Does the Kuznets curve apply for financial development and environmental degradation in the Asia-Pacific region?

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ABSTRACT

The Asia-Pacific region has faced conflicting objectives of achieving sustainable economic growth and simultaneously improving environmental quality. This paper, the first of its kind, applies the concept of the Kuznets curve to financial development in this region. The long-term effect of financial development on environmental degradation is examined using a sample of 26 countries in the 2007–2017 period. This paper uses the long-term estimation techniques – the panel autoregressive distributed lag, including the pooled mean group model; the mean group; and the dynamic fixed effect estimator. The second-generation Granger test is used to determine the causality between financial development and environmental degradation. The U-shaped nexus and a bi-directional relationship between financial development and environmental degradation are found.

1. Introduction

The Asia-Pacific region is projected to capture up to 80 per cent of international trade of oil by 2040. Most of the demand is associated with double India's imported values (International Energy Agency, 2019). The region is expected to account for half of global GDP in 2040 and 40 per cent consumption values (McKinsey Global Institute, 2019). Such an astounding growth and a high level of urbanization leave the region with significant pressure on housing, infrastructure, and constantly high demand for goods and services. Despite having a huge comparative advantage against other continents, such as an inexpensive labour force, the degradation of the infrastructure and non-specialized labour are problematic to remain competitive in the future. The low-cost labour force of the region is because of the low-paid workforce. As such, the marginal product of labour is much higher than the marginal product of capital. The manufacturing process uses labour-intensive assembly lines with old-fashion producing technologies. The usage of outdated technologies leads to environmental degradation, reduced workers’ productivities and increased social health expenditure.

The Asia-Pacific region experiences a high level of urbanization associated with the rapid expansion of industrial parks and infrastructure quality deterioration. Heavy industries and the power sector are projected to account for most of the CO2 emissions in 2050. The region is currently responsible for the primary sources of greenhouse gases (GHGs) emissions. Countries in the region are about to encounter the middle-income trap unless strategic and timely policies are initiated and implemented.

Despite these difficulties, the region is undergoing the initial phase of the economic transition by reducing total exports to China and India (McKinsey Global Institute, 2019). More final goods are consumed domestically. The Asia-Pacific region is gradually shifting from the dependence on imported intermediate materials and sophisticated goods. R&D is currently at the centre of value chains and industries across the region. Green and economical energy sources are vital for the region to reduce CO2 emissions. The development and efficiency of the financial sector play a significant role in the future of the region. Adopting advanced technologies from foreign direct investment (FDI) via financing channels are considered the necessary and primary steps to attain inclusive growth. We are particularly interested in modelling the level of financial development concerning CO2 emissions due to a significant increase of the FDI inflows into this region for the last decade (Dinh et al., 2019; To et al., 2019).

In recent years, many empirical studies have focused on the inter-linkage between financial development and environmental quality. However, most of them are related to their specific case. For example, Kwakwa (2020) examines the linkage between energy use, urbanization and financial development using annual time-series data for Tunisia. In the context of Indonesia, Shahbaz et al. (2013a) consider the impact of
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GDP, financial development and trade on CO₂ emissions. Islam et al. (2013) investigate the effects of financial development on energy consumption in Malaysia. In another study, Shahbaz et al. (2013b) examine the long-run relationship between financial development, economic growth, coal consumption and trade openness in South Africa. Tang and Tan (2012) analyze the causal effects of financial development, CPI and FDI using Malaysia data, whereas Komal and Abbas (2015) explore the nexus of the trinity of growth-financial development-energy using data of Pakistan. Zhao and Yang (2020) employ the panel FMOLS and DOLS for Chinese provincial data to explore the relationship between financial development, growth, energy use and CO₂ emissions. The conclusions on the inter-relationship between these two important aspects vary significantly. Karanfil (2009) considers that the mixed findings from previous studies are due to the endogeneity, mainly due to the omissions of variables.

The novelty of this study is briefly summarized as follows. First, previous studies employ one aspect of financial development, such as stock market capitalization to GDP or stock market total value traded to GDP. In this paper, we employ the Bayesian model averaging approach to determine the factors that potentially influence the establishment of the international financial centres in the Asia-Pacific region. Like the industrial parks and high-tech zones, financial services are likely clustered in the megacities, which are so-called international financial centres. We consider those cities as representative of the level of financial development. Our innovative approach uses the determinants, leading to the establishment of the international financial centres, to construct the financial development index. The principal components analysis is used. Second, we focus on the long-term relationship between financial development and environmental degradation using panel autoregressive distributed lag (P-ARDL) to ensure the findings’ robustness. Third, our study uses Johansen and Juselius (1990) method to determine a Granger causality between financial development, economic growth and environmental degradation. We use the second generation Granger causality test proposed by Dumitrescu and Hurlin (2012) because this new test is valid even under cross-sectional dependence.

Following the introduction, the remainder of this paper is structured as follows. Section 2 discusses and synthesizes relevant papers on the topic to identify a research gap. Section 3 presents a research methodology. Empirical findings are presented and discussed in section 4, followed by the conclusions and implications for policy in section 5 of the paper.

