The Triplet Link of Carbon Emission, Economic Development, and Income Inequality: A Global Panel Model Perspective

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Abstract: The paper analyzes a triplet link between carbon emission, economic development, and income inequality. Carbon neutrality, or even reductions, have often been viewed as costly economic endeavor, and carbon inequality is known for having a link with income inequality. Through a global panel data set, we show that carbon emission can be reduced without slowing down economic development or increasing inequality. More specifically, we find that carbon emissions are likely to decline in economies that are widely diversified in terms of production and exports, and that have achieved more equal income distribution. The finding might prove relevant for policymakers who need to tackle multiple challenges – development, sustainability, and inequality – in a simultaneous way, in both developed and emerging economies.

Keywords: Carbon neutrality; Economic complexity; Income inequality; Veblen effect; Pareto improvement

Classification: Q56, F18, F64

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1 Background

The link between economic development and income inequality is key in development studies, with findings indicating a complex relation that changes across stages of development. For example, although inequality gaps tend to widen in the early phases of industrialization, these tend to reduce in late or post-industrialization stages, as material and cultural factors make it easier to redistribute resources across various segments of the society and meet the demands from different income groups.

With several economies entering a post-industrial phase, in which quality of life is increasingly important, the problem of environmental degradation became fully embedded to the indicators of economic development. Since then, research has focused on the relationship between economic development and carbon emission, a proxy of environmental degradation (Al-mulali *et al.*, 2013; Huang *et al.*, 2008; Ozturk and Al-Mulali, 2015; Ji *et al.*, 2022; Piñero *et al.*, 2019). On the other hand, studies started to also explore the link between income inequality and carbon emissions.

Recent contributions have attempted to bring the three dimensions together, although this was done mainly with empirical analyses that focus on specific countries or world regions (Abdon and Felipe, 2011; Al-mulali *et al.*, 2013; Alvaredo and Gasparini, 2015; Basu and Stiglitz, 2016; Choi *et al.*, 2010; Fang and Wolski, 2021; Ferraz *et al.*, 2018; Oshin and Ogundipe, 2014; Palma, 2011; Wolde-Rufael and Idowu, 2017; Zhang, 2018). For the first time, this research investigates the triplet link on a global scale, by using panel data of 125 countries, from 1964 to 2017. The global dimension of this research provides new insights on the relationship between the variables investigated – carbon emission, economic development and income inequality – as new comparison among countries can be drawn.

The Environmental Kuznets Curve (EKC) proposed by Dinda (2004) is a seminal study in the field exploring the economic development vs. carbon emission nexus. It shows that the environmental cost of development is an inverted U-shape function of development. More specifically, the model argues that carbon emissions grow in the initial stages of economic development, particularly during the process of industrialization, while declining in correspondence of the transition to more developed stages of development. This has been explained by subsequent studies as determined mainly by advances in technology, namely by the so called "technological effect" (Ajmi *et al.*, 2015; Aung *et al.*, 2017; Balibey, 2015; Can and Gozgor, 2017; Choi *et al.*, 2010; Oshin and Ogundipe, 2014; Özokcu and Özdemir, 2017; Zhang, 2018). In other words, the productivity increase led by advances in technology entails that for a given level of output fewer inputs are required, including polluting raw materials among others.

Subsequent studies have built on this and found that other important factors explain the reduction of carbon emission at developed stage of development. The main are de-industrialization, higher sensitivity towards the quality of the environment, higher tolerance of the costs deriving from stringent green policies and regulation.

Nevertheless, several studies have found empirical evidence that Environmental Kuznets Curve (EKC) theory does not always hold (Can *et al.*, 2020; Doğan *et al.*, 2019, 2021; Li *et al.*, 2021). This mixed evidence has led research to slightly change the perspective and focus increasingly on a specific aspect of development dynamics, namely the income level of specific groups. The relation between carbon emission and income inequality has revealed a multifaceted reality, in which cultural aspects and consumption behavior of different income groups at different stages of development are relevant and may affect carbon emission as much as the "technological effect" would do.

For example, studies show that income inequality is positively correlated to carbon emissions (Teng *et al.*, 2011; Cantore and Padilla, 2010; Duro and Padilla, 2006; Heil and Wodon, 2000, 1997; Padilla and Serrano, 2006). One of the drivers of this trend is attributed to the behavior of low-income groups, which, in unequal societies, consume aggressively to emulate the rich, signaling their social status albeit this is not necessarily optimal for their welfare. The phenomenon is called Veblen effect (Bagwell and Bernheim, 1996; Fassnacht and Dahm, 2018; Veblen and Mills, 2017; Hodgson, 2004, 2007; Tool, 2005), and it is associated to inefficient energy consumption and higher carbon emissions. Consumption emulation is generally hard to measure due to a lack of comprehensive consumption data. Studies have argued that the result of Veblen effect is the worsened indebtedness of household (Bagwell and Bernheim, 1996; Davanzati and Pacella, 2010; Setterfield and Kim, 2016). Such consequences provided us with tools to test the role of Veblen effect in our conjectured framework.

The Veblen effect exists at each stage of development, although in newly industrialized economies is very relevant, as certain consumption behaviors are common in both low-income groups who attempt to emulate high income groups, but also among newly emerged high-income groups, which represent a remarkable share of the population in emerging economies (Frank *et al.*, 2014; Basmann *et al.*, 1988; Basmann, 1985; Wilk, 1998). Differences in levels of carbon emissions exist also within developed economies, not only because of supply side factors such as the energy-intensity of industrial sectors (Ji *et al.*, 2022; Searchinger *et al.*, 2018), but also as a result of the Veblen effect, and other factors related to consumption behavior such as consumption habits and reliance on private transportation. The paper argues that this missing role can be a crucial puzzle to reconcile the inconsistent effect of economic complexity of environmental degradation.

