Environmental Degradation & Role of Financialisation, Economic Development, Industrialisation and Trade Liberalisation

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Abstract

This paper is a pioneering endeavour to investigate the determinants of environmental degradation in Australia through a comprehensive framework of EKC and STIRPAT. Specifically, the impacts of multiple factors of socio-economic development including economic growth, trade openness, industrialization, energy consumption on CO₂ emissions are analysed. Furthermore, the influences of financial development through different dimensions (financial efficiency, access and depth) in two subsectors (financial markets and institutions) and other proxies of financial development are focused over the period 1980–2014. Empirical results show short as well as long-run differences in the association among the variables. Short-term bidirectional causality prevails between economic growth, energy consumption, industrialization, and stock market development with carbon dioxide (CO₂) emissions. However, there is no significant evidence found on EKC. This is due to the long-run positive impact of financial development, energy consumption, and trade openness on CO₂ emissions. Interestingly, the industrialization process is found to does not affect CO₂ emissions. Empirical findings provide insight into why the quality of the Australian environment is truncated with frequent and widespread bushfires and suggest policymakers to have selective and strict environmental-friendly strategies to fulfil a sustainable development goal.

Keywords: Carbon emissions; EKC; STIRPAT, Industrialization, Population, Economic Development, Trade Openness, Financial development.

1. Introduction

Geographically one of the largest countries in the world, Australia with its unique and precious climate, rich oceans, vast forests and wildlife. Despite, a comparatively small population, the geographical size makes Australia ecologically very important. Unfortunately, the Australian environment is under threat as there have been many land-use changes, habitat fragmentation and degradation, especially continuous bush fires happening recently. Furthermore, the emissions of Green House Gasses (GHGs) particularly CO₂ is one of the curial cause of rising global temperatures, also been quite high in Australia in per capita terms. The ecosystems have rather more restricted capacity to manage different kinds of pressures compared to human systems. For example, the too big and too fast bush fires have been destroying climatically suitable areas for different precious species making it difficult for them to follow their natural migration patterns. The year 2019 is considered as the worst year on a record since 1950 for bushfire risk, and by the beginning of 2020, bushfires have destroyed approximately six million hectares, hundreds of homes and killed thousands of people and billions of wildlife losses. According to NASA (2020), GHG emissions are one of the major causes of climate change and global warming. As a consequence, climate change results in bushfires in Australia (Phillips and Nogrady, 2020). This misery in the form of bushfires raises the crucial question about climate change and environmental degradation in Australia and its causes. Specifically, what are the contributing factors to the increasing environmental degradation and emissions in Australia? Furthermore, climate change is a global issue that poses existential challenges to the human civilisation requiring an appropriate policy response from the governments and stakeholders. The responsibility of saving the world from the deterioration of environment particularly falls upon the countries which are the major emitters of GHGs, including Australia with one of the world highest per capita emissions. Australia has not always been at the forefront of the fight against climate change, for instance, it had hesitated to ratify the Kyoto Protocol and to end fossil fuel subsidies. However, it is a signatory of Conference of Parties (COP:21) held in Paris in 2015 and for that reason has committed herself to reductions in emissions. The Australian government, although, has expressed strong commitments to reduce emissions with the target of 50-52 per cent emissions reduction. However, curbing carbon emissions would mean to have implications for economic growth and therefore it

may cause the reluctance to honour the COP21 commitments. Therefore, it is important to explore the nexus between economic growth, financial development and other relevant socio-economic factors and environmental degradation in Australia. Concomitantly, a study on driving factors affecting climate change and causing the environmental degradation conducted in the Australian context has the prospect of shedding some light and draw crucial policy lessons to tackle the existentially important environmental challenges.

The remarkable development of the Australian economy is often associated with higher levels of FDI and trade openness as compared to its counterparts. The GDP figures indicate a resilient and stable growth over many decades that has enabled Australia to stand among the 20 largest economies *i.e.* G-20. Despite the fact that this is a success story in terms of economic growth, it is vital to see in the environmental context. Due to the adverse implications of unsustainable economic growth for the environment, there has been increasing emphasis to take an inclusive and more sustainable approach to economic development. Environmental damage by the emissions of greenhouse gases has led to calls for renewable energy as a substitute source to reduce CO₂ emissions, particularly in the context of increasing global demand. Increasing emissions are also likely to come from trade liberalisation, where taking advantage of globalization, the rich nations cut the production of the pollution-intensive goods (Pham et al 2020). As a result, the treaties associated with the increase in renewable/green energy in total energy consumption and through energy innovation, all of which are subject to the governor of environmental degradations, have an attractive debate among scholars (Lorente and Álvarez-herránz et al., 2017 and Álvarez-herranz, 2016). Nevertheless, the empirical evidence nexus among FDI, consumption of energy and economic growth as well as nexus between FDI and environmental degradation suggest inconclusive results (Nasir et al. 2019, Pham et al. 2020). Therefore, the Australian context requires further insight and research to examine the effects of FDI inflows and trade openness on the environment.

Theoretically, socio-economic activities are the main cause of environmental degradation (Minh et al., 2020). The EKC implies that there is an inverted-U shaped association prevails between environmental degradation and the level of income *i.e.* growth of the economy (Kuznets, 1955, See Dinda (2004) for the survey on the EKC). Whereas, the STIRPAT model explains in more detail with economic development, population,

technology as main drivers of environmental degradation (Dietz and Rosa, 1997). Furthermore, similar to the economy – environment nexus, there are contrasting views regarding the role of financial development in environmental degradation. On the negative view, the growth of the financial market opens more credits lines to customers who then spend on “large-ticket” items, such as automobiles and machinery, which consume a large amount of energy. Besides, financial development is closely associated with the expansion of the stock market which is also accounted as a vital sign of economic progress and opens more opportunities for customers to access to financial capital at lower borrowing costs, through which more plants and machines are constructed, all of which boost the demand for energy. A higher degree of energy consumption accompanies higher CO₂ emissions and may result in environmental degradation. The positively supporting view suggests that the financial development, *i.e.* resourceful inflows of domestic credits to private sectors or stock market capitalization, provide debt and equity to the host country to develop green and renewable energy projects (Dasgupta et al., 2004). Therefore, financial development assists as an impetus for the technology innovation to reduce the energy use (Alfaro et al., 2004; Hermes and Lensink, 2003) and simultaneously enhanced lending to the development of green-energy industry and hence increased usage of the green energy. Hence, the empirical evidence on the impact of financial development on the degradation of the environment is contrasting. A point also worth emphasising here is the financial development and how it is measured. Often researchers have only looked at one aspect of the financial sector, yet, it is crucial to take a comprehensive approach to the measurement of financial development to fully comprehend its impact (Nasir, et al 2019). Contextualising on the severity on climate change in Australia, our study examines the implications of economic growth (real income, trade openness, industrialization), financial development (overall financial development, financial market access, financial institution efficiency, financial market development, financial market efficiency) with three dimensions (financial efficiency, financial access and financial depth) and consumption of energy for Australian emissions of CO₂ from 1980 to 2014. In terms of its analytical and theoretical framework, this study is based on two imperative theories in environmental economics, the EKC and the STIRPAT, developed by Dietz and Rosa (1997). The EKC implies that there is an inverted-U shaped association prevails in the relationship between environmental degradation and levels of income in an economy (Kuznets, 1955), Whereas, the STIRPAT model

explains in more detail the role of economic development, population, technology as main drivers of environmental degradation (Dietz and Rosa, 1997). Therefore, these two models manifest the underlying factors contributing to environmental degradation. The results from the models could lead to policy implication for the Australian government whether financial development, population, and economic growth increase or mitigate the environmental degradation, and whether the technology could be a solution to improve the environmental degradation and reduce GHGs. The key empirical findings obtained from the application of both frameworks suggest that there are causal relationships between the growth of the economy, consumption of energy, industrialization, and stock market development with emissions of CO₂ in the short run. The growth of economy does not confirm the presence of the EKC. In contrast, the financial development, consumption of energy and trade liberalisation have a long-run positive effect on the CO₂ emissions. Interestingly, the industrialization process is found to have no significant effect on CO₂ emissions. Our findings contribute to the debate on the implications of socio-economic and financial development for the environment by particularly focusing on the Australian case which has suffered from severe ecological degradation in recent years.