2. Literature review

In recent years, global warming and its effects on human beings have been an important topic in climate change discussions. It has been taken to the centre stage that the greenhouse gas (GHGs) originating from anthropogenic activities is the underlying cause of the global environmental changes. Taking up to 75 per cent and being considered seizing the most proportion of GHGs, CO₂ emissions are considered the real villain (World Development Indicators, 2010). In the empirical context, many studies often attribute GHGs emissions, especially CO₂ emissions, to the main cause of environmental degradation. Recent researches from Abdouli and Hammami (2016), Bhattacharyya et al. (2017), and Sinha (2016), and Vo et al. (2020) support the unilateral causality from energy consumption to pollution. Remarkably, in these studies, fossil energy and renewable energy have a relationship with CO₂ emissions in the long run.

Meanwhile, Adewuyi and Awodumi (2017) confirm the bi-directional relationship between these two variables. CO₂ emissions have generally been considered as the most appropriate proxy for air pollution. The inter-relationship between the trio of financial development, economic growth, and CO₂ emissions has recently been an interesting subject to many researchers due to its necessity and importance to understanding the global warming process. Although the relationship between financial development and CO₂ emissions has been comprehensively investigated, the conclusion on their linkage is inconclusive and varies strikingly among studies (Karanfil, 2009). As such, the research question to which our analysis is related comprises two different interpretations. In what follows, we briefly discuss the strands of research regarding two different lines of thoughts on financial development and environmental degradation. Each of these research strands is discussed in turn below.

The first group of discussions is about the inhibited effects of financial development on CO₂ emissions. Studies in this strand argue that financial development acts as a major channel for attracting green FDI technologies. These advanced technologies result in energy usage efficiency (see, for example, Kahouli 2017; Farhani and Solarin 2017). Mielnik and Geldermanberg (2002) support the above hypothesis that FDI leads to a greater extent of new R&D engagements and hence decelerates the global warming process. On a different viewpoint, Wang and Jin (2007) argue that the decontamination effects of FDI seriously depend on the extent to which domestic firms are willing to satisfy pollution controls. These studies emphasize that environmental quality likely undergoes further enhancement. Moreover, they also highlight the importance of financial market efficiency in reining environmental pollution. Using various panel analytical methods, Tamazian et al. (2009) examine the nexus between economic growth, financial development, and environmental degradation in Brazil, Russia, India, and China (BRIC) in the 1992–2004 period. The results support the role of economic growth and financial development in reducing air pollution. Zhao and Yang (2020) find evidence to support the positive relationship between financial development and CO₂ emissions using China’s provincial data. They also argue that financial development acts as a catalyst in originating green innovations by inducing environmental-friendly technologies and enhancing firms’ financial accessibility. Shahbaz et al. (2013a, 2013b) find the polluting reduction effects of domestic credit to the private sector in the short-run and long-run in South Africa, Malaysia and Indonesia. Using the panel threshold regression, Chang (2015) presents evidence to confirm the technical effects of financial development using a sample of 53 countries in the 1999–2008 period. In the gulf cooperation council (GCC) context, Bekhet et al. (2017) provide evidence to confirm the inter-relationship between financial development, CO₂ emissions, and economic growth. Using the ARDL and the impulse response-VAR, the results confirm the positive impact of financial development on CO₂ emissions in Oman, Qatar, and Kuwait. In another attempt to examine the relationship between financial development, tourism, and CO₂ emissions, Başarır and Çakır (2015) advocate the role of financial development in stimulating tourism and decelerating CO₂ emissions.

The second group of discussions, which explains the inconclusive nexus between financial development and environmental degradation, focuses on the non-linear relationship and the lack of significant control variables. Karanfil (2009) considers that the omission of crucial variables is the primary reason for mixed results from previous studies. Abbasi and Riaz (2016) argue that financial development reduces pollution effects in the latter period at a higher level of trade liberalization and financial market integration. Utilizing the Pakistan dataset, the results favour financial development as the indispensable part of the EKC relationship between environmental quality and economic growth. Haider et al. (2018) mention two problems that are often inappropriately addressed in previous studies that could yield ambiguous results. The first problem is the omission of important variables. Crucial factors might not be taken into account. The second problem is the unobserved shock, slope heterogeneity, and cross-sectional dependency in the panel data. Failure to capture or improperly to deal with those problems might result in biased estimates. Mahalik et al. (2017) mention another problem, the lack of a significant link between financial development and environmental degradation in Saudi Arabia. Using the ARDL bound testing combined with Bayer-Hanck’s co-integration test, the results support the quadratic relationship between financial development and environmental pollution. Adam et al. (2018) argue that the directional impact of financial development can be negative or positive to the environmental quality concerning the magnitude of the scale effects and its technical effects. In a different context, Baloch and Meng (2019) present evidence supporting a
3. Method

Panel data for large N and short T is often associated with empirical issues, including (i) the cross-sectional dependence (CSD) induced by an unobservable correlation; and (ii) an invalid assumption of slope homogeneity.

### 3.1. Cross-sectional dependence test

In this study, the test developed by Pesaran (2004) is utilized. The test is highly recommended for both balanced and unbalanced panel and the standard normal distribution of a sum of pairwise correlation between panel units. The CD statistics are computed as follows:

\[
CD = \sqrt{\frac{2}{N(N-1)}} \sum_{j=1}^{N-1} \sum_{j'=j+1}^{N} T_{ij} \beta_{i}^{2} \rightarrow N(0,1)
\]

where \( \beta_{i}^{2} \) indicates the correlation between coefficients of residuals. N and T stand for the cross-section dimension and time-series dimension, respectively. The CD statistics are assumed normally distributed as T and N go to infinity.