This paper bridges the two above-mentioned bodies of literature on (i) the economic development vs. carbon emission nexus, and (ii) on the link between income inequality and carbon emissions. The research question addresses the problem of the extent to which "technological effect" and "Veblen effect" offset each other, one prevails the other, or working in coherence, explaining different carbon emissions trends across countries at different stages of development.

The paper finds that "technological effect" occur relatively consistently across our global data set. In other words, as countries industrialize and realize a transition to more developed stages of development, carbon emission are lower. This trend may have faced challenges in recent years or those most developed in terms of economic structure. Furthermore, the findings also confirm the importance of the "Veblen effect" as a counter force, and how this occurs mainly in presence of high-income inequality. In emerging economies, the "Veblen effect" seems to be part of a wider mechanisms in which inequality, consumption behaviors and challenges to economic development fuel each other, posing obstacles to the transition to a more virtuous circle. In developed economies, the "Veblen effect" is also caused by inequality, but its entity is rather negligible, as carbon emissions are likely to result from different types of consumption habits and the industrial structure of the economy. Into the 21st century, nevertheless, the developed economies may have to rely more on the Veblen effect to achieve carbon reduction goals.

The research relies on the Economic Complexity Index (ECI) and the Gini index to explore in each country the stage of development and level of inequality, respectively. ECI measures the diversification of a given economy's export, on the basis of specific categories of goods and services (Hidalgo and Hausmann, 2009). It is an indicator of economic diversification and flexibility of production measured in terms of export compositions, in addition to resilience to various economic shocks. It is thus representative of the quality and level of economic development, and it is a plausible proxy to test for EKC theory about carbon levels across stages of development. The combination of the two indexes (ECI and Gini) makes it possible to explore the triplet link of – carbon emission, economic development and income inequality. This combined approach might prove insightful for policymakers who have to address these challenges in a simultaneous way.

The paper is structured as follows. Section 2 discusses the choice of the methodology, methods of data collection, and the hypothesis. Section 3 discusses the findings, also in light of previously formulated hypotheses. Section 4 concludes the paper and provide policy suggestions.

2 Methodology and Data

Before we propose our hypothesis and model, we briefly describe our motivation, data collection and present descriptive analysis. The data we use is a fusion of information from multiple sources. The data on GDP, government effectiveness evaluation, income groups and region categorization is collected from the World Bank database (World Bank, 2022b,a). The carbon emission data is obtained through UNdata (2018). Our panel includes the annual data points for 125 countries, from 1964 to 2017. The data points are not well balanced, especially with the Gini index and government efficiency. Thus, a model with the Gini index as regressor usually has 4,034 samples for the entire panel. The number falls to 1616 for data with government efficiency, thus can only serve as robustness tests for economies that are less afraid to report government efficiency. Some auxiliary regressions in this paper leaved the Gini index out, and therefore contains 5316 samples to work with.

2.1 Motivation

The discrepancies in the change of carbon emission and GDP on both total and per capita level have suggested extra factors in their dynamics. Figure 1 illustrates a deceptive relationship between GDP per capita and carbon emission per capita, colored by income groups. The reasons why it is deceptive lies in the following Figure 2 to Figure 5. In Figure 2, the increment for the per capita emission in North America, Europe and Central Asia are almost unrecognizable, even dropping in recent years. East Asia Pacific, Middle East and North Africa areas realized massive increase in average carbon outlet during the decades. The trend does not hold strongly for the per capita income according to Figure 3. While an observed increment in the average GDP in these leading carbon emitter nations is no surprise, the fact that per capita emission has changed non-proportionally with income is beyond explanation. Even if we use descriptive statistics in a total-amount fashion, the numbers still fail to add up (Figure 4-5). This series of discrepancies points to some unconsidered factors. We suspect that there are other macroeconomic perspectives that can help explain the dynamics.

2.2 ECI Data

One of the key variable to be included in the framework is the economic complexity. The economic complexity here is proxied under the presumption that a good representation of economic complexity of an economy is the embodiment of its diversity in production, therefore export. The natural choice of such is the ECI from Hidalgo and Hausmann (2009). A higher ECI implies a higher diversification in categories of an economy's export list. A diversified export list brings about the diversity in the income of an economy's individual consumers. The data is obtained from The Growth Lab at Harvard University (2019) and the measure is calculated according to . The data is obtained from

