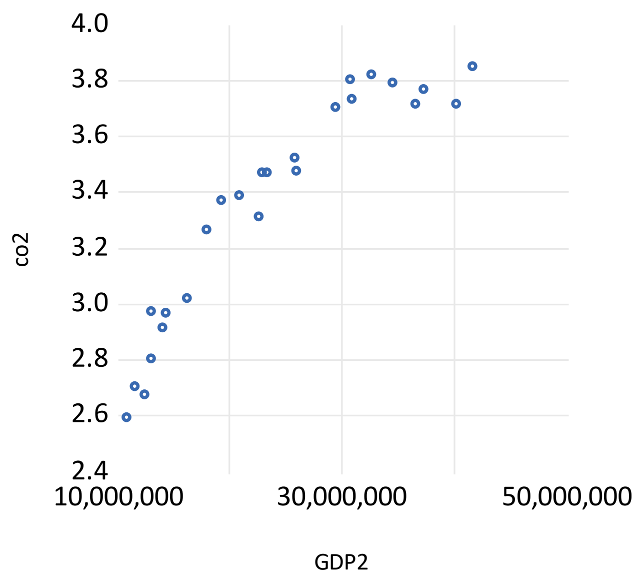


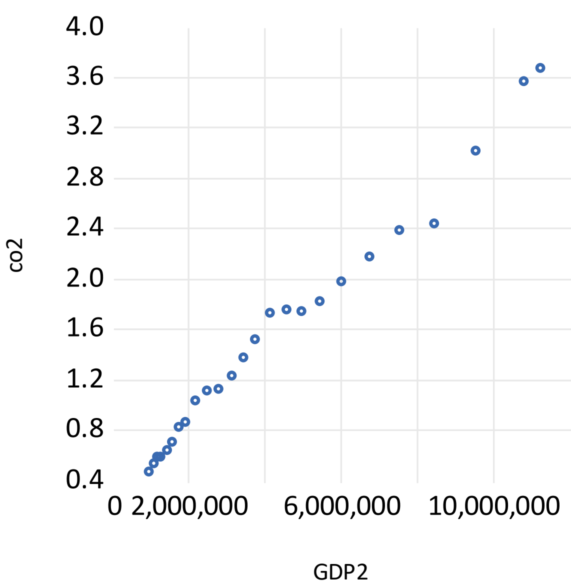
MALAYSIA



THAILAND



VIETNAM



Panel cointegration framework

Series: FDI GDP2 GDP_PER_CAP LL PRIVATE_CREDIT RD CO2_PER_CAPITA

Alternative hypothesis: common AR coefs. (within-dimension)

	Weighted Statistic	Prob.
Panel v-Statistic	-2.30245	0.9893
Panel rho-Statistic	1.824889	0.9660
Panel PP-Statistic	-1.3801	0.0838*
Panel ADF-Statistic	-1.75216	0.0399**

Alternative hypothesis: individual AR coefs. (between-dimension)

	Statistic	Prob.
Group rho-Statistic	3.302555	0.9995
Group PP-Statistic	-4.7851	0.0000**
Group ADF-Statistic	-1.9061	0.0283**

The findings of panel cointegration framework used Pedroni Residual Cointegration Test confirmed that out of the test's seven statistics, four statistics under the within-dimension and two statistics under the in between-dimension statistics is statistically significant. This means that there is a considerable long-run relationship among the variables under consideration.

In-depth Analysis: Interaction Variables Analysis

countries	Variable	Coefficient	Std. Error	t-Statistic	Prob.
JP	RD	10.26631	4.814722	2.132274	0.0456**
	PRIVATE_CREDIT	0.176971	0.07965	2.221847	0.0380**
	RD_PRIVATE_CREDIT	-0.06462	0.026623	-2.42706	0.0248**
KR	RD	4.471989	0.573247	7.801161	0.0000**
	PRIVATE_CREDIT	0.062491	0.009213	6.782678	0.0000**
	RD_PRIVATE_CREDIT	-0.0243	0.003872	-6.27594	0.0000**
KR	RD	2.977362	0.192701	15.45066	0.0000**
	LL	0.078398	0.010226	7.666124	0.0000**
	RD_LL	-0.02132	0.00236	-9.03489	0.0000**
MY	RD	-10.9759	5.526348	-1.9861	0.0644*
	LL	-0.12207	0.038479	-3.17235	0.0059**
	RD_LL	0.104407	0.042884	2.434659	0.0270**
MY	RD	-12.8563	4.031013	-3.18936	0.0057**
	PRIVATE_CREDIT	-0.11055	0.027643	-3.99905	0.0010**
	RD_PRIVATE_CREDIT	0.123327	0.033969	3.63054	0.0022**
ID	RD	20.04568	3.805374	5.267728	0.0001**
	PRIVATE_CREDIT	0.044336	0.009577	4.629292	0.0003**
	RD_PRIVATE_CREDIT	-0.46244	0.097789	-4.72892	0.0002**

In-depth Analysis

The author examined and further analysed each country's pattern. The author found that there are some paired variable patterns in some countries. The pattern we saw in Japan, Korea, Malaysia, and Indonesia. The author tested R&D expenditure of GDP, private credit of GDP, and liquid liabilities of GDP. Based on the results of the in-depth analysis, the author concluded that Japan and Indonesia had a similar pattern in which private credit of GDP was paired with R&D expenditure of GDP to reduce carbon emissions.

Meanwhile, the other pattern we saw was that Korea and Malaysia had similar patterns. Korea and Malaysia had private credit of GDP, and the liquid liabilities of GDP were paired with the R&D expenditure of GDP to reduce carbon emissions.

Discussion

Based on the results, only Japan and Singapore had reached the reverse U-curve Kuznet EKC. That means Japan and Singapore have reached post-industrialized or knowledge-based economies. The Korean curve exhibited an incomplete of the reverse U curve. That means Korea is going into the post-industrialized, or knowledge economy phase. Meanwhile, the other countries don't show the reverse U curve as still in progress in the industrial phase.

In all selected Asia countries, the proxies of financial development variables, which are liquid liabilities to GDP and private credit of GDP, had a negative coefficient even that was not significant. GDP per capita and GDP per capita squared significantly impacted CO2 emissions. That means that in all selected countries, there is a pattern of sustainable development that reduces CO2 emissions.

The author was concerned with the financial innovation proxy in this research. The author saw that Japan, Korea, and Singapore as the high-income countries had promising results patterns. The private credit coefficients in Japan and Korea had negative results and were significant. That means the private credit of GDP had a significant effect on reducing carbon emissions. The Singapore results had a negative and significant coefficient at liquid liabilities of GDP. That means the Singapore liquid liabilities of GDP significant effect on reducing carbon emissions.

The other countries also had promising patterns. Indonesia had negative and significant R&D and private credit of GDP. That means the R&D expenditure paired with private credit had a significant effect on reducing carbon emissions.

Thailand and Vietnam had similar patterns. Thailand and Vietnam have negative and significant coefficients in R&D expenditure. In that case, Thailand and Vietnam had significant R&D expenditure of GDP on reducing carbon emissions.

Malaysia exhibited also promising variable patterns. Malaysia had negative and significant GDP per capita and GDP per capita squared. That means Malaysia's GDP per capita had a significant effect on reducing carbon emissions. It means Malaysia's growth also had a sustainable development pattern proven by its pattern in carbon emissions reduction.

In conclusion, in all selected Asia countries, there are some promising results patterns. In each country, we found the proven sustainable development pattern at some proxy variables. The selected Asia countries could manage this to a sustainable future.

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