### 3.2. Slope homogeneity test

Breitung and Das (2005) indicates that the assumption of homogeneity (\( b_1 = b_2 = b_3 = \cdots = b_n \)) does not consider the unit's unobserved characteristics. This paper follows the slope homogeneity test procedure, which is developed in Pesaran and Yamagata (2008) study:

\[
S = \sum_{i=1}^{N} \left( \beta_{i} - \beta_{WFE} \right) \frac{\hat{\gamma}_i}{\hat{s}_i} \left( \beta_{i} - \beta_{WFE} \right)
\]

\[
\Delta = \sqrt{N} \left( N^{-1} S - k \right) \sqrt{2k}
\]

where S and \( \Delta \) are test statistics, \( \beta_{i} \) is the estimate obtained from pooled ordinary least squares, \( \beta_{WFE} \) is the estimate obtained from the weighted fixed effect pooled estimator, \( \hat{\gamma}_i \) is the matrix of independent variables in deviations from the mean, \( M_{T} \) is the identity matrix, \( \hat{s}_i^{2} \) is the estimate of \( \sigma_{i}^{2} \), k is the number of regressors. The bias-adjusted form \( \Delta \) is as follows:

\[
\Delta_{adj} = \sqrt{N} \left( N^{-1} S - k \right) \sqrt{2k+1}
\]

### 3.3. Panel unit root test

In this paper, the second generation unit root test is used. We use the cross-sectional augmented Dickey-Fuller (CADF), which is well articulated in Pesaran (2003).

\[
CIPS = N^{-1} \sum_{i=1}^{N} \text{CADF}_i
\]

where N denotes the number of panels. CIPS denotes the cross-sectional Im, Pesaran and Shin test. The \( \text{CADF}_i \) is abbreviated of the t statistic of the following equation:

\[
\Delta y_{it} = \alpha_i + \beta_i y_{i,t-1} + \theta_i \Delta y_{i,t-1} + \sum_{j=0}^{\gamma} \delta_{ij} \Delta y_{i,j-1} + \sum_{j=0}^{\gamma} \gamma_j \Delta y_{i,j-1} + \epsilon_i
\]

where \( \Delta y_{i,j-1} \) and \( y_{i,j-1} \) stand for the lag of the first difference cross-sectional average of the dependent variable and its lag values, respectively.
3.4. Panel co-integration test

Estimating two or more non-stationary covariate variables can induce spurious regression. One common solution is to take the first difference in order to make the variables stationary. Nevertheless, doing so could potentially harm the long-run relationship between interested variables. Two highly regarded co-integration tests are developed by Pedroni (1999) and Westerlund (2005). These two tests take into account the effect of the heterogeneous slope across countries. The Westerlund test is expressed as follows:

$$ \Delta y_{it} = c_i + \alpha_i(y_{i,t-1} - \beta_i x_{it-1}) + \sum_{j=1}^{p} \alpha_{ij} \Delta y_{i,t-j} + \sum_{m=1}^{q} \beta_{jm} \Delta x_{i,m-1} + \varepsilon_{it} $$

where $\alpha_i$ is the coefficient of the correction term. Westerlund (2005) indicates that the null hypothesis is $\alpha_i = 0$ for all panels, whereas the alternative hypothesis is $\alpha_i < 1$ for at least one panel. The rejection of the null hypothesis indicates a long-run equilibrium relationship.

3.5. Granger causality tests using Dumitrescu and Hurlin Granger causality test

The test shows a robust direction of causality, even with the presence of multi-collinearity because the variable $FD_i$ only receives value within $[0, 1]$ interval. We note this problem is analogous to the spurious regression. One common solution is to take the first difference in order to make the variables stationary. However, the inclusion of $FD_i$ makes our model suffers from the multi-collinearity problem also exists.

$$ y_{it} = \alpha_i + \sum_{m=1}^{M} \delta_{0m} y_{i,m-1} + \sum_{m=1}^{M} \delta_{1m} x_{i,m-1} + \varepsilon_{it} $$

where $\delta_{0m}$ and $\delta_{1m}$ respectively denote the coefficients of the lagged value of the dependent variable and its explanatory variables. Dumitrescu and Hurlin statistic test include the Wald test with the null hypothesis that there is no evidence of Granger causality between included variables:

$$ H_0: \forall m: \delta_{0m} = 0 $$

$$ H_a: \exists m: \delta_{0m} \neq 0 $$

3.6. The long-run relationship between financial development and CO2 emissions

We employ the panel ARDL with $(p_1, p_2, \ldots, p_k; q_1, q_2, \ldots, q_k)$ to examine the financial development-CO2 emissions nexus:

$$ y_{it} = \sum_{j=1}^{p} \beta_{0j} x_{i,j-1} + \sum_{k=1}^{q} \beta_{kj} x_{i,k-1} + \varepsilon_{it} $$

\[\varepsilon_{it} = \gamma_i f_t + u_{it}\]

where $p, q$ are respectively the optimal lag defined by BIC or AIC criterion, subscript $i = 1, 2, \ldots, N$ denotes the cross-sectional dimension of the dataset. $t$ and $l$ are the serial dimensions and the corresponding lag order. $x_{it}$ is the vector of explanatory variables, which comprises FD, GDP, FD$^2$ and energy consumption. $f_t$ and $\gamma_i$ are the vector of unobservable shock and their loadings which could not be fully captured.