The rest of the paper is organized as follows: In § 2 we critically discuss the literature concerning CO₂ emissions and its contributing factors, particularly the role of economic and financial development. § 3 sets out the methodology and data. Subsequently, § 4 presents and discusses empirical results whereas § 5 concludes and provides implications for policymaking.

2. Economic Development & Environmental Degradation

Considering the obvious importance of the subject, several studies investigated the implications of economic development for environmental degradation. Kalyoncu et al. (2013) reviewed the nexus between energy and growth and devised three principal viewpoints. First, highlights that the energy is an input of production process and therefore it formulates a causal relationship between energy usage and growth of the economy (Stern and Cleveland, 2004). Second, that the causality runs from the development of the economy to consumption of energy (Toman and Jemelkova, 2003; Aziz, 2011) and there prevails an EKC. That is when income level (a proxy of economic

development) increases, environmental pollution increases but then decreases after peaking a threshold. Finally, the third point of view presents that the association is a bidirectional way, which means economic development's effect on consumption of energy and vice versa (Aziz, 2011). Existing literature fails to establish any consensus since there are a number of crucial contextual factors to account for as well as idiosyncratic characteristics of various countries. For example, Shahbaz and Sinha, (2019) confirmed the inconclusiveness in the relation between income and CO₂ emissions (EKC) due to the discrepancies regarding the contexts, various periods, samples, and methodologies in the existing literature.

The fast growth of the economy is associated with increasing energy demand, especially in the emerging economies (Ouyang and Lin, 2017) since many emerging economies are growing at a faster rate and as economies grow so does the energy demand. Therefore, the economic activity plays the part of the driving factor for the increase in CO₂ emission (Ouyang and Lin, 2015; Nasir et al 2019). The study by Ghosh and Kanjilal (2014) reported a causal relationship (unidirectional) between consumption of energy consumption economic activity and from economic growth to urbanization in India, whereas the stable growth of Chinese economy is found to increase the emissions of CO₂ (Ouyang and Lin, 2017; Ouyang and Lin (2015), which supports the EKC model. In their analysis on implications of the growth of economy and consumption of energy for CO₂ emissions through 17 countries in the South and Southeast Asian region, Behera and Dash (2017) argue in favour of EKC and report that the consumption of energy in middle-income countries is noticeably snowballing the CO₂ emission, and resulting in a greenhouse gas problem. The EKC theory is found to be applicable to a larger sample. For example, in the panel data of 136 countries which are divided into low, middle and high incomes (OECD and non-OECD countries), Mamun et al. (2014) reported existence of the EKC in all regions except for high-income OECD countries. Furthermore, the Population growth is also associated with an increased while economic liberalization is linked to a reduction in CO₂ emissions.

There is also a strand of literature that supports the bidirectional relationship between economic growth, consumption of energy and CO₂ emissions. It has been argued that a highly developed economy and then rapid urbanization drive the high demand for private vehicles and transportation, contributing to a growing level of CO₂ emissions. The greater

the economy is likely to connect with the extended transportation system and higher energy consumption as higher economic development requires more energy usage (Halicioglu, 2009). Saboori et al. (2014) reported a positive association between the growth of the economy, consumption of energy and CO₂ emissions in OECD countries which have experienced remarkable economic growth. Salahuddin et al. (2015) conduct a study on the Gulf Cooperation Council (GCC) countries. These economies have also shown fast growth and contribute to approximately 8% of the world's carbon emissions. Their empirical results indicated a long-run association between overall energy consumption as well as by the road sector, growth of economy and emissions. Similarly, Saboori and Sulaiman, (2013) find bidirectional Granger causality in ASEAN countries. Specially, they found a long-run causal relationship between growth, CO₂ emissions, and electricity consumption in Indonesia, Malaysia and Philippine, while the short-run causal relationship was found between the growth of economy and CO₂ emissions for Indonesia, Singapore and Thailand, and consumption of energy and CO₂ emissions in Malaysia and Singapore.

There is also a considerable amount of evidence (see *e.g.* Pao et al., 2011; Acaravci and Ozturk, 2010; Özokcu and Özdemir, 2017) suggesting that neither environmental pollution nor consumption of energy cause growth of the economy. Also, Begum et al. (2015) reported a U-shape relationship (*i.e.* or EKC) on the effect of economic and population growth, consumption of energy on CO₂ emissions in Malaysia. Specifically, the CO₂ emissions decline with an increase in GDP for the period of 1970–1980, but after 1980, the CO₂ increase is caused by the growth of GDP. Most of the existing on the subject are either on a single but different country or multiples countries. For example, on China (Ouyang and Lin, 2017; Ouyang and Lin, 2014; Ouyang and Lin, 2015); Turkey (Acaravci Ozturk, 2010); Brazil (Pao and Tsai, 2011); Russia (Pao et al., 2011); Malaysia (Begum et al., 2015); India (Ghosh, 2010); Australia (Salahuddin and Alam, 2015); Iran (Lotfalipour et al., 2010). Concerning multiple countries, there are studies on ASEAN (Behera and Dash, 2017; Saboori and Sulaiman, 2013; Nasir et al, 2019); on emerging countries in OECD (Mamun et al., 2014; Saboori et al., 2014; Belke et al., 2011; Al-mulali et al., 2012); in Africa (Adom et al., 2012); on the GCC economies (Salahuddin and Gow, 2014; Salahuddin et al., 2015), on a larger sample of lower, middle and high-income and OECD and non-OECD countries (Mamun et al., 2014); on the BRICS (Apergis and Payne, 2011)

and on European Countries (Pham et al, 2020). Despite the great volume of work which has been conducted exploring the nexus between energy consumption, growth of economy (GDP, income) and CO₂ emissions, there seems to be no unanimous consensus while provides the rationale to the subject study on Australia.

There is a strong emphasis in the literature that solely focusing on the growth of the economy as a determinant of emissions is not a cogent strategy to comprehend the causes of environmental degradation. For instance, Lantz and Feng (2006) argued that the EKC can be influenced by technological as well as population. In this regard, York et al (2003) argued that the STIRPAT framework is more suitable to investigate the effects of determinants of CO₂ emissions. However, the studies that used STIRPAT to investigate the effect of the population reported the impact of different magnitude (Wei, 2011). Similarly, while employing the STIRPAT framework, Poumanyvong and Kaneko (2010) reported that the effect of urbanisation on emissions varies among, low, middle- and high-income countries. Shi (2003) reported that the impact of population on emissions is more pronounced in developing than developed economies. However, Martínez-Zarzoso and Maruotti (2011) reported that the results varied even among a single income group of developing countries. These contrasting results provide the rationale to our strategy of using both EKC and STIRPAT framework and taking an inclusive approach to the determinants of environmental degradation while specifically focusing on Australia.

2.2 Financial development, Trade and environment nexus

Financial development is a board phenomenon which entails increase in foreign direct investment (FDI), capital account liberalisation and trade openness, enhanced banking services, expansion of the stock market. It is also a channel of economic development that can also have ecological consequences (Frankel and Romer, 1999). Stated differently, international financial activities enhance technological progress and proficiency and through connection with domestic firms, enhances economic activities (Alfaro et al., 2009). Therefore, financial development is crucial for innovation (Tadesse, 2005; King and Levine, 1993) and such advanced technologies might contribute to emission reduction (Kumbarog˘lu et al., 2008).