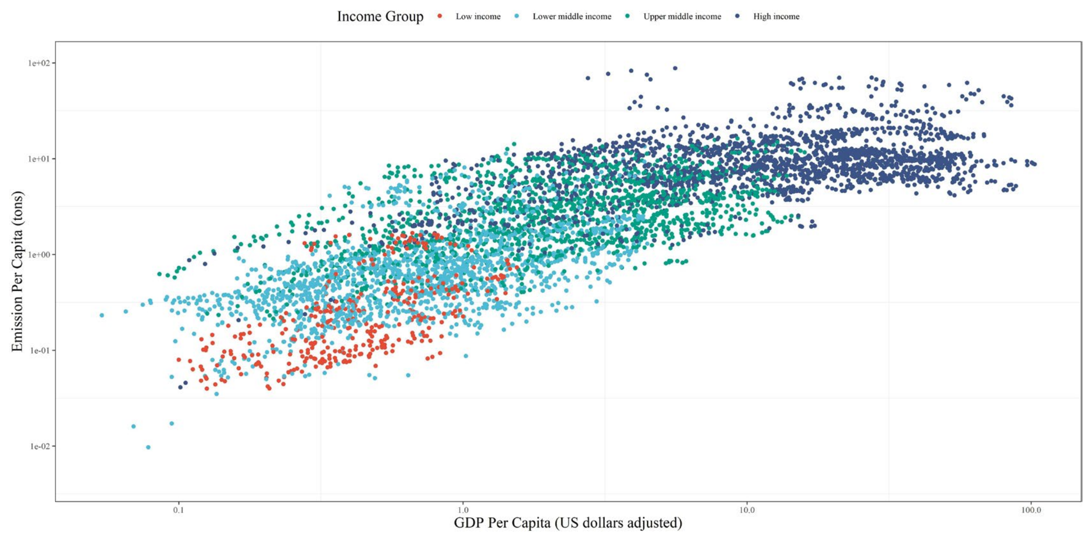

Figure 1: Per capita GDP vs. Per capita Emission by Income Groups

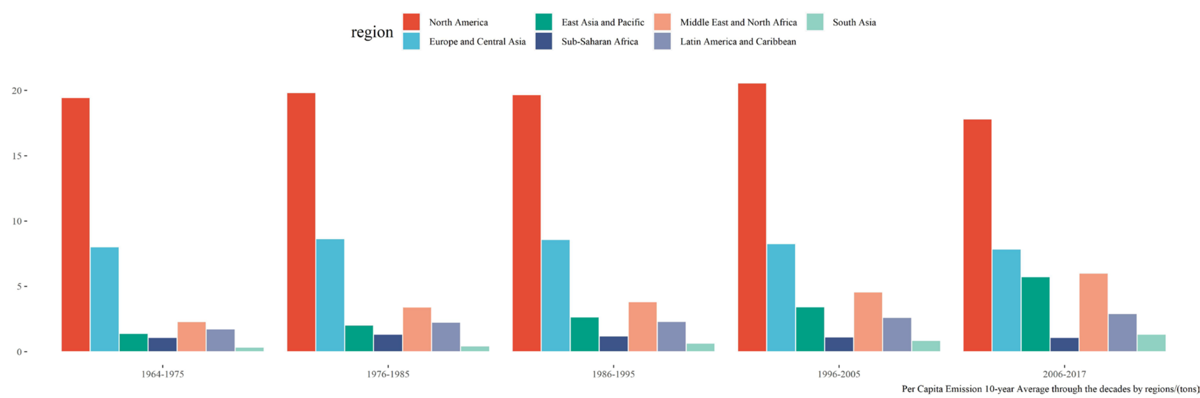

Figure 2: Per capita Emission 10-year Average through the Decades by Regions

the said site on a older version, thus dated way back compared to the currently available data on the site. The ECI level ranges between -2.25 and 2.5 for our entire panel sample. A negative note simply means an extreme lack of diversity in an economy's export repertoire. If we view the period as the time horizon of a social experiment, the ECI level serves as a semblance of initial

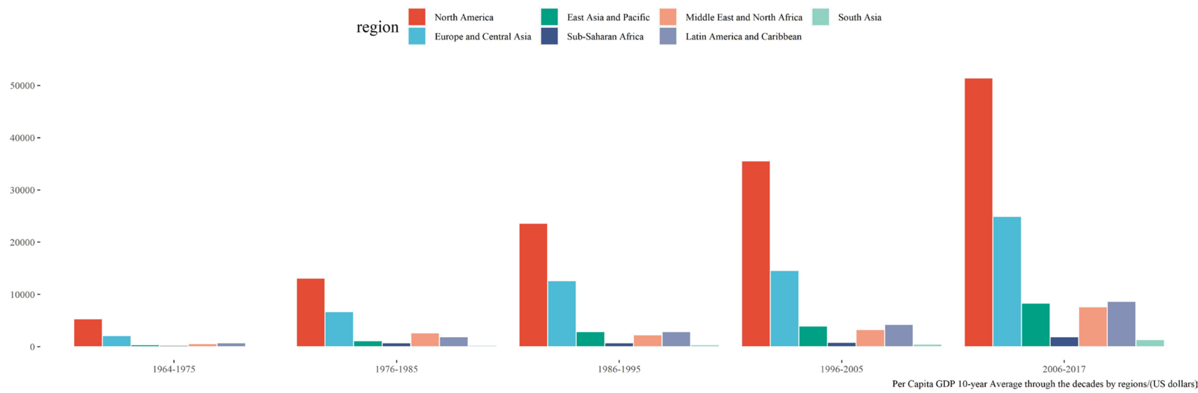

Figure 3: Per capita GDP 10-year Average through the Decades by Regions

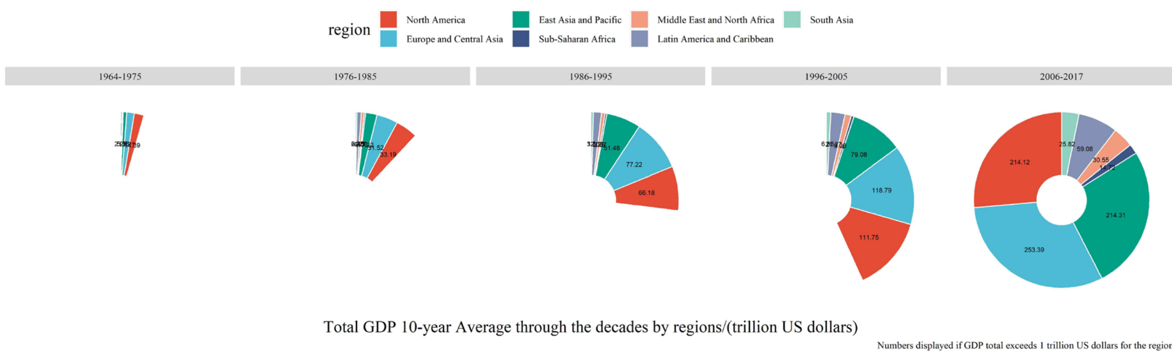

Figure 4: Total GDP 10-year Average through the Decades by Regions

condition or endowment for each country. For an average high-income country, the mean of its ECI is 0.92 for the past two decades, and 0.89 for the thirty-four years before that. The numbers for the middle-income countries and low-income countries can be found in Table 1 and are all below zero.

