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An interpretation of the economic structural change decomposition versus sustainable growth path challenge : An empirical assessment in Asia-Pacific economies

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Abstract

This paper assesses for 9 Asian-Pacific countries over the period 2000-2019, the response of the green growth path indicator to an interpretation of Economic Structural Change (ESC) decomposition. ESC can be dissociated by the following combined factors: production, energy consumption, natural resources, Economic Complexity or know-how, international trade, environmental regulation with tax. Using Ordinary Least Squares, two-step sytem-Generalized Method of Moments, Driscoll-Kraay estimation and Panel Quantile Regression strategies with different specifications (alternative dependent variable, additional control variable), results consistently evidenced that the Asia-Pacific environmental curve's corresponds to a specific polynomic association or an inverted U-Shaped.

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1. Introduction

Countries in Asian such as China, South Korea, Japan, India, Malaysia, Vietman, Philipine, Singapore and Thailand are usually cited among the fastest growing economies in the world (Lau et al. 2014, Apergis & Ozturk, 2015). On the backyard of this growth, although these countries are classified among the top higher technological products producers with an important part of their prodution exported worlwide, some of them such as China and India are nevertheless usually cited among the most polluters in Asian continent (Zambrano-Monserrata et al. 2018b, IPCC, 2022), without any concern in the past years relative to environmental pollution issues Apergis & Ozturk, 2015. Concern related to environmental protection, climate change and pollution mitigation is one of the Asia Pacific region's main environmental problems. More so, Asia Pacific's share of global emissions has seen an increase from 5338 millions metric tons of CO2 (MtCO2) in 1990 to 17.955[1] millions MtCO2 in 2019 because the region has become a global manufacture hub, and rising middle class with rising income levels that impacts consumption-based emissions (IPCC, 2022, Low, 2023). At term in 2022, the increase of emissions level in this region was far more than the combined total emissions of all other regions (North America, Middle East, Africa, Europe, South and Central America) and China alone accounted for nearly 60% of Asia Pacific carbone missions (Tiseo, 2023).

The headlong rush to economic growth that characterized Asian countries during these last years raises four main concerns : the first is directly related to the needs of Natural Resources (NRs) which is necessary for supporting the rapid increase of the population and economic growth. The second is in link with the production diversification patterns (Bustos et al. 2012) that provides an advantage in export, trade and competitiveness capabilities. The third is resumed in the factors that can provide insight to predict changes in economic structure (Hausmann et al. 2014). The last point is about the consequent environmental degradation that comes parallel to this fast growth (Zambrano-Monserrate et al. 2016) while raising the questions of environmental goals, sustainability and green achievements.

These four concerns present above are characterizing and defining the Economic Complexity (EC) or Economic Sophistication (ES) concept usually represents by the Economic Complexity Index (ECI) (Hausmann et al., 2007, Hidalgo & Hausmann, 2009, Hausmann et al., 2011, Hausmann & Hidalgo, 2011). In Asian economies, the evolution of the economic data used to measure these aforementioned realities (NRs consumption, diversification capabilities, comparative advantage in production and exportation of complex product, environmental challenge) can lead to appreciate the long run development and sustanaibility achievements coupled with the structural change path. As underlined by Hausmann et al. (2014), focusing on transformation of the economic structure is motivated by the ECI's ability to explain and predict important macroeconomic outcomes, from economic growth to the abatement of pollution emissions level and reduction of income inequality challenges. Therefore, the well-known inverted U-Shaped curve hypothesis framework from Grossman and Krueger (1995) that characterises a sustainable relationship between economic growth, capabilities, transformations, achievements and the environmental quality with the generation of the reduction of environmental degradation can be used as main theoretical underpinning of this research.

The aforementioned close link between ECI and environmental improvements has received widespread attention in the literature only within the European context (Laverde-Rojas et al. 2021, Neagu & Teodoru, 2019), in a selected world sample (Dogan et al. 2019), or by focusing on the exportation diversification capabilities (Mania, 2020 ; Apergis et al. 2018, Can & Gozgor, 2017).

[1] Statista (2023), Statistical Review of World Energy 2023, from Energy Institute.

From the aforementioned determinant role of NRs to support economic growth (Topcu & Aslan, 2020), we address that issue by including it among the main explanatory control variables. Given that it is a particular issue with a long history and great significance in the debate within the framework of the natural resources curse hypothesis, we therefore use it for controlling the effect of natural resources on environmental degradation. More so, we hypothesizing that the other transmission channels that can have significant direct effects on the green path development are through environmental regulations with green taxation, energy consumption per capita and pollution that comes from international exchange of products. All these variables are tested together to capture the jointly effect of all the variables. The results obtained in the baseline that aim at explaning whether the development path is sustained can be considered as obtained from a jointly realistic factors.

Hypothesis: Justification of the study

Hypothesis 1: Let assume that ESC is an combined factor that efficiently agregated the following individual factors through the use of an optimal know-how capabilities: energy consumption, natural resources, economic complexity, international trade, environmental regulation with tax. We know from Hidalgo and Hausmann (2009) that ECI accounts for the changes in the economic structure. This variable is reflecting the high capabilities to produce diverse and less ubiquitous goods and is a helpful measurement of economic development. Therefore, this study differs from that of Hidalgo & Hausmann as it assumes that ESC combined factor is used as a set of explanatory variables to account for the changes in the Economic system while evaluating for improvements in environmental quality in Asia-Pacific countries as required in the COP28 framework (less fossil energies strategy). In fact, it is assumed here that ECI interact with other variables in the set of the ESC components above for targeting an improved environmental quality.

Hypothesis 2: Individual factors through which ESC can be dissociated are introduce simultaneously to evaluate the environmental quality index, and can be considered as additional explanatory control variables.