Nexus between various aspects of financial development and environment has gain attention in recent years. Some studies report an inverse relationship between FDI and energy intensity (Mielnik and Goldemberg, 2002). A financial sector that functions effectively can be associated with a decrease in CO₂ (Tamazian et al., 2009) since financial development enhances opportunities for the environmental project at a lower financing cost. There is also empirical evidence on the banking sector, focusing on bank deposits to GDP and financial system deposits to GDP, that suggest a positive impact on energy consumption in the economies of Central and Eastern Europe (Sadorsky, 2011). There is also empirical research which explored how capital inflows might impact the environment. In one of the pioneering study, Tamazian et al., (2009) asserted that financial development enhances the environment by reducing emissions in BRICS countries. Supporting this view, Jalil and Feridun (2011) explored the effect of financial development, economic growth, and energy usage on environmental degradation in China and conclude that financial development decreases air pollution which supports EKC hypothesis. Later, Shahbaz et al. (2013) reported a reduction in South African emission due to financial development, while Dogan and Seker (2016) found that financial development lowers CO₂ emission in countries that are ranked at the top in the renewable energy attractiveness index. However, there are other researchers which have argued that as a financial sector develops, it is likely to encourage customers to rely more on energy, which ultimately results in a greater level of greenhouse gas emissions (Zhang, 2011; Al-mulali et al., 2012); Shahbaz et al 2016a; Shahbaz et al., 2016b; Javid and Sharif, 2016; Salahuddin et al., 2018).

In addition to the positive or negative impact of financial development on the environment, some studies suggest a neutral effect. The neutral results show no significant correlation between financial development. For example, Ozturk and Acaravci (2013) used credit to the private sector as a measure of financial development and indicated the absence of any relationship with carbon dioxide emissions in Turkey. Furthermore, exploring data from multiple countries and different regions, Omri et al. (2015), Charfeddine and Ben (2016), and Bekhet et al. (2017) reported the neutral impact of financial development on environmental degradation in selected MENA, UAE, and GCC countries, respectively. Addition to this, using the bank index as a measure of financial development, Çoban and Topcu (2013) provide evidence of a neural association between

the development of the financial sector and CO₂ emissions in 27 EU economies. It is vital to consider the role of the financial sector in environmental degradation as climate change can also adversely affect financial stability (Dafermos et al., 2018).

Trade openness is also a vital factor which could influence the environment through technique and composition effects (Antweiler et al., 2001). The first group of scholars argue that trade openness enhances more opportunities for a country to access global markets, but it opens more competition which forces the country to increase the efficiency of utilizing scarce resources and importing technologies to mitigate carbon emissions (Helpman, 1998). Therefore, trade openness is fruitful for the environment due to the technique effect (Shahbaz et al., 2012; Grether et al., 2007; Ferrantino, 1997). The second group of scholars oppose this argument suggesting that the international trade leads to depletion of natural resources and deterioration of environment (Copeland and Taylor, 2001; Schmalensee et al., 1998). Hence, the overarching evidence on the relationship between trade openness and the environment is also contrasting. To reiterate, the findings on the effect of financial development and environment are also inconclusive. Most likely this could be due to the reason that the scholars have used various methodologies and different proxies to measure financial development and other pollutants. As Ang (2009) asserted, usage of different proxies could have implications for the empirical findings. Further, many studies on this subject have employed panel data as well as time-series data to examine how financial development affect CO₂ emissions at multi-country and single country levels. The panel datasets consist of five Asian (Chandran and Foon, 2013; Behera and Dash, 2017; Zhu et al., 2016; Baek, 2016;) Africa (Kiviyiro and Arminen, 2014; Bokpin, 2017); Middle East (Al-mulali et al., 2012) and BRICS (Pao and Tsai, 2011). Similarly, there are studies which have focused on a single-country and employed time-series data (Zhang, 2011; Lau et al., 2014; Seker et al., 2015; Sbia et al., 2014); or panel data (Ren et al., 2014; Peng et al., 2016; Zhang and Zhou, 2016). The literature shows various methodologies, although the subject paper follows Poumanyvong and Kaneko (2010), Shahbaz et al., (2015), Shahbaz et al., (2016), Sheng and Guo (2016), Lin et al (2017) and Pham et al (2020) as they used the STIRPAT model by Dietz and Rosa (1997) to explore the determinants of CO₂ emissions. The STIRPAT model was extended from IPAT model developed initially by (Ehrlich and Holdren, 1971), in which a stochastic version of the Impact = Population*Affluence*Technology (IPAT)

model to estimate the effects of population, affluence, and technology on national CO₂ emissions. Several empirical studies explore the issues regarding CO₂ emissions in many single and multiple countries. The lack of a comprehensive study on environmental degradation in Australia calls for more research to fill this gap and give us an understanding of factors driving the Australian environment degradation. Furthermore, most of the previous empirical research has used a single proxy of financial development while this paper measures financial development as different proxies (overall financial development, financial institution efficiency, financial market access, financial market development, financial market efficiency) with three dimensions (financial depth, financial efficiency and financial access). Nonetheless, we have also included a comprehensive set of explanatory factors that includes energy consumption, industrialisation and trade openness gain a deeper insight into the factors that leads to environmental degradation.

3. Methodology and data

This study investigates the factors driving Australian environmental degradation and in this endeavour, it is based on two most important theoretical frameworks in environmental economics, the EKC and the STIRPAT based on the seminal work by Dietz and Rosa (1997), as our baseline model. The EKC is developed from the Kuznets curve of Kuznets (1955), which states a non-linear association between economic development and inequality of income, to explain the dynamics between economic development and degradation of the environment. Specifically, the non-linear relationship follows the inverted-U shape. Empirically, investigation of the EKC is carried out by using income level and it's squared value and CO₂ emissions to depict degradation of the environment (e.g. see Pata (2018)).

The STIRPAT model is likely more detailed in investigating the causes of environmental degradation by defining three main factors, *i.e.* population, economic development (or affluence), and technology (or the efficiency in economic production and energy consumption). Both the EKC and STIRPAT model are widely employed (*e.g.*, Shahbaz et al., (2018), Phuc Nguyen et al., (2020), Pham et al (2020)). The STIRPAT is developed from the Influence, Population, Affluence, and Technology (IPAT) framework based on the seminal work by Ehrlich and Holdren (1971). The IPAT model relates the impacts of the population (P), affluence (A) and technology (T) on the environment (I) as follows:

$$I = PAT \quad [1]$$

Dietz and Rosa (1997) modified this version to a stochastic version to tackle reformulations of IPAT model in empirical investigations as follow:

$$I_t = \alpha_t P_t^{\pi_1} A_t^{\pi_2} T_t^{\pi_3} \varepsilon_{it} \quad [2]$$

where t denotes time t . α characterizes the country-specific effect, π is the elasticity of environmental impacts of right-hand factors (P, A, T). The model [2] is taken in logarithms for testing as follow:

$$\ln I_t = \alpha_t + \pi_1 \ln P_t + \pi_2 \ln A_t + \pi_3 \ln T_t + \varepsilon'_{it} \quad [3]$$

To adjust for the population size, the model [3] can be transformed into per capita forms for all variables by dividing both sides by total populations. That is, the empirical estimations for the case of Australia can be formed as follow:

$$CO2_t = \beta_0 + \beta_1 Income_t + \beta_2 Energy_t + v_{it} \quad [4]$$

In which: CO_2 is per capita emissions of CO_2 which represents for degradation of the environment by the notion that higher CO_2 emissions mean lower environmental quality; $Income$ is real GDP per capita, which represents for economic development (or affluence); $Energy$ is energy consumption per capita, which represents for energy consumption (or technology) with the notion that a higher energy consumption per capita means lower efficiency of energy usage or lower technological development. All these variables are taking in logarithms forms as in model [3]. To incorporate the framework of the EKC in empirical investigation, the square term of income level is added as done in many previous studies (Javid & Sharif, 2016; Katircioğlu & Taşpınar, 2017; Pata, 2018; Nasir et al 2019). The empirical estimations would be:

$$CO2_t = \beta_0 + \beta_1 Income_t + \beta'_1 Income^2_t + \beta_2 Energy_t + v'_{it} \quad [5]$$