In the recent two decades, situation has improved for the upper middle-income countries and high-income countries and is further worsen off for the relatively less wealthy nations. When we look at this trend in the increasing gap from the perspective of regions, we can see from Table 2 that East Asia Pacific and North America are the only two regions with improved ECI over the

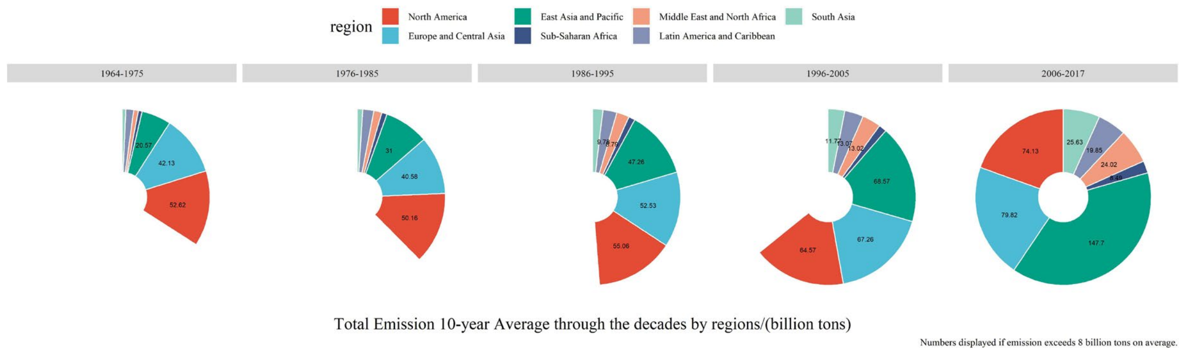

Figure 5: Total Emission 10-year Average through the Decades by Regions

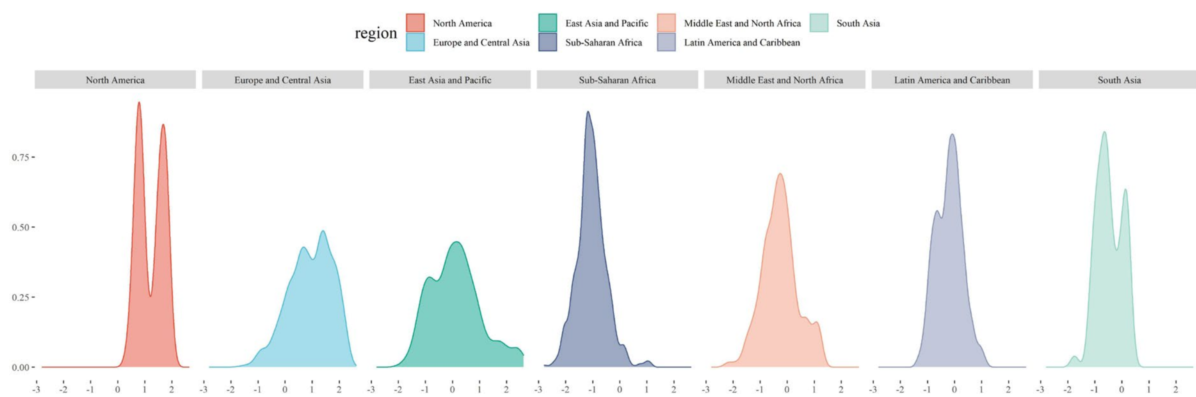

Figure 6: Across Time Distribution of the ECI by Regions

recent two decades. This gap in export diversity is another factor that renders the economy so different from each other, apart from plain GDP numbers and income inequality. Figure 6 gives more information in terms of across time distribution of the ECI for each region, and the regional advantage remains to be obvious.

2.3 Income Inequality Data

To introduce income inequality into our discussion, we resort to the Gini index. The income Gini index contains the crucial information about income distribution among market participants in an economy. As argued by (Cobham and Sumner, 2013), Palma measure of income inequality, by taking into account the top 10 percent and bottom 40 percent of the households, can reflect more explicitly the status of inequality. Data accessibility constraints, however, undermine the usability of the Palma measure, since the missing required data for its calculation is usually the same reason why the Gini index data is unbalanced. Since the two measures work virtually the same, the Gini index is sufficient for our analysis. The data source of the Gini index is mixed, for good reasons. The World Bank database possessed information about income distribution globally, which indeed gave us good reference for several years. Throughout most of our observation period, however, this source alone leaves us a highly unbalanced panel to work with. To complement for the data integrity, we resort to two extra sources, University of Texas Inequality Project (2015) (Galbraith *et al.*, 2015a; Galbraith and Kum, 2005; Galbraith *et al.*, 2015b; Solt, 2016) and World Income Inequality Database (UNU-WIDER, 2022).

The UTIP provides an estimated data on the inequality data based on Theil's T statistic. In principle, the estimation of this inequality indicator takes into account the population, industry pay, and income gap (Galbraith *et al.*, 2015b). Apart from filling in the missing values for some countries within our panel, it also provides more information beyond the scope of Gini index constructed by estimating the discrepancies between the income allocation and demographic distribution (Conceicao and Ferreira, 2000). After scaling, the data is compatible to be joined and used with the Gini index. The UTIP data made for losses of around 600 data points, aside from adding to the reliability of existing data.