This study contributes to number of research areas and presents some implications. First, to the best of our knowledge, there are not previous studies that investigate the link between changes in economic structure and improvements in environmental quality or degradation under NRs constraint in Asian-Pacific context. The study closes to the vision developed in this paper is the one of Tchapchet-Tchouto (2023b) that mainly investigated the existence of EKC when controling for NRs, with a particular focus on how NRs and its different components can impact environmental quality. At all, the study shows that Asia-Pacific economies are on a so-called « green-resilience » path. However, this study differs in twofolds with that previous work : first, regarding the initiative of decoupling the economic structural change through its different mechanism including the economic sophistication feature ; second, by using a different econometric methods, we test the whole factors effect simultaneously in the Environmental Kuznets Curve framework. Therefore, taking advantage of these constributions, this article is filling a gap in the literature, within the Asian-Pacific context. More so, the approach developed in this paper differs in two strands from the previous studies that are within the scope of the investigation of the green development path hypothesis: indeed, we contribute to the literature by initially documenting a strong relationship between sustainable environmental quality indicators and economic growth with ECI among the explanatory variables on one hand. This consistent result is the first that aims at evaluating ECI as well as other structural change factors effects with Environmental Kuznets Curve framework in Asian-Pacific context. On a second hand, we continue by estimating the effect of total NRs, and after that we verify if the sustainable development path holds when controlling for each natural resources rents component (oil, mineral, gas and forest rents).

Third, compared with other studies that had focused on Environmental Kuznets Curve in the context of Asian-Pacific countries, we used the most recent data length available at this stage to conduct our research. Fourth, the study also presents some results about the impacts of controlling Trade issues to account for pollution degradation that comes from exchanging manufactured goods including sophisticated goods between countries, international movement of technology, goods physical and financial capital (Dreher & Langlotz, 2020); Information Communication and Technology (ICT) effects through the part of population that has access to phone, mobile, internet and broadband subscription (Epule et al., 2017). Following Tchapchet-Tchouto (2023b), the study also considers inflation for reflecting an increase general and sustainable level of prices and Tax on revenue scenario. We applied Ordinary Least Squares, two-step system Generalized Method of Moments to account for endogeneity which which we suspect to exist between environmental quality indicator and economic growth, Driscoll-Kraay estimator in response to cross sectional dependency and panel Quantile Regression. Hayakawa (2006) demonstrated that system-GMM estimator in small sample dynamic panel models is less biased than the first differencing or the level estimators even though the first uses more instruments.

The remainder of the paper is organized as follows: The section 2 presents the literature review; third part introduces data description and the empirical method for studying the effects of green development path hypothesis under the decomposing factors of economic structural change constraint in Asian-Pacific economies. Fourth part presents empirical findings, the robustness analysis including discussion. The last section concludes with implications and policy recommendations.

2. Linking Sustainability Indicators with Economic Structural Change and Growth in the literature

Before carrying out our analyses, it is important to briefly survey the existing literature on Environmental Kuznets Curve in Asian countries, some recent developments on NRs and as well as on ECI in the contexts where it has been studied. Studies that includes Environemental Kuznets Curve in the context of Asian economies have increased recently (Taguchi, 2013, Lau et al. 2014, Apergis & Ozturk, 2015, Zhang, 2019), and those with NRs are still ongoing (Amineh, 2006 and Haseeb, 2021). In the investigation of relationship between NRs and Greenhouse Gas (GHG) emissions, Tchapchet-Tchouto (2023b), Kuo et al. (2022), Xu et al. (2021), Wang et al. (2020) and Zambrano-Monserrata et al. (2018a) jointly found that NRs exhacerbated environmental quality by increasing GHG emissions in Asian countries.

Taguchi (2013) used Generalized Method of Moments to estimate the effects of carbon emission and sulfure in 19 Asian countries for the period 1950-2009. The results show that while carbon emissions increase along the pathway of the per capita GDP, sulfur emissions follow the inverted U-Shaped. In Malaysia, Lau et al. (2014) have investigated for the period 1979-2008, the relationship between carbon emissions and per capita income using bounds testing approach and Granger causality estimation technique. They found as result that the development of the economy is linked in short and long run, with the lower level of carbon emissions. Zambrano-Monserrata et al. (2018b) have tested the Environmental Kuznets Curve hypothesis in Singapore from data spanning 1971 – 2011 with Granger causality and autoregressive distributed lag bound testing methods. The study confirms in both short and long term, the existence of an inverted U-Shaped. Lee et al. (2021) established with ARDL that Environmental Kuznets Curve hypothesis is verified in China from data spanning the period 2002-2018.

Using Generalized Method of Moments estimation strategy, Apergis and Ozturk (2015) investigate the relationship between environmental degradation and GDP per capita in 14 Asian economies. With data spanning from 1990-2011, the results show a sustainable path in favour of an inverted U-

Shaped. Methan gas emissions was used by Adeel-Farooq et al. (2020) as proxy of the mesurement of environmental damage to test the relationship with Economic growth in a panel of six southeast Asian economies from the period 1985-2012. The methodologies used were the Mean Group (MG) and Pool Mean Group (PMG) estimation methods. Even findings converge to confirm evidence of an inverted U-Shaped, the study particularly underlined that energy consumption has a positive effect on CH_4 emissions concentration. In the streamline of Environmental Kuznets Curve studies on ASEAN countries, using the cointegration estimation analysis, Wei and Lihua (2022) have characterized that Environmental Kuznets Curve hypothesis is valid.

The second part of the state of arts is mainly focusing of studies that have considered ECI withing their estimations strategies. Can and Gozgor (2017) have characterized with DOLS method, the evidence of Environmental Kuznets Curve in France from the period 1964-2014. They investigated the effect of ECI and energy consumption. They found a negative effect of economic complexity on environmental quality. Laverde-Rojas et al. (2021) investigated if Environmental Kuznets Curve hypothesis is valid on the long term In Columbia. Using the Vector Error Correction Model (VECM) and database from the period 1971 – 2014, their findings show that the GHG emission is increasing in the trend of income per capita. In the same time, there is no positive effect of ECI on Colombian economy due to the country's institutional rigidities. With quantile analysis estimations, Dogan et al. (2019) investigated the Environmental Kuznets Curve hypothesis with a database covering 55 countries in the world and data spanning the period 1971 – 2014. From this study, there is a positive effect of the production quality through ECI process only for low and medium income countries. Using FMOLS and DOLS methods with data spanning from 1995 to 2016, Neagu and Teodoru (2019) investigated if production quality can increase environmental degradation within a sample of 25 European countries. Apergis et al. (2018) demonstrated that countries' exportations on which Economic Complexity feature is mainly based can decrease CO_2 emissions in 19 high income countries[2] (including 15 European countries). Churchill et al. (2018) found heterogenous figures (U-Shaped, Inverted U-Shaped, N-Shaped, and Inverted N-Shaped) in OECD countries' sub-groups with data spanning from 1870-2014. Tchapchet-Tchouto (2023a) demonstrated with data covering the period 2005-2019 in 22 European (Nordic and Non-Nordic) countries, that Economic Complexity has a consistent leveraging effect that can change the initial characterized U-Shaped into an inverted U-Shaped. Results are heterogenous when Euro zone feature[3] is taking into consideration.