Besides that, there are other important drivers of CO_2 emissions, namely trade openness (Hanif, 2018; Pham et al., 2020), industrialization (Jiang and Lin, 2012; Shahbaz and Lean, 2012), and financial development (Adams and Klobodu, 2018; Shahbaz et al., 2018). Therefore, these factors are added as augmented drivers of CO_2 emissions as follow:

$$CO2_t = \beta_0 + \beta_1 Income_t + \beta'_1 Income^2_t + \beta_2 Energy_t + \beta_3 Industry_t + \beta_4 Trade_t + \beta_5 FD_t + v''_{it} \quad [6]$$

in which: *Industry* is the industrial value-added per capita, which represents for industrialization; *Trade* is total trade value per capita, which represents for trade openness; and *FD* is financial development, which will be measured in different forms and will be explained later in this section. Both industrialization and trade openness are calculated in log forms as well.

In term of data, the study collects data from two main sources. First, the data of CO2 emissions, real GDP per capita, trade openness and industrialization are collected from the World Development Indicators of World Bank (WDIs). The Department of the Environment and Energy publishes regular Quarterly Updates on Australia's greenhouse gas emissions. Concerning economic variables, the real GDP per capita is a measurement of the total Australian economic output divided by its population and the figures are adjusted for inflation. The Australian economy is dominated by its service sector, comprising 62.7% of the GDP and employing 78.8% of the labour force in 2014. One of the highest value of services in Australia comes from the mining sector which accounted for 8.4% at around 2009-2010. Although trade in Australia is less than in other countries, or in other words, Australia's trade openness ratio is below the average for developed countries. The main reason is that Australia may produce many goods internally and does not need to trade for them externally. However, Australia's geographic location creates strong trade links with China and India, two of which are currently fast developing countries in the BRICS. Overall, these economic variables are collected in total values and then divided by the total population (which is also collected from WDIs as well) to obtain the per capita values. We have also transformed the data by taking natural logarithms.

In term of financial development, the study takes the liberty to make another contribution by examining different dimensions of financial development on emissions of CO2 in Australia. Therefore, we collected new proxies for financial development from financial development database of IMF. As argued by Svirydzenka (2016), the traditional proxies of FD such as domestic credit or stock market capitalization cannot capture all dimensions and sectors in the financial system. Furthermore, there are two main pillars of financial systems, financial

institutions (*i.e.* venture capital firms, funds, insurance companies, banks and other non-bank financial institutions) and financial markets (*i.e.* bond markets, stock markets, money markets (wholesale) and by-passing traditional bank lending); they play a different role in economy which may have different impacts on CO₂ emissions. Svirydzienka (2016) has constructed a new database of FD including nine indicators with three dimensions (financial access, financial depth, and financial efficiency) of each sub-sector (financial markets and financial institutions) and overall FD, which is freely provided by IMF. This database provides a very comprehensive database of financial development for empirical studies (Canh and Thanh 2020, Canh and Thong 2020). Therefore, we used this database for financial development. In Australia, financial services are the largest sector contributing to GDP, averaged around \$140 billion in 2016 (Treasury, 2020), it has been the main driver of economic growth. Consequently, Australia was rated as the best performing financial markets regarding its strength in financial stability and financial intermediation. The burgeoning development in the financial sector in Australia is worth to study if this development can push up or hinder the level of CO₂ emissions.

Since the database from Svirydzienka (2016) is calculated in the form of indices, we do not transform them in the form of per capita. However, it does not influence the meaning of per capita since the index represents the development of financial systems. All financial proxies are transformed by taking natural logarithms. Furthermore, we collected five traditional proxies of FD for robustness check. They are the domestic credit by financial sector per capita (FD1), the domestic credit to private sector per capita (FD2), the domestic credit to the private sector by banks (FD3), capitalisation of domestic listed firms per capita (FD4), and the stocks traded value per capita (FD5). In fact, FD1, FD2, FD3 are likely proxies of credit supply from financial institutions, while FD4 and FD5 represent the development of financial markets (*i.e.* stock market).

Table 1. Variables Details and Descriptive Analysis

Variables	Definitions	Calculations	Sources	Availability	Obs	Mean	S.D.	Min	Max
CO2	CO2 emissions	Log of CO2 emissions (metric tons per capita)	WDIs	1960-2014	35	2.792	0.063	2.684	2.901
Energy	Energy intensity	Log of Energy use (kg of oil equivalent per capita)	WDIs	1960-2015	35	8.565	0.083	8.424	8.694
Income	Economic development	Log of GDP per capita	WDIs	1960-2018	35	10.612	0.203	10.304	10.909
Industry	Industrialization	Log of Industry (including construction) value added per capita	WDIs	1975-2018	35	9.295	0.151	9.046	9.541
Trade	Trade openness	Log of Total trade value per capita	WDIs	1960-2018	35	13.653	0.683	12.706	14.894
OFD	Overall financial development	Log of overall financial development index	FD-IMF	1980-2017	35	-0.441	0.345	-1.094	-0.049
FI	Financial institutions' development	Log of financial institutions index	FD-IMF	1980-2017	35	-0.263	0.207	-0.639	-0.045
FID	Financial institutions depth	Log of Financial institutions depth index	FD-IMF	1980-2017	35	-0.336	0.347	-1.072	-0.029
FIA	Financial institutions access	Log of Financial institutions access index	FD-IMF	1980-2017	35	-0.367	0.223	-0.761	-0.149
FIE	Financial institutions efficiency	Log of Financial institutions efficiency index	FD-IMF	1980-2017	35	-0.320	0.106	-0.585	-0.155
FM	Financial markets' development	Log of financial markets index	FD-IMF	1980-2017	35	-0.729	0.598	-2.004	-0.075
FMD	Financial markets depth	Log of Financial markets depth index	FD-IMF	1980-2017	35	-0.732	0.667	-2.079	-0.024
FMA	Financial markets access	Log of Financial markets access index	FD-IMF	1980-2017	35	-0.694	0.561	-1.900	-0.128
FME	Financial markets efficiency	Log of Financial markets efficiency index	FD-IMF	1980-2017	35	-0.811	0.618	-2.435	0.000

Notes: WDIs is World Bank's data base Development Indicators (Dec/2019 version, see <http://datatopics.worldbank.org/world-development-indicators/>); FD-IMF is the IMF's financial development database (version 2019, see <https://data.imf.org/?sk=F8032E80-B36C-43B1-AC26-493C5B1CD33B>).