WIID offers, though unbalanced, multiple sources for the analysis of income inequality. It gathers both data from the World Bank survey, but also surveys performed by the demographical department of local government, among some other surveys. Each entry, with some exceptions, usually comes with a survey quality score. The importance of the score is not negligible, since the distribution of it, through kernel estimation, does not show normality and displays left-skewness for all income group data.

To attend to the reliability of all surveys, we summarize the weighted average of the Gini index based on survey quality whenever possible, before averaging between the UTIP data if available. The main conclusions of this study are based on the weighted average Gini index to cope with the data contamination. To add to the robustness and consider the difference of the Gini index and the Theil's T index, we checked the result when using solely the data from the WIID. During the course of this robustness check, Gini index is calculated as the arithmetic mean of all entry of the time point at a certain nation. The model result, after verification, is not much different in coefficient direction or significance. A collateral benefit of this method is that it helped reduce the unbalanced nature of our data and improved the goodness of fit. We hereafter refer to our inequality index computed using the merge information from the Gini index and UTIP data as the adjusted Gini index for simplicity.

Hartmann *et al.* (2017) proposed that on a global scale, ECI is in negative correlation with the Gini index. Our data on the Gini index verifies this proposition in a sense. Inequality situation for different regions differs in mean level as it is with ECI and is not normally distributed across time. Decomposing the data into income groups throughout the decades, we can see that, though slight, a decrease in inequality has happened across all income groups, except the high-income group (Table 3 - 4 and Figure 7).

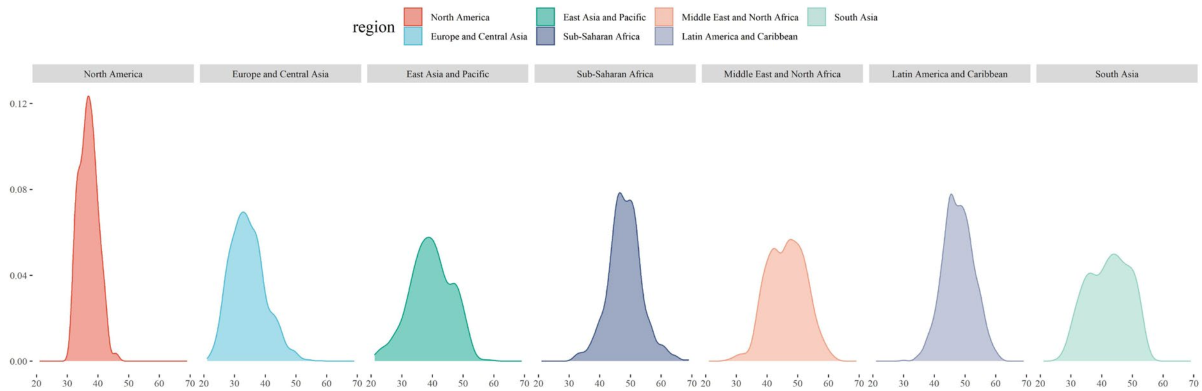

Figure 7: Across Time Distribution of the Gini by Regions

2.4 Robustness Tools

Government effectiveness variable originates from a comprehensive survey initiated by Worldwide Governance Indicators project (WGI), which conclude with a score measuring various sources of opinions on each government with regards to aspects such as civic service quality, independence, regulatory quality, rule of law (Kaufmann *et al.*, 2010; World Bank, 2022a). The score is standard-normalized to range roughly between -2.5 and 2.5.

Since Veblen effect is linked with consumption emulation and indebtness of consumers (Bagwell and Bernheim, 1996; Davanzati and Pacella, 2010; Setterfield and Kim, 2016), we collect household loan and debt data from Global Debt Database (GDD) (Mbaye *et al.*, 2018). The variable we used is household loan and debt as a ratio of GDP, to suggest the burden to families, potentially due to consumption emulation. Debt data faces the similar problem as government efficiency does, due to a general lack of data. Samples with both government efficiency and debt data amount to a total number around 1600. To see how these two variable make the panel data unbalance, please refer to Table 5 Appendix Table A1 and A2.

Table 5 is the descriptive statistics for the key variables along the timeline. The timeline is divided into five decades, which will help us identify changes in time.

Table 1: ECI by Income Group

incomegroup	1964-1998	1998-2017
Low income	-0.855	-1.018
Lower middle income	-0.632	-0.749
Upper middle income	-0.23	-0.133
High income	0.892	0.922

Table 2: ECI by Region

region	1964-1998	1998-2017
North America	1.209	1.239
Europe and Central Asia	1.107	0.758
East Asia and Pacific	0.048	0.225
Sub-Saharan Africa	-1.034	-1.068
Middle East and North Africa	-0.227	-0.325
Latin America and Caribbean	-0.179	-0.241
South Asia	-0.395	-0.582

Table 3: Gini by Income Group

incomegroup	1964-1998	1998-2017
Low income	47.202	44.767
Lower middle income	46.334	44.576
Upper middle income	44.36	44.045
High income	36.195	36.394

Table 4: Gini by Region

region	1964-1998	1998-2017
North America	35.851	38.683
Europe and Central Asia	33.985	34.708
East Asia and Pacific	38.945	40.092
Sub-Saharan Africa	48.366	47.838
Middle East and North Africa	45.512	47.5
Latin America and Caribbean	47.419	48.41
South Asia	41.757	43.228

2.5 Empirical Design and Hypothesis

The empirical study of the three factors revolve largely around panel model, ARDL, VECM, GMM estimation and their subordinates (Can *et al.*, 2020; Huang *et al.*, 2008; Hübler, 2017; Kijima *et al.*, 2010). Even for the most concise panel model, the question remains whether a fixed effect model or a random effect model should be developed, both of which haves their merits and is are unifiable under proper framework (Mundlak, 1978). A yet more applicable approach may be to choose not only based on the widely used Hausman test (Hausman, 1978), but also choose according to the characteristics of the data, by its amplitude of correlation and the size of the panel (Clark and Linzer, 2015).