4. Measuring a new index of financial development

Previous studies generally consider financial development as a single-faceted concept. As such, each of the following indicators has been used to proxy for financial development. These indicators include (i) liquid liabilities to GDP; (ii) deposit money bank assets to GDP; (iii) private credit by deposit money banks to GDP; (iv) financial system deposits to GDP; (v) stock market capitalization to GDP; (vi) stock market total value traded to GDP; and (vii) stock market turnover ratio.

This paper is different from previous studies. Financial development is a multi-faceted concept. As such, its proxy should take into account various aspects of financial development. We consider that establishing a global financial centre is a necessary and sufficient condition to enhance and increase the degree of financial development of a nation. A global financial centre is generally named for a city where capital and financial markets operate on a large scale, leading to an enhancement of financial development. As such, a global financial centre's fundamental determinants can be used to proxy various financial development aspects for a nation.

We consider that establishing a financial development index using the four fundamental determinants as the weight (He et al., 2017). The financial development index (FD) can be expressed as follows:

$$ PC_{it} = \sum_{s=1}^{4} \text{Loading}_{st} \times \text{Determinant}_s $$

$$ FD_{it} = \sum_{s=1}^{M} PC_{it} \times IVC_{ms} $$

where the Determinants includes market size, freedom to trade internationally, size of government and higher education and training; $n = (1, 2, 3, 4)$ represents the four fundamental determinants of a global financial centre. $PC_{it}$ denotes the selected principal components for each country. Loading stands for the factor loadings of the corresponding indicators. IVC stands for the individual variance contribution of the corresponding.

1 We note that the variable FD$^2$ is the non-linear transformation of FD (Financial development), and their relationship will never become the perfect linearity. However, the inclusion of FD$^2$ makes our model suffers from the multi-collinearity because the variable FD only receives value within [0, 1] interval. However, our review indicates that the problem exhibited in this study is trivial because of the following reasons. First, even with the presence of multi-collinearity, the ARDL estimators are the appropriate point estimates. This means that the estimated coefficients are still unbiased (Gujarati and Porter, 2008). Second, the multi-collinearity is likely unavoidable when one variable, which receives only positive values, and its squared value is simultaneously included in the same regression equation. This is because the function $f(x) = x^2$ is monotonic in the interval $[0, +\infty)$. We note this problem is analogous to the case when both GDP and GDP$^2$ are included in the same model, which is used to examine the validity of the Kuznets curve hypothesis. Another example is that when Age and Age$^2$ are included in the same model investigating the relationship between income and age, the multi-collinearity problem also exists.

2 These analysis results are not reported in this paper to minimize the distraction and due to a concern of the paper's length. Complete results will be provided upon request from the corresponding author. For further details, please see Magnus et al. (2010), Magnus and De Luca (2014), Nguyen et al. (2020) and Vo and Nguyen (2020).
component. Table 1 presents the individual variance contribution (IVC) and a number of components selected for each country in the sample. Table 1 indicates that a number of principal components for each Asia-Pacific country vary between 1 and 3. To develop a single index of financial development, we decide to take an 85 per cent threshold of the cumulative variance contribution, which is favoured in previous studies such as He et al. (2017) and Zhao and Yang (2020). The corresponding IVCs of principal components are used as the weights.

### Table 1. The individual variance contribution and a number of selected components for each country.

| Country   | IVC   | Number of components | Country   | IVC   | Number of components |
|-----------|-------|----------------------|-----------|-------|----------------------|
| UAE       | 0.8634 | 2                    | Kyrgyzstan | 0.8986 | 2                   |
| Armenia   | 0.8763 | 2                    | South Korea | 0.9390 | 3                   |
| Australia | 0.9294 | 3                    | Sri Lanka  | 0.9099 | 2                   |
| Azerbaijan | 0.9449 | 2                    | Mongolia   | 0.9467 | 2                   |
| Bangladesh | 0.9394 | 3                    | Malaysia   | 0.9643 | 3                   |
| China     | 0.8966 | 2                    | Nepal      | 0.9199 | 2                   |
| Cyprus    | 0.9078 | 3                    | New Zealand | 0.9562 | 3                   |
| Georgia   | 0.8567 | 2                    | Pakistan   | 0.9533 | 3                   |
| Indonesia | 0.9364 | 2                    | Philippines | 0.9592 | 3                   |
| India     | 0.8956 | 2                    | Singapore  | 0.9377 | 2                   |
| Israel    | 0.9595 | 3                    | Thailand   | 0.9244 | 2                   |
| Japan     | 0.8761 | 2                    | Turkey     | 0.8799 | 2                   |
| Kazakhstan| 0.8504 | 1                    | Vietnam    | 0.9455 | 2                   |

Number of country — 26, from 2007 to 2017.

Notes: The individual variance contribution (IVC) is the variation proportion captured by those principal components. The study only takes into account those vectors with cumulative explanatory variation up to 85 per cent.