Table 2. Unconditional correlations

Correlation	CO2	Energy	Income	Industry	Trade	OFD	FI	FID	FIA	FIE	FM	FMD	FMA	FME
CO2	1.00													
Energy	0.92***	1.00												
<i>p-value</i>	0.00													
Income	0.81***	0.92***	1.00											
<i>p-value</i>	0.00	0.00												
Industry	0.79***	0.90***	0.99***	1.00										
<i>p-value</i>	0.00	0.00	0.00											
Trade	0.72***	0.86***	0.97***	0.97***	1.00									
<i>p-value</i>	0.00	0.00	0.00	0.00										
OFD	0.84***	0.92***	0.96***	0.93***	0.87***	1.00								
<i>p-value</i>	0.00	0.00	0.00	0.00	0.00									
FI	0.83***	0.94***	0.96***	0.94***	0.89***	0.99***	1.00							

FID	<i>p-value</i>	0.00	0.00	0.00	0.00	0.00	0.00												
		0.75***	0.89***	0.88***	0.85***	0.81***	0.94***	0.97***	1.00										
FIA	<i>p-value</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00											
		0.85***	0.95***	0.95***	0.92***	0.86***	0.99***	1.00***	0.95***	1.00									
FIE	<i>p-value</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										
		0.57***	0.57***	0.72***	0.73***	0.74***	0.60***	0.57***	0.35**	0.57***	1.00								
FM	<i>p-value</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00									
		0.82***	0.88***	0.93***	0.90***	0.84***	0.99***	0.97***	0.93***	0.97***	0.58***	1.00							
FMD	<i>p-value</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00								
		0.82***	0.89***	0.93***	0.90***	0.83***	0.98***	0.96***	0.91***	0.97***	0.60***	0.98***	1.00						
FMA	<i>p-value</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00							
		0.76***	0.81***	0.89***	0.85***	0.78***	0.96***	0.93***	0.89***	0.94***	0.57***	0.98***	0.96***	1.00					
FME	<i>p-value</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00						
		0.83***	0.89***	0.90***	0.87***	0.83***	0.96***	0.94***	0.93***	0.94***	0.49***	0.96***	0.91***	0.91***	1.00				
	<i>p-value</i>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00				

Notes: **, *** are significant levels at 5% and 1%, respectively; All variables are in logarithms forms.

1a) CO2 emissions per capita

1b) GDP per capita

1c) Energy use per capita

1d) Industry value added per capita

1e) Trade value per capita

1g) Financial development indices

Figure 1. CO2 emissions and Economic factors in Australia over the period 1980-2014

Table 1 entails details on the definition of variables, calculations, sources of data, time availability, and data description. In our dataset, the data of CO2 emissions is available to

2014, while the data of financial development from IMF is available from 1980 thus the period of 1980–2014 is chosen for empirical analysis as best period. *Table 2* presents the unconditional correlation matrix for all variables. It is important to notice high positive correlations among variables. *Table 2* shows that there may be the issue of multicollinearity between variables as high correlations. That suggests us to do further tests, especially cointegration tests for our model. It can be observed in *Figure 1* that most variables have the same increasing trends over the period 1980–2014. This hints an important notice for empirical analysis about the cointegration among variables.

Table 3. Stationary tests

Variables		Stationary tests for level				Stationary tests for 1 st difference			
		Dickey-Fuller test - Test statistic – Z(t)	DF-GLS test - DF-GLS tau Test Statistic at lag 1	Phillips-Perron test Test statistic – Z(rho)	KPSS test Test- statistic for lag 0	Dickey-Fuller test - Test statistic – Z(t)	DF-GLS test - DF-GLS tau Test Statistic at lag 1	Phillips-Perron test Test statistic – Z(rho)	KPSS test-Test statistic for lag 0
CO2	No trend	-1.585	-1.255	-4.994	2.35***	-5.537***	-2.871	-35.69***	.273
	With trend	-0.677		-5.279	0.235***	-5.714***		-36.56***	.122
Energy	No trend	-1.293	-0.934	-2.302	3.08***	-6.100***	-3.640**	-39.45***	.231
	With trend	-0.819		-4.889	0.392***	-6.295***		-39.30***	.126
Income	No trend	-0.379	-1.862	-0.183	3.52***	-4.838***	-3.349	-25.61***	.116
	With trend	-1.857		-8.945	0.267***	-4.763***		-25.48***	.113
Industry	No trend	-0.115	-3.257	0.097	3.43***	-5.124***	-4.629***	-23.28***	.058
	With trend	-3.321		-13.93	0.144	-5.086***		-23.55***	.038
Trade	No trend	0.173	-2.029	0.130	3.34***	-4.286***	-3.562**	-22.84***	.113
	With trend	-2.026		-8.138	0.396***	-4.289**		-23.05**	.059
OFD	No trend	-1.871	-0.861	-1.927	3.25***	-4.549***	-3.702**	-27.06***	.351
	With trend	-0.791		-3.681	0.487***	-4.912***		-27.49***	.075
FI	No trend	-1.666	-0.901	-1.451	3.28***	-5.222***	-3.783***	-29.08***	.305
	With trend	-0.860		-2.329	0.664***	-5.641***		-27.86***	.062
FID	No trend	-2.895	-0.518	-2.300	2.88***	-4.347***	-3.508**	-27.24***	.855***
	With trend	-0.811		-1.451	0.816***	-5.608***		-29.04***	.074
FIA	No trend	-1.757	-0.968	-1.728	3.23***	-4.281***	-3.861***	-22.97***	.403
	With trend	-0.418		-1.689	0.603***	-4.712***		-23.04**	.102
FIE	No trend	-0.493	-1.282	-1.241	2.15***	-5.355***	-3.792***	-30.16***	.252
	With trend	-1.871		-5.163	0.648***	-5.514***		-30.47***	.066
FM	No trend	-2.072	-0.918	-2.800	3.07***	-4.583***	-3.912***	-27.50***	.306
	With trend	-1.355		-6.175	0.393***	-4.845***		-28.23***	.057
FMD	No trend	-1.238	-1.163	-2.211	3.08***	-5.106***	-3.682**	-27.68***	.093
	With trend	-1.928		-10.80	0.312***	-5.121***		-26.99***	.057
FMA	No trend	-2.079	-1.639	-3.824	2.77***	-3.556**	-3.709**	-19.61***	.231
	With trend	-1.857		-8.840	0.280***	-3.682**		-20.49**	.071
FME	No trend	-2.949	-0.719	-4.844	2.92***	-9.036***	-4.419***	-44.88***	.317
	With trend	-2.848		-11.49	0.430***	-10.02***		-44.67***	.029

Notes: The critical values of Dickey-Fuller test no trend are -3.689 and -2.975 (and -3.696 & -2.978 for tests with 1st difference of variables) for significant levels of 1% and 5%, respectively; The critical values of Dickey-Fuller test with trend are -4.297 and -3.564 (and -4.306 & -3.568 for tests with 1st difference of variables) for significant levels of 1% and 5%, respectively; The critical values of DF-GLS test no trend are -3.770 and -3.386 (and -3.770 & -3.400 for tests with 1st difference of variables) for significant levels of 1% and 5%, respectively; The critical values of Phillips-Perron test no trend are -17.812 and -12.788 (and -17.744 & -12.756 for tests with 1st difference of variables) with significant levels of 1% and 5%, respectively; The critical values of Phillips-Perron test with trend are -23.652 and -18.584 (and -23.524 & -18.508 for tests with 1st difference of variables) with significant levels of 1% and 5%, respectively; In KPSS test: the null hypothesis is stationarity; The critical values of KPSS test with no trend are 0.463 and 0.739 (and 0.463 & 0.739 for tests with 1st difference of variables) with significant levels of 1% and 5%, respectively; The critical values of KPSS test with trend are 0.146 and 0.216 (and 0.146 & 0.216 for tests with 1st difference of variables) with significant levels of 1% and 5%, respectively; **, *** are significant levels at 5% and 1%, respectively; All variables are tested in logarithms forms.

In term of econometric techniques, the study follows the standard robust procedures for time series by checking stationarity of each variable first. Four different stationary tests are employed including Dickey-Fuller (DF) test (Dickey and Fuller, 1979), the DF-GLS test (Elliot, et al., 1996), Phillips-Perron test (PP) test (Phillips and Perron, 1988), Kwiatkowski-Phillips-Schmidt-Shin test or KPSS test (Kwiatkowski et al., 1992). The tests are done for both level and 1st difference of each variable. The results in Table 3 show insignificant statistics of DF, DF-GLS, and PP tests and statistical significance of the KPSS test, which imply the non-stationarity of all variables at levels. The tests for 1st differences of variables show opposite results with statistical significance of DF, DF-GLS, and PP, and the insignificance of the KPSS test, which means the variables are stationary at 1st differences.