Characterizing the literature gap

Based on the outcome of the empirical literature review, it is instructive to note that structural transformation factors are crucial to sustainable development and the evidence on this linkage is partially under researched in the literature (Ahmed et al., 2022, Tchapchet-Tchouto, 2023a, Tchapchet-Tchouto et al., 2024). At time, no study has clearly explored the effect of ECI within the green development path lens on one side and under the prism of the structural change decomposition as postulated in this research. Therefore, this study fill that gap in the literature and establishes a linkage between economic sophistication, energy consumption, trade, environmental policies and other factors that could mediate the link between the economic structural transformation and sustainable development indicators in Asia-Pacific economies.

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[2] Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, The Netherlands, New Zeland, Norway, Portugal, Spain, Sweden, Switzerland, The UK, USA, Uruguay.

[3] With evidence of U-Shaped structure in Euro zone (Nordic or Non-Nordic) countries whereas inverted U-Shaped in Non-Nordic & Non-Euro zone countries.

3. Data and methodology

3.1. Data

The panel data of 9 Asian countries (China, India, Japan, South Korea, Malaysia, Philippine, Singapore, Thailand, Vietnam) is selected for this study from 5 main sources (see **Table 7** in **Appendix**) over the period 2000 - 2019. The key drivers for building the sample and selecting these Asian-Pacific countries[4] were subject only to the availability of the key variables data on the period of the study. In **Table 4** (**Appendix**) we summarize the definitions of the statistical variables while **Table 5** presents the table of correlation matrix.

Dependent variable

As main dependent variable, the composite index - Carbon Emission per capita – taken from the World Development Indicator (WDI) is using as indicator to capture the environmental quality in baseline estimation. Furthermore, to improve the efficiciency of the initial test given some weaknesses in data errors measurements, Ecological Footprint Index is further used as alternative dependent variable within the robustness check estimation.

Table 1: Summary statistics

	N	Min	Mean	Max	Range	SD	Skewness	Kurtosis
Co2 per capita index	180	.078	.328	.907	.828	.166	1.543	6.007
Ecofootprint Index	180	.799	3.355	8.217	7.418	1.993	.42	1.941
Ln GDP	180	5.966	8.692	11.108	5.141	1.438	.016	1.808
Ln GDP Square	180	35.598	77.611	123.38	87.782	25.105	.209	1.765
Economic Complexity Index (ECI)	180	-.946	.653	2.262	3.208	.881	.153	2.015
ECI Square	180	0	1.198	5.117	5.117	1.484	1.291	3.415
Ln Energy per capita	180	5.885	7.419	8.905	3.02	.926	-.221	1.552
Environmental Tax	180	0	.893	2.837	2.837	.788	.941	2.915
Trade	180	19.56	120.567	437.327	417.767	101.028	1.548	4.636
Tax on Revenu	140	6.129	12.659	17.795	11.666	2.325	-.505	2.838
Research & Development	180	.105	1.411	4.763	4.658	1.195	.763	2.491
Internet users (population)	180	.254	43.63	96.158	95.903	29.795	.101	1.691
Inflation	180	-1.71	2.99	23.115	24.826	3.215	2.442	13.433
Foreign Direct Investment	180	-.052	4.318	32.17	32.222	6.147	2.589	9.165
Natural Resources Rents	180	0	3.185	14.183	14.183	3.799	1.237	3.419
Gas Rent	180	0	.395	3.174	3.174	.659	2.181	7.027
Mineral Rent	180	0	.277	2.362	2.362	.491	2.618	9.885
Oil Rent	180	0	1.438	8.978	8.978	2.141	1.819	5.384
Forest Rent	180	0	.678	4.939	4.939	1.047	2	6.445

Source : Author's construction

Table 2: Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
(1) co2pcindex	1.000																		
(2) ecoFPindex	-0.193*	1.000																	
(3) lngdp	-0.331*	0.914*	1.000																
(4) lngdpsq	-0.345*	0.918*	0.997*	1.000															
(5) ECI	-0.212*	0.793*	0.878*	0.888*	1.000														
(6) ECIsq	-0.286*	0.687*	0.801*	0.829*	0.855*	1.000													
(7) lnenergypc	-0.092	0.942*	0.928*	0.921*	0.770*	0.681*	1.000												
(8) envtax	0.254*	0.331*	0.279*	0.291*	0.502*	0.431*	0.316*	1.000											
(9) tradepergdp	-0.401*	0.502*	0.328*	0.335*	0.072	0.018	0.359*	-0.439*	1.000										
(10) taxrev	-0.544*	0.315*	0.448*	0.420*	0.081	0.247*	0.396*	-0.173	0.363*	1.000									
(11) resdev	-0.008	0.787*	0.806*	0.818*	0.875*	0.840*	0.790*	0.711*	-0.047	0.041	1.000								
(12) internetpop	-0.314*	0.796*	0.884*	0.880*	0.812*	0.724*	0.800*	0.349*	0.249*	0.397*	0.766*	1.000							
(13) inflation	0.035	-0.419*	-0.475*	-0.475*	-0.382*	-0.419*	-0.485*	-0.103	-0.048	-0.202	-0.398*	-0.375*	1.000						
(14) fdingdp	-0.316*	0.445*	0.326*	0.347*	0.157	0.102	0.314*	-0.361*	0.843*	0.069	0.010	0.222*	-0.045	1.000					
(15) natrentpergdp	0.292*	-0.368*	-0.468*	-0.480*	-0.442*	-0.455*	-0.329*	-0.349*	0.060	0.109	-0.505*	-0.310*	0.428*	-0.087	1.000				
(16) gasrentgdp	0.018	-0.068	-0.073	-0.107	-0.183	-0.277*	0.054	-0.403*	0.155	0.406*	-0.330*	0.046	-0.012	-0.103	0.675*	1.000			
(17) mineralrentgdp	0.283*	-0.417*	-0.399*	-0.408*	-0.203*	-0.360*	-0.428*	-0.007	-0.277*	-0.397*	-0.264*	-0.400*	0.451*	-0.124	0.271*	-0.136	1.000		
(18) oilrentgdp	0.226*	-0.311*	-0.435*	-0.435*	-0.440*	-0.356*	-0.300*	-0.338*	0.107	0.193	-0.453*	-0.280*	0.370*	-0.043	0.942*	0.580*	0.058	1.000	
(19) forestrentgdp	0.089	-0.195*	-0.273*	-0.292*	-0.317*	-0.340*	-0.164	-0.358*	0.195*	0.362*	-0.428*	-0.109	0.190	-0.060	0.858*	0.797*	-0.070	0.807*	1.[illegible]