We propose our hypothesis as follows:

- **H1:** ECI quadratically influence the carbon emission. The coefficient for the quadratic term reflect that development leads to reduction in carbon, i.e., technological effect exists.

- **H2:** The adjusted Gini index has positive impact on the carbon outlet, i.e., Veblen Effect exists.

Table 5: Descriptive Statistics

Variable	Year	Obs	Mean	Sd	Median	Min	Max
ECI	1964-1975	1125	0.017	0.995	-0.186	-2.09	2.353
ECI	1976-1985	972	0.008	0.992	-0.077	-2.476	2.261
ECI	1986-1995	1049	0.006	0.995	-0.1	-2.175	2.559
ECI	1996-2005	1172	0.007	0.997	-0.05	-2.408	2.625
ECI	2006-2017	1408	0.011	0.995	-0.087	-2.791	2.404
Emission Per Capita	1964-1975	1125	4.894	11.107	1.307	-0.02	100.969
Emission Per Capita	1976-1985	972	5.034	7.755	1.974	0.004	69.905
Emission Per Capita	1986-1995	1046	5.063	6.63	2.809	0.04	61.774
Emission Per Capita	1996-2005	1172	5.667	7.582	3.533	0.047	69.853
Emission Per Capita	2006-2017	1408	5.682	6.746	3.899	0.068	61.793
Gini	1964-1975	760	42.034	7.798	43.297	21.657	61.027
Gini	1976-1985	730	41.045	8.064	42.429	21.158	60
Gini	1986-1995	785	41.769	8.793	42.383	22.451	68.905
Gini	1996-2005	915	41.984	8.467	41.746	24.9	61.856
Gini	2006-2017	997	39.905	7.855	39.096	23.2	65.548
GDP Per Capita	1964-1975	947	1.357	2.017	0.529	0.054	26.848
GDP Per Capita	1976-1985	847	4.403	5.963	1.709	0.131	44.987
GDP Per Capita	1986-1995	990	6.419	8.886	1.753	0.095	48.717
GDP Per Capita	1996-2005	1168	8.505	11.875	2.58	0.112	66.836
GDP Per Capita	2006-2017	1400	15.512	19.354	6.166	0.195	102.96
GDP Growth	1964-1975	934	0.121	0.135	0.103	-0.755	1.226
GDP Growth	1976-1985	840	0.07	0.143	0.077	-0.832	0.938
GDP Growth	1986-1995	978	0.062	0.173	0.075	-1.396	0.788
GDP Growth	1996-2005	1167	0.065	0.126	0.065	-1.013	0.537
GDP Growth	2006-2017	1400	0.063	0.126	0.066	-0.506	0.783
Emission Per Dollar GDP	1964-1975	947	2.88	2.315	2.331	-0.062	25.055
Emission Per Dollar GDP	1976-1985	847	1.339	1.068	1.106	0.085	9.702
Emission Per Dollar GDP	1986-1995	993	1.411	1.729	0.832	0.085	13.67
Emission Per Dollar GDP	1996-2005	1168	1.345	1.764	0.746	0.112	15.345
Emission Per Dollar GDP	2006-2017	1400	0.567	0.551	0.386	0.055	6.907
HHLD	1964-1975	102	25.948	15.263	29.78	1.389	47.116
HHLD	1976-1985	147	32.734	14.781	32.885	5.391	60.771
HHLD	1986-1995	218	37.454	20.231	38.744	0.084	73.32
HHLD	1996-2005	495	32.422	28.71	22.68	0.183	110.595
HHLD	2006-2017	783	43.372	32.016	33.4	0.279	137.939
Government Effectiveness	1964-1975	0	NaN	NA	NA	NA	NA
Government Effectiveness	1976-1985	0	NaN	NA	NA	NA	NA
Government Effectiveness	1986-1995	0	NaN	NA	NA	NA	NA
Government Effectiveness	1996-2005	815	0.112	0.971	-0.12	-1.644	2.31
Government Effectiveness	2006-2017	1396	0.129	0.957	-0.035	-1.915	2.437

Emission Per Capita(T/Person), Emission Per Dollar GDP(T/ 1000 Dollar US), and HHLD is Household Loan and Debt.

Our choice of model is the panel model to accommodate the data, which uses ECI, quadratic term of ECI, and the adjusted Gini index as our main regressors. The adjusted Gini index is composed of Gini index data and similar inequality measurement to complement for missing data as described in the appendix. Control variables include GDP growth, GDP per capita, region dummies and income group dummies. Both dummies are given by the World Bank database.

To further analyze the development pattern of countries, we apply k-means clustering analysis to the ten yearly-phased data. As such, we aim to identify whether certain countries have similar traits in the triplet for each decade, thereby showing similarities in their trade-off decisions in terms of economic development and environmental preservation. If any economies jump to different clusters, the economy succeeded in altering the triplet characteristics, but the jump can be lasting or transitory.

We apply a series of panel models that use carbon emission per capita as the dependent variable. Some of the robustness test are done using carbon emission per dollar of GDP. The baseline model uses carbon emission per capita, in units of tons per person, as the dependent variable. The dependent variable is one period ahead of the independent variable. The robustness check models uses emission per GDP, in units of tons per 1000 US dollar adjusted, as the dependent variable. GDP per capita has units of 1000 US dollar adjusted. Gini index has unit of percent, e.g. 35 for some sample. Similarly, HHLD is measured as ratio of household loan and debts to GDP, in unit of percentage.