In this case, all variables are found to be stationary at the first difference $I(1)$, the study employs the Granger causality (Granger, 1969) for the 1st differences of all variables to examine the causalities among variables. Moreover, the Johansen cointegration test (Johansen, 1991) is employed to examine the cointegration among variables in levels. Next section will present the results and the estimate.

4. Empirical results

4.1 Granger causalities

Results of Granger causality tests are presented in *Tables 4* and *5*. It shows that the income, industry and energy have a statistically significant causal association with CO₂ emissions in most cases. Meanwhile, trade openness is found with no statistical significance. Interestingly, no indicator of FD has causality on CO₂ emissions. The test for traditional proxies of FD shows that only FD4 (stock market capitalization) has statistically significant causality. That is, economic development, consumption of energy and industrialization are likely the core causes of CO₂ emissions in Australia over the period of study. In return, CO₂ emissions are documented with statistically significant causality on income, energy, industry as well. In term of financial development, CO₂ emissions have no causality on all nine indicators from financial development database of IMF. The tests for traditional proxies of FD shows that CO₂ emissions has causality on FD4 only. That is, there is two ways causal association between economic development, consumption of energy, industrialization, stock market capitalization and CO₂ emissions.

Table 4. Causality tests

Model with		OFD		FI		FID		FIA		FIE	
Equation	Excluded	chi2	Prob>chi2	chi2	Prob>chi2	chi2	Prob>chi2	chi2	Prob>chi2	chi2	Prob>chi2
ΔCO_2	$\Delta Income$	4.16**	0.04	4.69**	0.03	5.01**	0.03	4.29**	0.04	6.42***	0.01
ΔCO_2	$\Delta Energy$	3.76**	0.05	3.55	0.06	3.93**	0.05	3.57	0.06	2.95***	0.09
ΔCO_2	$\Delta Industry$	6.14***	0.01	6.64***	0.01	7.23***	0.01	6.40***	0.01	8.03***	0.01
ΔCO_2	$\Delta Trade$	1.03	0.31	1.20	0.27	1.68	0.20	1.26	0.26	1.48	0.23
ΔCO_2	ΔFD	0.00	0.98	0.00	0.99	0.56	0.45	0.01	0.92	1.65	0.20
ΔCO_2	ALL	10.30	0.07	10.30	0.07	11.04**	0.05	10.32	0.07	12.46**	0.03
$\Delta Income$	ΔCO_2	7.19***	0.01	10.56***	0.00	9.20***	0.00	11.57***	0.00	10.11***	0.00
$\Delta Income$	$\Delta Energy$	3.99**	0.05	5.77**	0.02	3.88**	0.05	6.69***	0.01	4.52**	0.03
$\Delta Income$	$\Delta Industry$	0.27	0.60	1.23	0.27	1.75	0.19	0.68	0.41	0.76	0.38
$\Delta Income$	$\Delta Trade$	0.24	0.63	0.04	0.85	0.07	0.80	0.03	0.87	0.46	0.50
$\Delta Income$	ΔFD	5.63**	0.02	4.08**	0.04	1.53	0.22	5.21**	0.02	1.63	0.20
$\Delta Income$	ALL	20.20***	0.00	18.06***	0.00	14.55***	0.01	19.62***	0.00	14.69***	0.01
$\Delta Energy$	ΔCO_2	4.01**	0.05	4.13**	0.04	3.89**	0.05	4.18**	0.04	3.94**	0.05
$\Delta Energy$	$\Delta Income$	0.00	0.95	0.04	0.83	0.00	1.00	0.05	0.82	0.08	0.78
$\Delta Energy$	$\Delta Industry$	0.01	0.93	0.03	0.85	0.02	0.88	0.06	0.80	0.00	0.96
$\Delta Energy$	$\Delta Trade$	0.19	0.67	0.61	0.43	1.19	0.28	0.52	0.47	0.44	0.51
$\Delta Energy$	ΔFD	0.05	0.82	0.81	0.37	3.26	0.07	0.42	0.52	1.24	0.27
$\Delta Energy$	ALL	5.06	0.41	5.94	0.31	8.75	0.12	5.48	0.36	6.43	0.27
$\Delta Industry$	ΔCO_2	6.89***	0.01	8.63***	0.00	8.19***	0.00	8.70**	0.00	8.66***	0.00
$\Delta Industry$	$\Delta Income$	1.99	0.16	2.94	0.09	3.80**	0.05	2.64	0.10	2.78	0.10
$\Delta Industry$	$\Delta Energy$	5.42**	0.02	6.19***	0.01	5.52**	0.02	5.93**	0.02	5.83**	0.02
$\Delta Industry$	$\Delta Trade$	0.08	0.78	0.00	0.98	0.00	0.98	0.01	0.94	0.07	0.79
$\Delta Industry$	ΔFD	1.15	0.28	0.88	0.35	0.50	0.48	0.53	0.47	0.51	0.47
$\Delta Industry$	ALL	15.68***	0.01	15.29	0.01	14.76***	0.01	14.80***	0.01	14.77***	0.01
$\Delta Trade$	ΔCO_2	0.45	0.50	1.00	0.32	0.93	0.33	0.92	0.34	1.05	0.31
$\Delta Trade$	$\Delta Income$	0.16	0.69	0.02	0.88	0.03	0.86	0.22	0.64	0.00	0.98
$\Delta Trade$	$\Delta Energy$	0.60	0.44	0.60	0.44	0.63	0.43	0.22	0.64	0.73	0.39
$\Delta Trade$	$\Delta Industry$	0.06	0.81	0.03	0.87	0.06	0.80	0.10	0.75	0.00	0.95
$\Delta Trade$	ΔFD	2.22	0.14	0.01	0.91	0.27	0.60	0.97	0.32	0.27	0.60
$\Delta Trade$	ALL	3.40	0.64	1.11	0.95	1.38	0.93	2.10	0.84	1.38	0.93
ΔFD	ΔCO_2	0.31	0.58	3.28	0.07	0.76	0.38	6.16***	0.01	1.99	0.16
ΔFD	$\Delta Income$	1.53	0.22	0.38	0.54	0.75	0.39	0.21	0.65	0.14	0.71
ΔFD	$\Delta Energy$	0.04	0.85	1.21	0.27	0.34	0.56	1.77	0.18	2.15	0.14
ΔFD	$\Delta Industry$	1.41	0.24	0.26	0.61	0.76	0.38	0.38	0.54	0.13	0.72
ΔFD	$\Delta Trade$	2.04	0.15	0.02	0.88	0.05	0.82	0.07	0.80	0.12	0.73
ΔFD	ALL	4.80	0.44	4.17	0.53	1.89	0.86	7.24	0.20	2.90	0.72

Table 5. Causality tests (cont.)