Source : Author's construction, *** p<0.01, ** p<0.05, * p<0.1

4 It is acknowledged in this study that the sample does not include all countries of the Asia-Pacific region, and that this may be source of an eventual statistical analysis selection bias. For example, Indonesia which has an important economic weight in the region is not represented in the sample. However, including this country with missing values on main variables in the sample would have induced estimations errors or bias in results when processing with econometrics tests.

Independent variable within ESC factor variables

In the baseline estimation, the independent variable of interest is GDP that describes economic expansion, proxied by the GDP per capita obtained from the World Development Indicators. In addition to the GDP, the economic structure is also described with a set of variables that are combined to the GDP to form the ESC factor. Therefore, the study steps back in the literature to construct the ESC factor and they will be used to test simultaneously their influence on the environmental degradation. So, relying on Hypotheses 1 and 2, as well as Equations (1) and (2) below, the ESC factor variables group also includes these four elements: *Natural Resources*; their exploitation worsened environmental quality by increasing pollutant emissions indicators. Following the studies of Zambrano-Monserrata et al. (2018a), Xu et al. (2021), Kuo et al. (2022) and Tchapchet-Tchouto (2023b) for Asian countries, we expect a positive coefficient. The NRs constraint is tested with NRs rents as a whole (Total Natural Resources Rents) in a first strand, and through its fourth components that are Gas, Mineral, Oil and Forest rents in percentage of GDP in a second strand following Tchapchet-Tchouto (2023b) approach. The environmental policy effectiveness is also given by *Environmental Tax* variable through its capacity to negatively impact the carbon emissions level (Saucedo, 2017). In consequence, a negative sign is expected. *Trade openness* ; it takes into account international movement of technology, exchanging of manufactured goods, physical and financial capital (Dreher & Langlotz, 2020) and can improve environmental sustainability by reducing emissions level (Erdogan et al. 2021, Grossman & Kruegger, 1995, Antweiler, 2001 and Awan et al. 2020). In these circumstances, a negative sign is expected. *Energy consumption* ; from estimated, energy accounts for more than three-quarters of total GHG emission globally (IEA, 2023). A positive sign is expected.

Control variables

Research and Development (R&D) ; based on Ramos et al. (2018) and Shaari et al. (2016)' findings, technological development can increase the environmental degradation. *FDI*; theoretically, FDI effect is apprehended in twofold. On one side, as far as the amount of FDI increases, carbon emissions can decrease in the host countries. This is named as the Pollution Halo Hypothesis (PHH) that claims a better environmental management, spreading of advance and clean technology (Hoffman, 2005). On the other side, with the free international trade, production is shifted in countries where environmental legislation is less restrictive. This provides a comparative global advantage to pollution intensive goods and the direction of FDI flows (Copeland, 2008). In the literature applied to Asian countries, FDI is found to be positively correlated to CO2 emission in Malaysia by Lau et al. (2014). Regarding the previous analysis, the further result will help to conclud between the two hypothesis in Asia-Pacific countries. According to Tchapchet-Tchouto (2023b) findings, increasing *Tax on revenue* leads to better environmental quality. From the same study, a negative sign is jointly expected for *Inflation* and *Internet*. The data of all these control variable are extracted from Wolrd Development Indicators

3.2. Methodology

The study adopts the quadratic function developed by Kuznets (1955) and well adapted to the study of green path development assessment by many other successive studies (Grossman & Kruegger, 1995, Panayotou et al., 2000). The studies of Apergis and Ozturk (2015), Dasgupta et al. (2002) and Tchapchet-Tchouto (2023b) is modified to include all Economic Structural Change factors which may drive the green path development. Therefore, the following equations are specified :

$$\boldsymbol{CO2} \quad = \boldsymbol{f}(\boldsymbol{ESC}, \boldsymbol{X})\ \boldsymbol{with\ ESC} = (\boldsymbol{GDP}^{n}, \boldsymbol{ECI}, \boldsymbol{Energy\ Consumption}, \boldsymbol{Envtax}, \boldsymbol{Trade}, \boldsymbol{NRs}) \qquad \textbf{(1)}$$

With $n \in [1, 2)]$ given the quadratic function form.

$$\boldsymbol{CO2_{i,t}} = \boldsymbol{\alpha_0} + \boldsymbol{\alpha_1} LnGDP_{i,t} + \boldsymbol{\alpha_2} LnGDP_{i,t}^{2} + \boldsymbol{\alpha_3} ECI_{i,t} + \boldsymbol{\alpha_4} Energy_{i,t} + \boldsymbol{\alpha_5} Envtax_{i,t} + \boldsymbol{\alpha_6} Trade_{i,t} + \boldsymbol{\delta_j NRs_{j,t}} + \boldsymbol{\delta_k X_{k,t}} + \boldsymbol{u_i} + \boldsymbol{v_t} + \boldsymbol{\varepsilon_{it}} \qquad \textbf{(2)}$$

In the equation 2, t is a time variable, $CO2_{i,t}$ is the carbon emissions level per capita index, $\boldsymbol{\alpha_0}$ the scale parameter. $\boldsymbol{\alpha_1}$, and $\boldsymbol{\alpha_2}$ are the coefficients of Gross Domestic Product (GDP) and Gross Domestic Product Squared both considered in logarithm which will be determined to validate the green development path hypothesis. We are expecting $\boldsymbol{\alpha_1}$ to be positive and $\boldsymbol{\alpha_2}$ to be negative.