### Table 2. The descriptive statistics.

| Country name | LnGDP  | LnENE  | FD    | LnCO₂  | Country name | LnGDP  | LnENE  | FD    | LnCO₂  |
|--------------|--------|--------|-------|--------|--------------|--------|--------|-------|--------|
| UAE          | 26.537 | 11.550 | 0.4193| 5.197  | Kyrgyzstan   | 22.511 | 7.144  | 0.0573| 2.170  |
| (0.163)      | (0.190)| (0.106)| (0.123)|        | (0.231)     | (0.314)| (0.082)| (0.208)|        |
| Armenia      | 23.065 | 7.726  | 0.1944| 1.644  | South Korea  | 27.831 | 12.758 | 0.3472| 6.411  |
| (0.102)      | (0.376)| (0.105)| (0.089)|        | (0.162)     | (0.127)| (0.019)| (0.081)|        |
| Australia    | 27.844 | 12.309 | 0.6067| 6.009  | Sri Lanka    | 24.844 | 8.794  | 0.5159| 2.825  |
| (0.205)      | (0.027)| (0.029)| (0.015)|        | (0.337)     | (0.250)| (0.117)| (0.221)|        |
| Azerbaijan   | 24.680 | 9.905  | 0.4978| 3.405  | Mongolia     | 22.893 | 8.436  | 0.6223| 2.832  |
| (0.283)      | (0.144)| (0.089)| (0.107)|        | (0.423)     | (0.167)| (0.101)| (0.230)|        |
| Bangladesh   | 25.667 | 10.725 | 0.3186| 4.162  | Malaysia     | 26.340 | 11.686 | 0.7537| 5.438  |
| (0.367)      | (0.219)| (0.034)| (0.212)|        | (0.196)     | (0.126)| (0.057)| (0.090)|        |
| China        | 29.659 | 15.116 | 0.7182| 9.176  | Nepal        | 23.575 | 1.182  | 0.4502| 1.678  |
| (0.414)      | (0.192)| (0.056)| (0.138)|        | (0.272)     | (1.653)| (0.052)| (0.358)|        |
| Cyprus       | 23.905 | 8.432  | 0.2740| 1.983  | New Zealand  | 25.830 | 9.282  | 0.6865| 3.563  |
| (0.107)      | (0.099)| (0.028)| (0.120)|        | (0.178)     | (0.256)| (0.037)| (0.031)|        |
| Georgia      | 23.377 | 7.430  | 0.6660| 2.079  | Pakistan     | 26.099 | 11.126 | 0.1970| 5.088  |
| (0.188)      | (0.415)| (0.052)| (0.242)|        | (0.231)     | (0.066)| (0.052)| (0.086)|        |
| Indonesia    | 27.356 | 12.046 | 0.8314| 6.097  | Philippines  | 26.171 | 10.869 | 0.7977| 4.588  |
| (0.293)      | (0.219)| (0.059)| (0.092)|        | (0.264)     | (0.199)| (0.055)| (0.199)|        |
| India        | 28.201 | 13.660 | 0.7333| 7.562  | Singapore    | 26.299 | 10.689 | 0.3712| 3.935  |
| (0.256)      | (0.217)| (0.042)| (0.189)|        | (0.231)     | (0.063)| (0.071)| 0.072  |
| Israel       | 26.289 | 11.001 | 0.4176| 4.233  | Thailand     | 26.615 | 11.905 | 0.4541| 5.545  |
| (0.209)      | (0.067)| (0.030)| (0.052)|        | (0.185)     | (0.061)| (0.056)| (0.068)|        |
| Japan        | 29.271 | 13.614 | 0.2210| 7.153  | Turkey       | 27.426 | 12.063 | 0.1796| 5.826  |
| (0.114)      | (0.111)| (0.073)| (0.057)|        | (0.124)     | (0.098)| (0.070)| (0.117)|        |
| Kazakhstan   | 25.815 | 11.279 | 0.2135| 5.522  | Vietnam      | 25.695 | 11.118 | 0.5070| 5.084  |
| (0.270)      | (0.084)| (0.094)| (0.071)|        | (0.343)     | (0.360)| (0.059)| (0.216)|        |

Number of country — 26; from 2007 to 2017.

Notes: Mean and standard deviation of selected variables. Standard deviation is reported in parentheses.

### 5. Data and empirical findings

#### 5.1. Data

Table 2 provides the variables used in the analysis and their corresponding descriptive statistics. Among these variables, a new index of financial development is constructed using the PCA analysis; natural logarithm of CO₂ emissions (CO₂); natural logarithm of the economic growth, which is proxied by the GDP (LnGDP) and natural logarithmic
form of energy consumption (LnENE). Data for the GDP represent the total domestic consumptions by country level and by the value in the US dollars in 2010. Data for CO2 emissions and energy consumption are collected from the Emission Database for Global Atmospheric Research (EDGAR) and the International Renewable Energy Agency (IRENA), respectively. We have the panel dataset of 26 countries in the Asia-Pacific region in the 2007–2017 period.

Table 3 provides the pairwise correlations of variables included in the model.

As presented in Table 3, a high positive correlation between CO2 emissions and GDP; and between energy consumption and financial development is observed. In addition, the variance inflation factor (VIF) is also presented. The high value of VIF is neither significant nor sufficient for the existence of multi-collinearity because it is counterbalanced by the low value of σ2 or high ∑ x2 (Gujarati and Porter, 2008).

To ensure this paper’s findings’ robustness, we conduct Theil’s R2 test. As presented in Table 4, this test’s findings indicate that multi-collinearity does not appear to be a significant problem. We note that when the variable FD is removed from the regression model, the VIFs values are significantly lower than 10.

Table 4 shows that autocorrelation and heteroskedasticity do exist in our model. In addition, Table 4 also indicates that multi-collinearity is not a major issue in this analysis.