Model with		FM		FMD		FMA		FME	
Equation	Excluded	chi2	Prob>chi2	chi2	Prob>chi2	chi2	Prob>chi2	chi2	Prob>chi2
ΔCO_2	$\Delta Income$	3.94**	0.05	4.63**	0.03	6.00***	0.01	5.24**	0.02
ΔCO_2	$\Delta Energy$	3.38	0.07	3.23	0.07	4.86**	0.03	3.89**	0.05
ΔCO_2	$\Delta Industry$	5.71**	0.02	6.84***	0.01	7.78***	0.01	7.01***	0.01
ΔCO_2	$\Delta Trade$	1.23	0.27	3.22	0.07	0.20	0.66	1.38	0.24
ΔCO_2	ΔFD	0.05	0.82	2.42	0.12	1.00	0.32	0.34	0.56
ΔCO_2	ALL	10.37	0.07	13.48**	0.02	11.62**	0.04	10.75	0.06
$\Delta Income$	ΔCO_2	5.55**	0.02	7.69***	0.01	6.20***	0.01	7.36***	0.01
$\Delta Income$	$\Delta Energy$	2.06	0.15	2.99	0.08	1.57	0.21	3.50	0.06
$\Delta Income$	$\Delta Industry$	0.15	0.70	1.19	0.27	0.56	0.46	0.44	0.51
$\Delta Income$	$\Delta Trade$	0.33	0.56	0.13	0.72	0.02	0.89	0.54	0.46
$\Delta Income$	ΔFD	6.48***	0.01	3.15	0.08	1.57	0.21	2.23	0.14
$\Delta Income$	ALL	21.37***	0.00	16.79***	0.01	14.61***	0.01	15.52***	0.01
$\Delta Energy$	ΔCO_2	4.18**	0.04	3.38	0.07	6.22***	0.01	4.40**	0.04
$\Delta Energy$	$\Delta Income$	0.02	0.89	0.01	0.94	0.56	0.46	0.01	0.94
$\Delta Energy$	$\Delta Industry$	0.00	0.99	0.03	0.86	0.07	0.79	0.00	0.98
$\Delta Energy$	$\Delta Trade$	0.11	0.74	0.74	0.39	0.09	0.76	0.42	0.52
$\Delta Energy$	ΔFD	0.20	0.65	0.45	0.50	2.49	0.11	0.37	0.54
$\Delta Energy$	ALL	5.23	0.39	5.52	0.36	7.87	0.16	5.42	0.37
$\Delta Industry$	ΔCO_2	5.78**	0.02	7.79***	0.01	6.61***	0.01	6.44***	0.01
$\Delta Industry$	$\Delta Income$	1.93	0.17	3.63	0.06	2.21	0.14	2.92	0.09
$\Delta Industry$	$\Delta Energy$	4.06**	0.04	5.11	0.02	3.78**	0.05	5.38	0.02
$\Delta Industry$	$\Delta Trade$	0.14	0.71	0.01	0.93	0.00	0.98	0.13	0.71
$\Delta Industry$	ΔFD	1.63	0.20	0.05	0.82	0.18	0.67	2.71	0.10
$\Delta Industry$	ALL	16.37***	0.01	14.11**	0.02	14.29***	0.01	17.89***	0.00
$\Delta Trade$	ΔCO_2	0.19	0.67	0.60	0.44	0.67	0.41	0.35	0.55
$\Delta Trade$	$\Delta Income$	0.21	0.65	0.01	0.93	0.00	0.99	0.01	0.91
$\Delta Trade$	$\Delta Energy$	0.15	0.70	0.41	0.52	0.32	0.57	0.53	0.47
$\Delta Trade$	$\Delta Industry$	0.14	0.71	0.02	0.90	0.00	0.95	0.12	0.73
$\Delta Trade$	ΔFD	3.10	0.08	1.19	0.28	0.12	0.73	3.20	0.07
$\Delta Trade$	ALL	4.30	0.51	2.33	0.80	1.22	0.94	4.41	0.49
ΔFD	ΔCO_2	0.08	0.78	1.27	0.26	0.07	0.80	0.00	0.99
ΔFD	$\Delta Income$	1.41	0.24	2.52	0.11	0.71	0.40	1.29	0.26
ΔFD	$\Delta Energy$	0.90	0.34	0.48	0.49	1.33	0.25	2.52	0.11
ΔFD	$\Delta Industry$	1.90	0.17	0.75	0.39	1.42	0.23	2.95	0.09
ΔFD	$\Delta Trade$	3.27	0.07	0.79	0.37	0.02	0.90	2.27	0.13
ΔFD	ALL	8.13	0.15	5.51	0.36	15.92***	0.01	12.56**	0.03

Notes: **, *** denote significant levels at 5% and 1% respectively. All variables are tested in logarithms forms.

4.2 Long-run cointegration

Next, the finding of cointegration testing are summarized in *Table 6*

Table 6. Co-integration tests

Model $f(\text{CO}_2)=f(\text{income}, \text{income}^2, \text{energy}, \text{industry}, \text{trade}, \text{FD})$ with FD as	Rank	Trace statistic	5% critical value	Conclusion
OFD	0	144.2	124.2	Cointegration at rank 1
	1	92.54*	94.15	
	2	56.93	68.52	
FI	0	143.3	124.2	Cointegration at rank 2
	1	94.80	94.15	
	2	58.93*	68.52	
FID	0	n/a	124.2	n/a
	1	n/a	94.15	
	2	n/a	68.52	
FIA	0	147.5	124.2	Cointegration at rank 1
	1	94.06*	94.15	
	2	57.01	68.52	
FIE	0	130.6	124.2	Cointegration at rank 1
	1	87.44*	94.15	
	2	52.87	68.52	
FM	0	148.5	124.2	Cointegration at rank 1
	1	91.32*	94.15	
	2	57.69	68.52	
FMD	0	137.6	124.2	Cointegration at rank 1
	1	89.17*	94.15	
	2	56.14	68.52	
FMA	0	156.1	124.2	Cointegration at rank 2
	1	97.06	94.15	
	2	63.98*	68.52	
FME	0	151.9	124.2	Cointegration at rank 1
	1	101.4	94.15	
	2	67.90*	68.52	

Notes: * the indicator of the number of cointegrations. All variables are tested in logarithms forms.

Observations show strong evidence of the existence of cointegration among emissions of CO₂, income and its square, energy, industry, trade openness, and FD with different proxies except for the case of FID. More interesting, there is evidence of more than one cointegration in the case of FMA. The tests for traditional proxies of FD shows that there are more than one cointegration between CO₂ emission with FD1, FD2, FD3, FD4, FD5, respectively. That is, the long-run relationships between variables may follow different regimes in these cases. However, a relatively short-time period (1980–2014) prevents us from estimating the long-run relationships with different regimes. It is devoted to further studies.

In subject, considering the presence of long-run relationships between these variables and the status of stationarity of all variables at $I(1)$ in the previous section, the vector error correction model (VECM) following the Engle-Granger approach (Engle and Granger, 1987) is applied as a most suitable approach. This approach helps to deal with the cointegration among variables, while it simultaneously deals with multicollinearity issues, which has been documented in the previous section. In estimations for FMA, we include in the estimate with two cointegration. It is same for the estimates with FD1, FD2, FD3, FD4, while the case of FD5 is estimated with three cointegration. All remained cases are estimated with one cointegration. The main results of cointegration equations from VECM estimates are presented in *Table 7*, while the remained results from VEAM are reported in Supplementary materials.