To decompose the ESC according to our hypothesis $\boldsymbol{\alpha_3}$ is the Economic Complexity Index coefficient. For a sustained structure, we expect $\boldsymbol{\alpha_3}$ to be negative. $\boldsymbol{\alpha_4}$ is the Energy consumption coefficient, knowing that the type of energy used can be a significant determinant of sustainable environment with a direct link to carbon emissions. $\boldsymbol{\alpha_5}$ is the environmental tax coefficient, $\boldsymbol{\alpha_6}$ is the International Trade coefficient, $\boldsymbol{\delta_j}$ is a vector of explanatory variables coefficients (NRs). Natural resources component is first considered as an aggregated factor and further, is dissociated in four components (mineral, forest, oil and gas) to be tested individualy as announced in 3.1. $\boldsymbol{\delta_k}$ is a vector of the coefficients of the controls variables, and $X_{k,t}$ is a vector of controls variables such as FDI, Inflation, Research & Development and Internet; u_i is an unobserved country-specific effect, v_t a time-specific effect and ε_{it} the error term.

In Equation 2, the independent variable GDP and its squared term describe the quadratic slope. This study aims at evaluating the Asia-Pacific green path development (environmental quality) through the constraint of selected individual factors for which the aggregation can explain the Economic Structural Change.

To estimate the different equations, several techniques are used, starting with the Ordinary Least Square (OLS) in baseline estimations. However, as underlined by Ketu et al. (2022), the OLS estimation does not account for country-specific factors or can be subject of bias that come from endogeneity. This occurs when one or more independent variables might be determined by other unknown factors, causing a relation between the independent variables an the error term. In consequence, these events that violate the OLS assumptions can theoretically yield to inconsistent estimates. To overcome the aforementioned difficulties and controlling for potential endogeneity problems, sensitivity analysis are estimated with two-step system GMM (Roodman, 2009, Arellano & Bond, 1991, Arellano & Bover, 1995) and further with Driscoll-Kraay estimator for resolving any potential cross sectional dependency presumption and panel Quantile Regression with different specifications (Koenker & Bassett, 1978, Koenker, 2005) to predict the likelihood of future events to occur around the conditional median value or other quantiles.

4. Results, robustness tests and discussion

4.1. Results

This section is organized in two parts: The first deals with the baseline empirical results, the second presents sensitivity analysis results of the baseline findings. Both parts contain some elements of discussion.

The Table 3 presents the baseline results of the green path development under structural change hypothesis and NRs constraints. The results reveal that Asia-Pacific countries are on the path of a sustainable development regarding the signs and significativity of the coefficients that characterized the economic development variable. Figure 1 illustrates how the estimated trend of the point cloud describes a quadratic function. By adjusting the per capita carbon emission index variable to the per capita GDP, the econometric methods based on different estimation techniques (OLS estimations, two-step system GMM, Driscoll-Kraay estimation and panel quantile regression) show the evidence that the Asia-Pacific environmental curve corresponds to a specific polynomic association or inverted U-Shaped as demonstrated by Grossman and Krueger (1995) after Kuznets (1955).

After a first test with total NRs rents, different specifications are performed with each natural resource component (oil, gas, mineral and forest rents) [columns (2 to 5)] and with all these

components together [column (6)]. The effect of total NRs on the level of hamful pollution is positive and strongly significant at 1% level. This result is consistent with the findings of Kuo et al. (2022). More so, under the jointly effects of the other characterized factors which derive from the decomposition of the structural change phenomenon, the relationship between variables are strongly confirming the inverted U-Shaped form in the different specifications of NRs. These results evidenced that GDP coefficients are all positive and strongly significant at 1% level. Morever, it can be seen from the results given by the Table 4 that represents a first robustness with Ecofootprint Index as an alternative mesure of the green path development, that the baseline results are robust under this alternative variable econometric analysis. Table 4 highlights that ECI effect is significant in column [2, 4, 6] and always positive as similar in Table 3. From both baseline and alternative dependent variable sensitivity tests, we also find that NRs seem to have a negative effect on the green path development mostly through oil consumption than other natural resources components.
Meanwhile, the rationale that can explain the results in whole could be the following : the leveraging effects of clean improvements that come from all the other factors, greenest achievements and strenghts from leadership in environmental policies of the Asia-Pacific context are helping to maintain a sustainable development path. So, pollution degradation obtains from international movement of knowledge, technology, exchanging sophisticated good between countries and change in the economic structure, yield to a sustainable path. This is consistent with Tchapchet-Tchouto (2023b). Likewise, energy consuption is found to significantly harm the green development and the result is consitent with Chen et al. (2019). Consistent with Saucedo et al. (2017), environmental tax significantly improve the green development path. However, international trade is detrimental to the environmental quality and the finding is opposite to that of Awan et al. (2020) and Erdogan et al. (2021).

Table 3: Baseline and robustness estimations results

	Dependent Variable : Carbon Emission per capita Index					
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Lngdp	0.2990***	0.3822***	0.4039***	0.3420***	0.3493***	0.5609***
	(0.1008)	(0.0987)	(0.1138)	(0.1039)	(0.1063)	(0.1300)
Lngdpsq	-0.0239***	-0.0294***	-0.0323***	-0.0277***	-0.0285***	-0.0399***
	(0.0065)	(0.0062)	(0.0073)	(0.0066)	(0.0067)	(0.0083)
ECI	0.0160	0.0354	0.0468	0.0236	0.0380	0.0430
	(0.0325)	(0.0318)	(0.0332)	(0.0351)	(0.0330)	(0.0365)
Energypc	0.0001***	0.0001***	0.0001***	0.0001***	0.0001***	0.0001***
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Envtax	0.0202	0.0184	0.0015	0.0049	0.0083	-0.0030
	(0.0244)	(0.0246)	(0.0268)	(0.0248)	(0.0250)	(0.0273)
Tradepergdp	-0.0007***	-0.0006***	-0.0006***	-0.0006***	-0.0006***	-0.0007***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Natrentpergdp	0.0109***					
	(0.0032)					
Oilrentgdp		0.0161***				0.0324***
		(0.0053)				(0.0093)
Gasrentgdp			-0.0085			-0.0595*
			(0.0190)			(0.0311)
Mineralrentgdp				0.0368		0.0204
				(0.0249)		(0.0263)
Forestrentgdp					0.0105	-0.0119
					(0.0112)	(0.0246)
Constant	-0.5982	-0.8943**	-0.8588*	-0.6732	-0.6730	-1.6406***
	(0.4185)	(0.4201)	(0.4658)	(0.4322)	(0.4423)	(0.5264)
Observations	180	180	180	180	180	180
R-squared	0.4221	0.4135	0.3832	0.3903	0.3857	0.4507