The baseline model is a panel model with the time fixed effect, where x_{it} denotes the vector of other control variables:

$$y_{i,t+1} = eci_{it}\beta_1 + eci^2_{it}\beta_2 + gini_{it}\beta_3 + \mathbf{x}'_{it}\beta + \theta_t + \epsilon_{it} \tag{2.1}$$

A crucial assumption here is that at least for a long time, climate change attracted not enough an amount of attention. The lack of worldwide attention may suggest that, for certain periods, time fixed effect may be the one that is relevant, rather than the individual effect. As the awareness rose in the past two decades, however, the individual effect can be more relevant, since country differs in their environmental policies and culture. This difference encourages us to look at models with both the time fixed effect and the individual fixed effect for the recent decade, where developed economies have more balanced data to model on.

$$y_{i,t+1} = eci_{it}\beta_1 + eci^2_{it}\beta_2 + gini_{it}\beta_3 + \mathbf{x}'_{it}\beta + \theta_t + \delta_i + \epsilon_{it} \tag{2.2}$$

Tests reported in Table 6 suggest that fix effect models outperform the random effect model and the pooling model. The random effect model is no better than pooling model according to Breusch-Pagan test. Nor does Hausman test support the random effect over the fix effect. All tests concur that the fix effect model is a better choice for our data. F test suggests we include the time fixed effect. We will hereafter focus on fix effect model framework, but refer to random effect models occasionally for the robustness of our baseline results.

Table 6: Test Statistics

Test	P_value
F test for time effects	0
Hausman Test	0
Lagrange Multiplier Test - (Breusch-Pagan) for unbalanced panels	0

To verify that missing out on the gini index can also lead to similar but misleading results, we introduce:

$$y_{i,t+1} = eci_{it}\beta_1 + \mathbf{x}'_{it}\beta + \theta_t + \epsilon_{it} \tag{2.3}$$

And to further verify Veblen effect, we introduce household loan and debt (HHLD) into the model in two ways: either to replace income inequality indicator in the model, or acts as an instrument in the panel model. The idea is that in the case of Veblen effect, consumption emulation and cascade happens (Veblen and Mills, 2017; Bagwell and Bernheim, 1996; Frank *et al.*, 2014), where consumption is not about the just the utility of goods for consumption, but the items you buy since richer people buy them. Veblen effects leads to two direct consequences, wasted goods and raised financial burdens. The former will inevitably lead to increased carbon emission per capita, while the later will be reflected in the instrument HHLD. The usefulness of such method is limited greatly by the amount of data available, to be more specific, as can be seen in Table A2, limited to developed economies. Nevertheless, it gives us an idea about how income inequality can lead to inefficient consumption via the form of in the form of intensified household debt burdens.

$$y_{i,t+1} = eci_{it}\beta_1 + eci^2_{it}\beta_2 + hhld_{it}\beta_3 + \mathbf{x}'_{it}\beta + \theta_t + \epsilon_{it} \tag{2.4}$$

$$y_{i,t+1} = eci_{it}\beta_1 + eci^2_{it}\beta_2 + \hat{gini}_{it}\beta_3 + \mathbf{x}'_{it}\beta + \theta_t + \delta_i + \epsilon_{it} \tag{2.5}$$

$$gini_{it} = hhld_{it}\alpha_1 + \mathbf{x}'_{it}\alpha + u_{it} \tag{2.6}$$

We have some models to test the robustness of results using emission per thousand US dollars adjusted of GDP. This idea serves two purpose: first, the result should more or less be similar to the previous ones; second, since the dependent variable measures also per dollar efficiency of energy, we may see different results in terms of how inequality works, since inequality may help utilitarian businesses to pool production together, thereby reducing per dollar emission while increasing the per capita income and carbon emission.

$$emitgdp_{i,t+1} = eci_{it}\beta_1 + eci^2_{it}\beta_2 + gini_{it}\beta_3 + \mathbf{x}'_{it}\beta + \theta_t + \epsilon_{it} \tag{2.7}$$

$$emitgdp_{i,t+1} = eci_{it}\beta_1 + eci^2_{it}\beta_2 + \hat{gini}_{it}\beta_3 + \mathbf{x}'_{it}\beta + \theta_t + \delta_i + \epsilon_{it} \tag{2.8}$$

$$gini_{it} = hhld_{it}\alpha_1 + \mathbf{x}'_{it}\alpha + u_{it} \tag{2.9}$$

And finally, we have government efficiency in our model to see if wise environmental policies can help reduce carbon outlets. Government can affect the policy efficiency directly, but intervention may cause disruption to amplify or suppress market's impact on carbon outlets. Thus we introduce both the efficiency term and its interaction terms with ECI terms. For the lack of data, this model can only help analyze what happens in the more developed economies in the recent years. We will run the baseline with the time fixed effect to keep setting in line with the baseline model, and the emission per capita model with both time and individual effect model.

$$\begin{aligned} y_{i,t+1} = {} & eci_{it}\beta_1 + eci^2_{i}\beta_2 + gini_{it}\beta_3 + efficiency_{it}\beta_4 \\ & + efficiency_{it} * eci_{it}\beta_5 + efficiency_{it} * eci^2_{i}\beta_6 + \mathbf{x}'_{i}\beta_i + \theta_t + \epsilon_{it} \end{aligned} \tag{2.10}$$

$$emitgdp_{i,t+1} = eci_{it}\beta_1 + eci^2_{i}\beta_2 + gini_{it}\beta_3 + efficiency_{it}\beta_4 + efficiency_{it} * eci_{it}\beta_5 + efficiency_{it} * eci^2_{i}\beta_6 + \mathbf{x}'\beta + \theta_t + \delta_i + \epsilon_{it} \quad (2.11)$$

We first run the aforementioned models based on the data set whose Gini index is built using a weighted average for all available Gini data. The weight is decided by the quality score of the data given by WIID. The WIID data will provide a weighted average for every available data point, before absolute averaging with all available Gini index data from UTIP at every data point. The result will be presented in Table 7 in the following section. To further improve robustness, we run the same models with Gini index computed as the arithmetic mean of all Gini index surveys data and UTIP data at every time point for a certain nation. The result is available in Table 8.