Table 7. VECM estimates

Cointegration equations with	<i>OFD</i>	<i>FI</i>	<i>FID</i>	<i>FIA</i>	<i>FIE</i>	<i>FM</i>	<i>FMD</i>	<i>FMA</i>	<i>FME</i>
<i>_ce1</i>									
CO2	1.0000	1.0000	n/a	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Income	31.55*** [4.8982]	0.0000 (omitted)		46.910*** [8.7305]	3.2402 [6.2854]	29.014*** [3.8256]	22.738*** [4.4623]	0.0000 (omitted)	1858.9*** [684.65]
Income^2	-1.4723*** [0.2204]	0.1228** [0.0569]		-2.2083*** [0.3983]	-0.1987 [0.2986]	-1.3605*** [0.1734]	-1.088*** [0.2074]	0.1004** [0.0395]	-74.298** [31.726]
Energy	-1.3685*** [0.1504]	-1.619* [0.9176]		-1.0201*** [0.2729]	-1.266*** [0.1683]	-1.4849*** [0.1413]	-1.4487*** [0.189]	-1.353*** [0.44]	32.793 [24.377]
Industry	0.9718*** [0.2638]	-5.3714*** [1.3358]		2.3225*** [0.4063]	1.5001*** [0.241]	0.8913*** [0.2272]	1.4975*** [0.2921]	-3.318*** [0.7839]	-324.0*** [38.97]
Trade	-0.0193 [0.03]	0.3223** [0.1451]		-0.1201** [0.0482]	0.0468 [0.0284]	-0.0047 [0.0247]	-0.0111 [0.0362]	0.161* [0.0907]	0.7462 [4.0061]
FD	-0.4013*** [0.0898]	-0.0299 [0.4991]		-1.0869*** [0.2298]	-0.216** [0.1027]	-0.1495*** [0.0304]	-0.1235*** [0.0296]	-0.128* [0.0674]	-25.62*** [3.567]
<i>_cons</i>	-169.05	42.8207		-263.57	-18.71	-153.1	-123.07	25.4442	-8650.4
<i>_ce2</i>									
CO2		0.0000						0.0000	
Income		1.0000						1.0000	
Income^2		-0.0487*** [0.0009]						-0.0523*** [0.0016]	
Energy		0.0059 [0.0151]						-0.0138 [0.0181]	
Industry		0.1043*** [0.022]						0.195*** [0.0323]	
Trade		-0.0041*** [0.0024]						-0.0063*** [0.0037]	
FD		-0.0219*** [0.0082]						0.003 [0.0028]	
<i>_cons</i>		-6.0983						-6.3078	
Equation of:									
<i>_ce1</i>	332.1***	101.8***		158.4***	341.7***	377.0***	236.4***	151.3***	110.2***
<i>_ce2</i>		294315***						160458***	
<i>_ce3</i>									
Diagnostic test									
Lagrange-multiplier test of lag 1	58.54	56.83		53.34	69.80**	61.49	65.11	82.77***	52.38
Jarque-Bera test:	chi2	chi2		chi2	chi2	chi2	chi2	chi2	chi2
CO2	0.795	0.448		0.048	0.058	0.633	0.595	0.993	0.899
Income	0.571	1.540		2.343	3.561	0.421	7.922**	4.053	0.552
Income^2	0.371	1.298		2.246	0.336	1.265	0.11	3.32	0.99

Energy	0.931	0.424	0.696	4.23	2.464	1.712	5.44	0.864
Industry	0.741	0.203	0.301	0.991	0.851	0.492	0.248	0.495
Trade	1.212	1.327	0.872	1.204	1.486	0.622	1.049	1.646
FD	0.786	2.180	3.887	0.579	3.011	1.877	1.326	0.215
All	5.405	7.421	10.393	10.958	10.131	13.329	16.429	5.66
Eigenvalue stability condition (no of unit moduli)	6	5	6	6	6	6	5	6
AIC	-1165	-1219	-1196	-1175	-1114	-1074	-1134	-1060
BIC	-1143	-1187	-1174	-1153	-1093	-1053	-1102	-1038
Log likelihood	596.5	630.5	611.9	601.5	571.2	551.2	588.0	544.0
N	34	34	34	34	34	34	34	34

Notes: standard errors are in []; **, *** are significant levels at 5%, 1%, respectively; All variables are in logarithms forms.

The observations show that the income squared in most estimates has a statistically significant negative coefficient in the cointegration model. Since it is the cointegration model of CO₂ emissions with other variables (all are in the same side, while the correction error is in opposite side) so that we can transform the cointegration equation by moving CO₂ emission to the side of correction errors and the correction errors is moved in revert. This transformation would help to form the equation of CO₂ emissions. In this form of the equation, the square of income would have a significant positive impact on CO₂ emissions. This is opposite to the expectation of the EKC on an inverted-U shape relationship between economic development and CO₂ emissions. In term of energy consumption, the estimates show consistent statistically significant coefficients, which means consumption of energy has a significant positive impact on emissions of CO₂. The results show statistically significant positive coefficients in estimates with OFD, FIA, FIE, FM, and FMD, while it has statistically significant coefficients in estimates with FMA and FME. This means the long-run impacts of industrialization on CO₂ emissions are not robust and consistent. In term of trade, the estimates show significant negative coefficients of trade estimates with one cointegrations (OFD, FIE, FIA, FMD, FM, FME and FMA). This means trade liberalisation has a significant positive impact on emissions of CO₂. Meanwhile, the estimates with two or three cointegrations show some variations in coefficients of trade openness but mostly negative. At last, the estimates with one cointegration show consistent and negative coefficients of FD (OFD, FIA, FIE, FM, FMD, FMA, FME). This means the increases in financial development have positive impacts on emissions of CO₂. Overall, the estimates of VECM show the long-run positive effects of economic development, consumption of energy and financial development on emissions of CO₂. Meanwhile, the impacts of industrialization and trade openness are varied by numbers of cointegrations in estimates and the proxies of financial development.

5. Conclusions and Policy Implications

In the context of environmental degradation in Australia, this study has explored the implications of economic and financial development, energy consumption, trade liberalisation and industrialization on emissions of CO₂. For inclusiveness, we employed the STIRPAT and EKC frameworks that help to explain the long-term association between the under-analysis variables. The notion of EKC is likely to not hold in Australia. The results in the short run indicate that there is a causal association between economic

growth, stock market capitalization, industrialization and consumption of energy with CO₂ emissions. In the policy context, it implies that to tackle the environmental change and honour the commitments of COP:21, Australia will have to account for the impact of growth, financialisation, industrial and consumption energy on environmental degradation. The strong causality implies that these variables have a non-trivial impact on the environment. The scales effect occurs as emissions and consumption of energy are enhanced with the growth of the economy, stock market, and industrialization. Therefore, an improvement in energy efficiency is indispensable. Nonetheless, a policy of focusing on the greener sectors of the economy and renewable energy consumption which Australia has been somewhat reluctant in the past are now the important elements of economic and energy policy. Particularly, if Australia wants to honour her COP21 commitments and stop the climate changes which has caused huge damaged to its environment and wildlife.

One of the most significant aspects of this study is to take a very inclusive approach to financialization and considering different dimensions of financial development (such as financial depth, financial efficiency and financial access) on CO₂ emissions. This has been particularly helpful in gaining a deeper insight into the crucial factors driving environmental degradation. The results indicate a strong long-run association with various regimes between different financial development proxies (credit provided by the financial sector, credit to the private sector; credit to the private sector by banks; stocks traded value; stock market capitalization of listed firm; and financial market access index) and emissions of carbon. These findings obtained by taking a very comprehensive view of the financialisation process implies that the Australian financial sector has a crucial role to play in the environmental sustainability of Australia. Specifically, the financial activity shall account for the environmental aspect and financial resources shall be allocated to the environmentally sustainable sector. The long-run estimates of VECM are consistent with the short-run which provides further support to inferences. Contrary to the expectation of having an inverted U-shape relation between the growth of the economy and degradation of environment or EKC, economic growth showed a continuously positive impact on CO₂ emission. In the policy context, this implied the perpetual growth and myopic policies of focusing only on the economic growth will be devastating for the Australian environment.

In addition to the economic growth, trade openness, energy consumption, and financial development are main factors driving the increase in CO₂ emissions in Australia. Particularly, our comprehensive approach to analysing the impact of various aspects of financial development manifests the important of financialisation in Australian environmental degradation. In contrast, industrialization has no statistically significant impact on CO₂ emission in the long run. This shall not be interpreted as no environmental consequences in the short-run which can then have long-run implications. In sum, the overarching analyses provide deeper understandings of the main factors that degrade the quality of the environment and are triggering a sombre existential threat to both human and wildlife in Australia. While a robust economy, an advanced stock market, and trade openness of Australia have been leading to a higher demand for energy and ultimately a degradation in the environment. The economic prosperity has come at a very high ecological cost. Concomitantly, in the policy context and to honour its COP21 commitments, it is advisable that there should be strict and selective environmentally friendly economic and financial policies concerning green and renewable energy to achieve sustainable economic development.

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