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 4: First robustness with Ecofootprint as alternative dependent variable

	Dependent Variable : Ecofootprint Environmental Index					
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Lngdp	1.1758***	1.3428***	1.1421***	1.4588***	1.1880***	1.9012***
	(0.3087)	(0.2970)	(0.3409)	(0.3121)	(0.3183)	(0.3974)
Lngdpsq	-0.0432**	-0.0530***	-0.0436**	-0.0661***	-0.0464**	-0.0889***
	(0.0198)	(0.0187)	(0.0217)	(0.0199)	(0.0202)	(0.0252)
ECI	0.1309	0.1616*	0.1615	0.2501**	0.1581	0.2966***
	(0.0996)	(0.0958)	(0.0994)	(0.1055)	(0.0990)	(0.1115)
Energypc	0.0005***	0.0005***	0.0005***	0.0005***	0.0005***	0.0005***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Envtax	0.4169***	0.4250***	0.4255***	0.3920***	0.3996***	0.4361***
	(0.0749)	(0.0741)	(0.0801)	(0.0744)	(0.0747)	(0.0836)
Tradepergdp	0.0051***	0.0051***	0.0053***	0.0053***	0.0050***	0.0057***
	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)
Natrentpergdp	0.0216**					
	(0.0097)					
Oilrentgdp		0.0473***				0.0942***
		(0.0161)				(0.0283)
Gasrentgdp			0.0714			-0.0042
			(0.0570)			(0.0950)
Mineralrentgdp				-0.1160		-0.1582*
				(0.0747)		(0.0803)
Forestrentgdp					0.0506	-0.1272*
					(0.0335)	(0.0753)
Constant	-5.9406***	-6.6395***	-5.6151***	-6.6245***	-5.7954***	-8.7287***
	(1.2821)	(1.2645)	(1.3949)	(1.2986)	(1.3242)	(1.6087)
Observations	180	180	180	180	180	180
R-squared	0.9624	0.9631	0.9616	0.9618	0.9618	0.9644

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

4.2. Sensitivity analysis

Regarding the OLS limits discussed before, the two-step system GMM estimation strategic and panel quantile regression are used to reinforce the power of the baseline findings. Results are displayed in Table 5. Regarding the Hansen test results, this empirical analysis demonstrates that the model estimated through the two-step system GMM is not over-identified. More so, regarding the Sargan test of overidentifying restriction, instruments are valid, exogeneity conditions is valid and uncorrelated with the error term. The diagnostic test also shows that the number of instruments is lower that the total number of observations, P-value of the AR(1) is significant and nearly equal to 0, and AR(2) is up to the prescribed limit of significancy. The AR(2) results suggest that the model doest not suffer from second order serial autocorrelation. The lagged dependent variable is positive and strongly significant at 1%. This finding reveals that the past level of pollution emission have an influence on the current level of pollution.

Likewise, Pooled OLS executed with Driscoll-Kraay estimation method, and the non-parametric estimation method that is panel QR (Koenker & Bassett, 1978) are realized in further sensitivity steps and results are presented in Table 6. From the Pooled OLS, we also introduce additional control variables that strenghten the estimated results and keep them in the QR analysis. Different hypothesis are therefore examined with the introduction of FDI inflows, R&D, inflation as well as the use of internet by the population. Before discussing the effect of introducing additional control variables, it should also be noted that the main appeal of using QR it that this methodology is more robust than OLS in that it is less affected by outliers in data than least-squared regression. More so, QR gives informations about the shape of a distribution, in particular whether a distribution is skewed or not. The interest is to determine a causal relationship beyond the mean-to-mean effects. Pooled OLS with additional control variables as well as 10th, 25th, 50th, 75th and 90th quantiles are consistent with the previous estimates. A comparative analysis reveals that the results are heterogeneous among different quantiles and that upper quantiles (75th and 90th) are the ones that present the most higher GDP coefficients. These methods are confirming the fact that Asia-Pacific countries are on a green development path.

For these results, estimated coefficients levels of control variables are given only for Driscoll-Kraay regression (column 1). Meanwhile, we will mention the other columns where the coefficients are significant. For the Asia-Pacific countries with Pooled-OLS model and QR approaches, the pollution Haven hypothesis is confirmed given that the effect of FDI (resp. R&D) on the environmental quality has been found positive but statistically significant except for estimated parameters [columns (4 and 6)] (resp. [Columns (1, 2, 3, 4 and 6)]. The estimations have the following impacts for Pooled OLS results : First, a 1% increase within the FDI process may bring up the pollution level with an average share of 0.05% (resp. 0.9%). FDI results are consistent with that of Lau et al. (2014) and R&D findings are similar with Ramos et al. (2018). Second, a 1% hike of the income taxation process may improve the green development path by 0.46%. Third, Internet and inflation are improving the green development path and for Pooled OLS regression, the result is significant at 1% level. Our findings present some similarities with that of Tchapchet-Tchouto (2023b).