5.2. Empirical findings

5.2.1. Cross-sectional dependence test

Test results are presented in Table 5 below. We note that most of the model variables suffer the cross-sectional dependence at a 1 per cent level of significance. It is important to utilize a method that will take into account the cross-sectional dependence.

5.2.2. Slope homogeneity test

Table 6 below provides the results from the slope homogeneity test for the panel. At the base level, the panel data experiences the heterogeneous slope in the cross-sectional dimension at a 5 per cent level (see Table 7).

5.2.3. Unit root test

The next step is to examine whether or not the time-series dimension is stationary at the level and at the first difference (D1). Results indicate that the variables have a long-run relationship with each other. The test results cast a strong confirmation on the stationarity at the first difference level of the model’s variables. In other words, we consider that the variables have a long-term relationship with each other. At a 1 per cent significance level, the results confirm the necessity for our further analysis using the co-integration test.

5.2.4. Co-integration test

Table 8 presents the Pedroni and Westerlund test results. The results support the presence of a long-run relationship between variables.

5.2.5. The long-run relationship between financial development and environmental degradation

In order to examine the long-run relationship between financial development and environmental degradation, we use the mean group ARDL (MGARDL), the pooled mean group ARDL (PMGARDL), and the dynamic fixed effect ARDL (DFEARDL). We note that these techniques (MGARDL, PMGARDL, and DFEARDL) are considered second-generation estimation techniques. As presented in sections 5.2.1 and 5.2.2 of this paper, our analysis confirms the presence of cross-sectional dependence and slope homogeneity. As such, we consider that findings obtained from second-generation techniques such as the MGARDL, PMGARDL, and DFEARDL provide robust findings.

Mean group ARDL; Pooled mean group ARDL and Dynamic fixed effect ARDL

We now move to the second-generation estimators using the mean group and pooled mean group ARDL to examine the long-term relationship between financial development and environmental degradation. We note that choosing the optimal lag order for long-run estimations is imperative for the consistency of ARDL techniques (Chudik et al., 2013). Table 9 presents estimates from analyses using the mean grouped ARDL, pooled mean group ARDL and dynamic fixed effect ARDL.

In three models, the results from the Hausman test for the difference in estimated coefficients indicate that the pooled mean group model (PMGARDL) is preferred to the mean group (MGARDL) and the dynamic fixed effect estimator (DFEARDL), meaning that the estimated coefficients across countries are not suffered from the heterogeneity. Based on the empirical evidence, the results are discussed as follows.

First, the error correction terms in all three regressions are significant and negative. These findings imply that the long-run relationship does exist among relevant variables, including financial development and environmental degradation. These results are also in line with results from the co-integration tests.

Second, it appears that economic growth in the Asia-Pacific region during the research period negatively affects the quality of the environment. GDP growth increases the amount of CO2 emissions by

Notes: * shows significance at the 5 per cent level.
Table 5. The cross-sectional dependence test results.

| Variable | Ln (CO2) | Ln (GDP) | FD | FD² | Ln (Energy) |
|----------|----------|----------|-----|-----|-------------|
| CD test  | 26.228***| 40.747***| 35.625***| 35.983| 19.918*** |
| p-value  | (0.0000) | (0.0000) | (0.0000) | (0.0000) | (0.0000) |

Notes: *** indicates the statistical significance at a 1 per cent level.

Table 6. The slope homogeneity test by Pesaran and Yamagata (2008).

| Test statistic | ∆ | ∆adj |
|----------------|----|------|
|                | 18.241*** | (0.000) |
|                | 34.125*** | (0.000) |

Note: The slope homogeneity test with Barlett HAC kernel and capturing for cross-sectional dependence structure. The null hypothesis is that the panel coefficients are homogeneous. Against the alternative is that the sample undergoes the heterogeneous slope.

Table 7. The second-generation unit root test.

| Cross-sectional ADF | LnGDP | LnCO₂ | LnENE | FD | FD² |
|---------------------|-------|-------|-------|----|-----|
|                     | Base level |       |       |     |     |
|                     | LnGDP     |       |       |     |     |
|                     | 1.802     | 0.169 | 2.632 | -3.692***| -3.322*** |
|                     | (0.964)   | (0.567) | (0.996) | (0.000) | (0.000) |
|                     | Lag(1) |       |       |     |     |
|                     | 3.288     | -0.023 | 1.961 | -1.967** | -2.670*** |
|                     | (0.999)   | (0.491) | (0.975) | (0.024) | (0.004) |
|                     | First difference (D1) |       |       |     |     |
|                     | -5.067*** | -4.415*** | -4.900*** | -7.232*** | -6.451*** |
|                     | (0.000) | (0.000) | (0.000) | (0.000) | (0.000) |

Notes: The CADF null hypothesis is that the variables of interest are non-stationary. Against the alternative of the variable is constructed by a stochastic process.

approximately 34 per cent, supporting a view that the region’s economic growth for the past few decades is neither eco-friendly nor sustainable. These findings also support the GDP’s income effects hypothesis, which concludes that anthropogenic activities are considered harmful to the environment. Similar findings on the income effects of growth can be found in Bekun et al. (2018) study. Interestingly, the PMG-ARDL regression technique’s empirical results confirm the asymmetric nature of financial development on CO2 emissions. These findings appear to be sensible for the emerging region such as the Asia-Pacific region because modernistic policies that aim to increase the supply and demand of the financial sector negatively affect the quality of the environment. For countries in the low and lower-middle-income group, the privatization of state-owned enterprises, the promotion of financial literacy, and financial deregulation attract more green technologies from foreign direct investment. The technological effects of financial development on environmental degradation are in line with Zhao and Yang (2020) and Shahbaz et al. (2013b) studies. A high level of competition may increase the risk of noncompliance to production standards. In addition, we also find the negative effects of energy consumption on CO2 emissions. Specifically, energy consumption decreases the amount of CO2 emissions by 33 per cent during the research period. These findings imply that governments are getting more cautious and conservative in using energy types about fossil and non-renewable sources.