Table 5 : Green development path measurement with system GMM

	Dependent Variable Carbon Emission Index				
VARIABLES	(1)	(2)	(3)	(4)	(5)
Lagged (CO2 per capita Index)	0.6427***	1.3607***	0.9945***	1.5271***	1.1836***
	(0.2304)	(0.1820)	(0.0714)	(0.2786)	(0.2474)
Lngdp	1.9468*	1.9730***	1.0628**	0.1099	0.9616
	(1.0988)	(0.7247)	(0.4554)	(0.4187)	(0.7367)
Lngdpsq	-0.1025*	-0.1107***	-0.0545**	-0.0089	-0.0493
	(0.0586)	(0.0405)	(0.0240)	(0.0226)	(0.0385)
ECI	-0.4529*	-0.1571*	-0.2367**	0.0271	-0.1722
	(0.2420)	(0.0892)	(0.1119)	(0.0936)	(0.1054)
Energypc	0.1398*	0.1088	0.0335	0.2070*	0.0000219
	(0.0814)	(0.1007)	(0.1538)	(0.1203)	(0.0000214)
Envtax	0.1832*	-0.1053**	0.0278	-0.0558	-0.0481*
	(0.1002)	(0.0534)	(0.0338)	(0.0444)	(0.0255)
Tradepergdp	-0.0002	-0.0002	-0.0003**	-0.0000	-0.0005
	(0.0001)	(0.0003)	(0.0001)	(0.0001)	(0.0009)
Natrentpergdp	0.0039				
	(0.0057)				
Oilrentgdp		-0.0458**			
		(0.0185)			
Gasrentgdp			0.0613		
			(0.0446)		
Mineralrentgdp				-0.0727**	
				(0.0367)	
Forestrentgdp					-0.0070
					(0.1186)
Constant	-9.7623*	-9.2183**	-5.1182**	-1.9624	-4.4432
	(5.4626)	(3.5913)	(2.4010)	(2.3326)	(3.4555)
Observations	171	171	171	171	171
Number of id1	9	9	9	9	9
AR(1)	7.24e-06	0.00403	0	2.48e-06	1.73e-08
AR(2)	0.105	0.172	0.804	0.123	0.649
Hansen	1	1	1	1	1
Sargan	0.476	0.135	0.932	0.866	0.102
Number of Instruments	32	56	64	48	80

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Table 6 : Robusness check with Discoll-Kraay and Panel Quantile Regression

	Dependent variable : carbon emission per capita index					
VARIABLES	Pooled OLS	Quantile 10th	Quantile 25th	Quantile 50th	Quantile 75th	Quantile 90th
Lngdp	0.57686***	0.21917***	0.36956***	0.52068***	0.93998***	1.15940***
	(0.07414)	(0.07649)	(0.09034)	(0.13103)	(0.24521)	(0.13624)
Lngdpsq	-0.02822***	-0.00844	-0.01315**	-0.02170**	-0.05268***	-0.06834***
	(0.00630)	(0.00510)	(0.00602)	(0.00873)	(0.01634)	(0.00908)
ECI	-0.10048***	-0.13416***	-0.16446***	-0.14411***	-0.08772	0.00910
	(0.03302)	(0.02395)	(0.02829)	(0.04103)	(0.07679)	(0.04266)
Energypc	0.00002	0.00003*	0.00001	-0.00001	0.00008*	0.00004
	(0.00003)	(0.00001)	(0.00002)	(0.00002)	(0.00004)	(0.00002)
Envtax	0.03593	0.05318***	0.09085***	0.09078***	0.01896	-0.00988
	(0.02541)	(0.01691)	(0.01997)	(0.02896)	(0.05421)	(0.03012)
Tradepergdp	-0.00084**	-0.00070***	-0.00063***	-0.00078***	-0.00037	-0.00066**
	(0.00040)	(0.00015)	(0.00018)	(0.00026)	(0.00049)	(0.00027)
Oilrentgdp	0.06242***	0.06771***	0.07167***	0.06731***	0.05848**	0.04827***
	(0.01026)	(0.00769)	(0.00908)	(0.01317)	(0.02465)	(0.01369)
Gasrentgdp	0.00331	-0.00925	-0.00825	0.01436	-0.01489	-0.01533
	(0.02910)	(0.01788)	(0.02112)	(0.03064)	(0.05733)	(0.03185)
Mineralrentgdp	0.00235	-0.02955**	-0.01544	0.00204	0.00258	-0.05203**
	(0.02046)	(0.01255)	(0.01483)	(0.02150)	(0.04024)	(0.02236)
Forestrentgdp	-0.00324	-0.02726**	-0.03103**	-0.01884	-0.00036	0.02339
	(0.02882)	(0.01307)	(0.01544)	(0.02239)	(0.04190)	(0.02328)
Fdingdp	0.00555	0.00184	0.00248	0.00638*	0.00157	0.01357***
	(0.00388)	(0.00201)	(0.00238)	(0.00345)	(0.00645)	(0.00359)
Resdev	0.09419***	0.02876*	0.03424*	0.06546**	0.07084	0.17533***
	(0.03166)	(0.01640)	(0.01937)	(0.02810)	(0.05259)	(0.02922)
Taxrev	-0.04662***	-0.03916***	-0.04498***	-0.04363***	-0.06577***	-0.04523***
	(0.00416)	(0.00361)	(0.00427)	(0.00619)	(0.01158)	(0.00643)
Inflation	-0.01340***	-0.00600**	-0.00713**	-0.01094**	-0.01211	-0.00772*
	(0.00219)	(0.00253)	(0.00299)	(0.00433)	(0.00810)	(0.00450)
Internet	-0.00518***	-0.00219**	-0.00358***	-0.00470***	-0.00509*	-0.00655***
	(0.00174)	(0.00086)	(0.00101)	(0.00147)	(0.00275)	(0.00153)
Constant	-1.79080***	-0.42491	-1.19303***	-1.81410***	-2.91783***	-3.84237***
	(0.29633)	(0.31065)	(0.36690)	(0.53215)	(0.99590)	(0.55332)
Observations	140	140	140	140	140	140
R-squared	0.84646					
Number of groups	7					

Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Pooled OLS is applied with Driscoll-Kraay standard errors. Panel Quantile is applied at conditional quantiles.

5. Conclusion

Structural transformation, green economic expansion and great improvements in sustainability challenges are at the core of Sustainable Development Goals in the context of fast-growing countries such as Asia-Pacific economies. The on-hand study is an effort to explore how green is the path of their economic development by proposing an interpretation of the structural transformation decomposition through its main characteristics: the implication of economic complexity that set up the importance of the need for factors that can predict change in economic structure such as knowledge process, diversification and technological sophistication (1), NRs that support economic expansion and population growth (2), energy consumption dimension (3), international trade that accounts for competitiveness capabilities and also exchange of sophisticated goods between countries, international movement of technology (4), and the challenge that goes beyond economic growth to the decrease of environmental degradation. To achieve this objective, this study has utilized the quadratic framework developed by Kuznets (1955) and popularized by Grossman and Krueger (1995) to bridge the research gap. In doing so with this demonstration, this study draws novel contributions and implications regarding the sustainable growth path. This research has attempted to establish the nexus among an environmental sustainable indicator (environmental quality index) and a strategy of defining or interpreting the ESC factor. This ESC is characterized as a composite of economic growth, economic sophistication, natural resources, trade, energy consumption and environmental policy tool for 9 Asian-Pacific countries. In doing so, the study utilized data from 2000 to 2019 and employed Ordinary Least Squares, two-step system-GMM, Driscoll-Kraay and Panel Quantile Regression estimations strategies under different specifications (alternative dependent variable and additional control variables). Findings evidenced that Asian-Pacific countries green development path in a context of structural transformation is characterized by a consistent inverted U-Shaped structure. The main limitation of this study can be related to the sample size and its regional application cannot provide a global perspective. As all pionner studies, this study leads many research perspectives and the four first main strands could be as follows: as soon as data will become available for all Asian-Pacific countries, it might be interesting to enlarge the panel sample (1). On another length, future reseach directions could explore the possibility for computing the composite ESC factor through different statistics calculation techniques[5]. By doing so, each component of this factor will be proportionally weighted (2). From this starting point further studies could also construct an energy composite deriving from a matrix of different types of energy that complied with COP28 agenda and fulfillments (3). Considering that this study is a pionner given the novelvy and contribution in Asia-Pacific that occupies and plays an important role in the world economy from international trade, technological innovation, high tech and growth perspective, it could be also interesting as research perspective to replicate the same in a panel of some leading countries from developing countries (America or Africa continent) that are also characterized by their regional leadership in growing fast economically (eg. In Africa: Botswana, Rwanda, Uganda, South Africa, Kenya, Egypt, Senegal, Tunisia, Morocco, Ivory Coast… Etc.), associates to a particular social, political stability and institutional transformation features (3). By initiating these new research areas.

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[5] Arithmetic mean, Principal Component Analysis, Entropy, Herfindahl Hirschman Index computation for examples.

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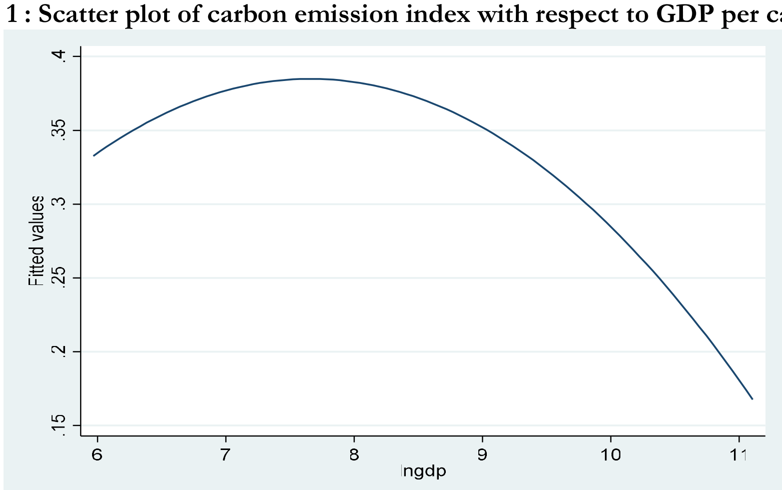
Appendix

Table 7: Variables and Sources of Data

VARIABLES	Definitions	Sources
Gdp per Capita	Gross Domestic Produc Per Capita	**WDI Data Base (2021)**
Gdp per Capita Square	Gross Domestic Produc Per Capita Square	**Author calculation**
Energy per capita	Energy per Capita	**WDI Data Base (2021)**
Env. Taxes	Environmental Taxes	**OECD Database (2021)**
Trade	Trade	**WDI Data Base (2021)**
Total NRR	Total natural resources rent (incl. oil, forest, gas & coal, as a percentage of GDP)	**WDI Data Base (2021)**
Tax revenu	Taxes on revenu in percentage of GDP	**WDI Data Base (2021)**
Research & Dev.	Research and Development	**WDI Data Base (2021)**
Internet	Population access to Internet	**WDI Data Base (2021)**
FDI	Foreign Direct Investment Inflows	**WDI Data Base (2021)**
Ecofootprint	Ecological Footprint per capita	**Global Footprint Network database (2022)**
CO2 Emission	Carbon Emission per capita Index	**WDI Data Base (2021)**
ECI	Economic Complexity Index	**MIT's Observatory of Economic Complexity (2021)**

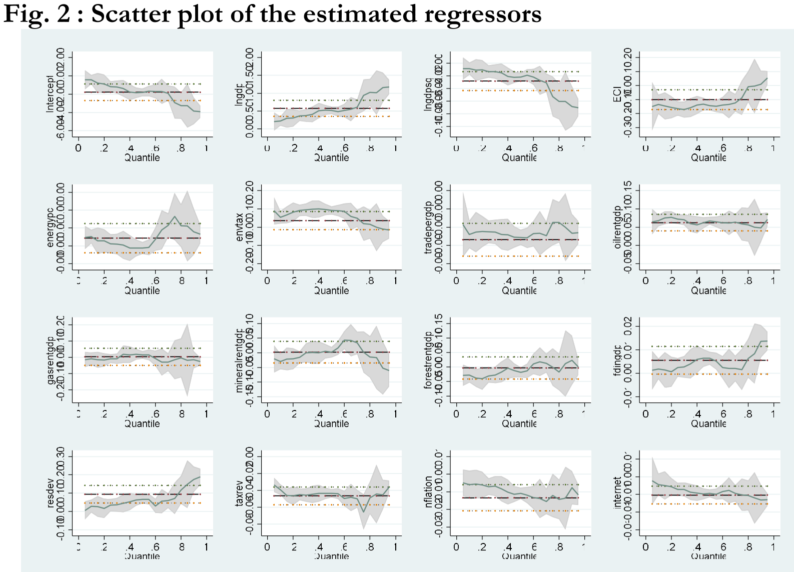
Source : Author's construction

Fig. 1 : Scatter plot of carbon emission index with respect to GDP per capita



Source : Author's construction

Fig. 2 : Scatter plot of the estimated regressors



Source : Author's construction