Third, findings on financial development on environmental degradation using the second-generation PMGARDL technique are interesting for policymakers and economists in the Asia-Pacific region. Financial development to improve the efficiency of the financial sector may put a negative effect on environmental degradation. It is because the financial deepening enables firms to access various financial channels. The capitalization process allows firms to lower their cost of capital and to minimize the level of unsystematic risks (often characterized by the host country macroeconomic conditions) and, as a result, to optimize their returns. Countries in the ASEAN, including Vietnam and Laos PDR, have managed to restructure the economies away from low-contributory sectors (agriculture) by applying new technologies to other sectors such as the manufacturing, the ICT, or the services sectors. Besides, the technological transition enriches the human capital and lessens urbanization on megacities in the Asia-Pacific region.

Our empirical results using the second-generation technique, the PMGARDL, indicate that CO2 emissions are directly affected by economic activities. These results are in line with findings from other studies such as Zhao and Yang (2020), Bekun et al. (2018), Abbasi and Riaz (2016). As previously indicated, the Asia-Pacific region’s development during an investigated period is neither environmental-friendly nor sustainable. In other words, the high economic growth rate in the Asia-Pacific region over the last decade is associated with the 12 per cent increase in the level of CO2 emissions. The results also raise the alarm concerning a middle-income trap where countries across the region find themselves stranded in attaining the comparative advantages of the low-cost labour force to export goods and services.

Table 8. The co-integration test results.

| Pedroni | Modified Phillips-Perron t | Phillips-Perron t | Augmented Dickey-Fuller t | Westerlund |
|---------|---------------------------|-------------------|---------------------------|------------|
| Test – statistic | 6.0786*** (0.0000) | -9.9247*** (0.0000) | -9.8284*** (0.0000) | 0.1446* (0.0743) |

Notes: P-values are reported in parentheses. The null hypothesis of Pedroni is that there is no co-integration in the panel. The alternative hypothesis is that there is a long-run relationship between the variables included in our model. Option demean is specified for mitigating the effect of cross-sectional dependent structure.
5.2.6. Granger causality test using Dumitrescu and Hurlin

We perform the panel Granger causality test using the method developed by Dumitrescu and Hurlin (2012). This method is generally considered to be capable of capturing the slope heterogeneity across the panel. The empirical results are shown in Table 10 below.

Table 10 presents empirical results to support the feedback hypothesis between financial development, energy consumption and CO₂ emissions. The improvement of financial development in the Asia-Pacific region interacts with CO₂ emissions and energy consumption. These findings mean that it is possible and doable to positively impact the overall environmental quality by loosening constraints on international capital inflows, improving legal framework and tax system efficiency.

Figure 1 presents a summary of Granger’s causality flows between financial development, environmental degradation; economic growth; and energy consumption.

6. Conclusions and policy implications

The Asia-Pacific region has played a significant and important role in economic growth in the world over the last three decades. In this paper, we apply the concept of the Kuznets curve with a focus on financial development. This study examines the effect of financial development on environmental degradation in the Asia-Pacific region for 26 countries in the 2007–2017 period.

Empirical findings confirm the long-term and U-shaped relationship between financial development and environmental degradation. These findings imply that extending financial development is associated with decreasing environmental degradation up to a certain threshold. After this threshold, an increase in financial development is linked with an increase in environmental degradation. In addition, our study confirms a bi-directional relationship between financial development and environmental degradation.

These findings provide implications for policy for countries in the region. The government should be cautious concerning financial development. Developing a financial sector may cause and affect environmental degradation in the long run. The relevant policies should be carefully prepared and implemented with a close focus on the current financial development level. An optimal degree of financial development is a dynamic concept. This optimal level should be put in the context of economic growth and the quality of the environment. We present below

Table 9. The mean group ARDL, pooled mean group ARDL and dynamic fixed effect ARDL.

| Hypothesis | ARDL | MG-ARDL | PMG-ARDL | DFE-ARDL |
|------------|------|---------|----------|----------|
| MGI         |      |         |          |          |
| LogGDP     | -0.17| 0.34*** | 0.33***  |          |
|            | (-0.38)| (13.66) | (3.23)   |          |
| FD         | 60.98| -0.84***| -0.27    |          |
|            | (1.08)| (-8.89) | (0.45)   |          |
| FD²        | -53.96| 2.60*** | 1.53**   |          |
|            | (-1.17)| (12.46) | (0.032)  |          |
| LnENE      | 1.26**| -0.33***| -0.03    |          |
|            | (1.98)| (4.27)  | (0.56)   |          |
| ECT        | -1.29**| 0.21**  | -0.22*** |          |
|            | (-2.32)| (2.33)  | (-5.7)   |          |
| Cons       | 2.14| 0.045**| -0.85    |          |
|            | (0.14)| (0.33)  | (-1.41)  |          |
| Hausman test of poolability | 0.00| 0.00 | 0.00 |
|            | (1.000)| (1.000) | (1.000)  |          |

Notes: The mean group and pooled mean group of two equations. The t-statistics are shown in parentheses. *, **, *** are respectively significant at 10, 5, 1 percent level.

Table 10. The Granger causality results.

| Hypothesis | Z-bar | Z-bar tilde | Conclusion |
|------------|-------|-------------|------------|
| CO₂ → FD   | 12.6248*** (0.0000) | 5.6481*** (0.0000) | The bidirectional link between CO₂ emissions and financial development is confirmed. |
| FD → CO₂   | 6.6183*** (0.0000) | 2.6143*** (0.0000) | The GDP growth does Granger affect CO₂ emissions, and the feedback effect is also confirmed. |
| GDP Growth → CO₂ | 4.3872*** (0.0000) | 1.4874 (0.1369) | The GDP growth does Granger affect CO₂ emissions, and the feedback effect is also confirmed. |
| CO₂ → GDP Growth | 7.3140*** (0.0000) | 2.9657*** (0.0030) | The empirical results indicate the unidirectional link between GDP growth and financial development. |
| Energy consumption → CO₂ | 7.2342*** (0.0000) | 2.9254*** (0.0034) | The energy consumption does increase CO₂ emissions. Their bidirectional relationship is statistically significant at the 10 per cent level. |
| CO₂ → Energy consumption | 5.0672*** (0.0000) | 1.8309** (0.0671) | The empirical results indicate the unidirectional link between GDP growth and financial development. |
| GDP Growth → FD | 12.8710*** (0.0000) | 5.7724*** (0.0000) | The empirical results indicate the unidirectional link between GDP growth and financial development. |
| FD → GDP Growth | 0.2221 (-0.8242) | 0.6162 (0.5377) | The empirical results indicate the unidirectional link between GDP growth and financial development. |
| GDP → Energy consumption | 11.4269*** (0.0000) | 5.0430*** (0.0000) | There is a bidirectional link between GDP growth and the increase in energy consumption. |
| Energy consumption → GDP | 6.3971*** (0.0000) | 2.5062*** (0.0123) | There is the bidirectional Granger causality between energy consumption and financial development. |
| FD → Energy consumption | 13.3028*** (0.0000) | 5.9905*** (0.0000) | There is the bidirectional Granger causality between energy consumption and financial development. |
| Energy consumption → FD | 13.7335*** (0.0000) | 6.2080*** (0.0000) | There is the bidirectional Granger causality between energy consumption and financial development. |

Notes: The Dumitrescu and Hurlin test is on Granger causality between included variables. P-values are reported in the parentheses. *, **, *** respectively denotes the statistical significance at 10, 5, 1 per cent level.
the following two critical solutions that should be considered to achieve sustainable growth for the next decade while remaining competitive with other regions.

First, capturing a comparative advantage on a low-cost labour force should only be considered a short-term strategy. The sustainable economic growth in the Asia-Pacific region moves towards the comprehensiveness of the value chains across countries. We suggest that all industries should engage in R&D activities. They should be parts of the value chain and advancing technologies. Countries in the Asia-Pacific region have demonstrated distinctly different cultures and landscapes. These differences are anticipated that countries in the region may never become one united economic alliance such as the European Union (EU) or the North American free-trade agreement (NAFTA). R&D investment and advancing technologies will expectedly address the low marginal cost of capital. It then increases workers’ productivities. Financial development is crucial for the region’s upcoming technological transition since a large R&D investment project requires stability in macroeconomic conditions and a decent legal framework. China and India are two leading countries that have started heading towards the efficiency of the value chain. Both countries have experienced a sharp increase in labour-intensive products over the last decade. These countries have also left the playground of labour-intensive manufactures for exports to the less-developed countries such as Vietnam, Cambodia and Bangladesh (McKinsey Global Institute, 2019).

Second, our empirical evidence favours the feedback hypothesis between financial development and CO2 emissions. This finding means that policies targeted at enhancing financial development do affect environmental quality. It seems that technological advancements are crucial for the Asia-Pacific region in the next decade. R&D investment can lower the level of CO2 intensity. The broadening financial market base is vital for technological reform. The advanced technologies often come under the FDI forms. On that basis, new policies should be designed to improve the following two important points. First, the essential condition for promoting the inward investment’s attractiveness is to enrich the cumulative human capital and improve specialization. The globalization process shifts the scale of local and traditional financial transactions to the global level. The countries in the region should let the capital flows and modern technologies travel freely across the nations. The globalization process also changes the financial system’s role, making them a pooled means of conveying, generating, processing and interpreting financial information. The financial systems must be primarily focused on a multiplex division and a labour specialisation in the skilled labour force and production materials. Second, the policies should promote and support the small and medium enterprises (SMEs) sector. Large corporations are important sources of innovation and capital for growth in many emerging markets. However, their sources of innovation hardly raise the demand for capital. Encouraging entrepreneurship and developing a vibrant start-up ecosystem will act as the main channel for financing innovation.

Declarations

Author contribution statement

Duc Hong Vo and Nhan Thien Nguyen: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Anh Vo: Contributed reagents, materials, analysis tools or data; Wrote the paper.

Chi Ho and Thang Nguyen: Analyzed and interpreted the data.

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Additional information

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