Lastly, we applied k-means clustering analysis to the ten yearly-phased , summarized panel data to find out whether clustering of similar countries in terms of the triplet changes during the five decades. First, we summarized the normalized mean of the carbon emission per capita, the ECI, and the Gini index for the five decades from 1964 to 2017. Then, the data, divided into five periods, undergoes K-means clustering analysis for each portion separately. The estimation of parameter k is obtained through the classic elbow approach and the Silhouette approach for multi-perspective analysis. We then create the data visualizations for the five periods and colored the countries consistently according to regions for better understanding of results. In addition, clusters are circled out by convex polygons on each ten-year sample graph.

3 Empirical Results

3.1 Panel Model Results

The results are visible in Table 7. Model (1) till (10) uses emission per capita as the dependent variable, among which (3) - (10) is our focus. Model (11) till (13) uses emission per dollar as the dependent variable

Model (3) is the simpliest fixed effect model and it turns out our variables of interests are significant. Specifically, ECI negatively, quadratically affects carbon emission per capita on $ECI \in [-1.25, 2.5]$, i.e., technological effect exists; meanwhile, Veblen effect is significant. Since the majority of samples has ECI larger than -1.5, and the developed economies generally have positive ECI as high as 1 or 2, the model suggests that most economies will have reduced emission per capita with improved economic development. Hypothesis 1 is thus verified in the simple case, and technological effect exists in general. The coefficient for Gini index remains positive and significant as well, suggesting that Hypothesis 2 is correct, and Veblen effect exists for these countries throughout this period. As can be seen in the following analysis, the impact of Veblen effect is economically significant, with each ten percentage points decrease in Gini index, half a ton of carbon emission per capita can be saved, roughly 10% of the world average.

To further verify the robustness of our basic model, cluster-robust standard error (CRSE) is introduced in model (5) to cope with heterogeneity and improve estimate efficiency. CRSE approach is efficient given that sufficient number of clusters exist and each cluster contains enough number of samples (Angrist and Pischke, 2009; Abadie *et al.*, 2017; Colin Cameron and Miller, 2015), which was satisfied here because of the sample size. CRSE approach strongly agrees with the findings of model (3). Adding to the reliability of model (3), random effect model (4) and the least-squares dummy variable (LSDV) model (2) agrees with model (3) on signs and significance of coefficients for ECI and Gini terms. We can also see in model (6) that models missing out the role of Gini index and quadratic terms of ECI can also lead to a similar result, even suggesting that growth can impact per capita emissions. Growth being significant is possibly an omitted-variable bias, which we briefly discuss in the next section.

The results so far contradicts recent studies arguing the absence of technological effect (Can *et al.*, 2020; Doğan *et al.*, 2021). The difference can be attributed to a different sample coverage in terms of countries and time period. To reconcile such difference, we thus turn to HHLD for further discuss how the framework respond to sample differences, the sample for which is more in line the past works in contradiction. Model(7) suggests that when household debt proxies for consumption cascade (Bagwell and Bernheim, 1996; Davanzati and Pacella, 2010; Setterfield and Kim, 2016) and emulation, increased debt leads to increases in emission. Although the coefficient has different signs, the aggregate impact of ECI follows a quadratic convex curve hitting bottom at around 0.8. This new estimate means that many developing economies, having ECI lower than 0.8, still enjoys the benefit of technological effect. Meanwhile, developed economies may suffer from further increased ECI, suggesting that developed economies may have exhausted the environment benefit from technological effect in the new era. The similar result holds true in Model (9) where we use HHLD as instrument for Gini index. Model (8) being very insignificant suggests that the lack of HHLD data for the developing economies hinders our analysis for them.

To note, model (8) and (9) agree that reduction in debt, or, consequently, inequality, can lead to statistically and economically significant reduction in emission per capita. HHLD as a proxy and instrument tells us that technological effect still holds for the developing economies and that

Veblen effect exists for economies in general. We should see that albeit lack of data, most models agree on the presence of Veblen effect.

Factoring in the influence of government efficiency, the government efficiency has a significantly negative coefficient, the Gini remains positively significant (Hypothesis 2 is still true). To iterate, samples before mid-1990s generally has no data on government efficiency and data for developed economies are more complete. The coefficients for the interaction terms is a bit more complicated. First, model (10) regards the coefficient of ECI and ECI^2 as insignificant on 5%. Second, the marginal effect on carbon emission per capita from ECI and ECI^2 interacting with a positive government efficiency is significantly negative on [-2.25, 2], significantly positive beyond 2. That effect is reversed if government efficiency score is negative. To note, the sample of this model is mostly from developed economies, with high 1 or 2 ECI and positive government efficiency score of 1 - 1.5. This means that for some economies, the technological effect is not working. Please refer to Table 5 and Appendix Table A3. Third, government efficiency has significantly negative coefficient.

Models with the emission per thousand dollars as dependent variable gives us some extra result, also showing us the role of government policy effectiveness from another perspective. Model (11) - (13) tells a different story for per dollar emission efficiency, where economies enjoy technological effect with positive ECI values. This result is accompanied by unanimously significantly negative effect of Gini index. Also, growth has a significantly negative effect on carbon per thousand dollars. All these results seems to suggest that the effect on per dollar emission efficiency is not the same as that for emission per capita. What they do agree with model (10) is that government efficiency has significant negative coefficients consistently.

Hypothesis 1 and 2 is evaluated as verified by the main model (3) - (5). Specifically, ECI negatively, quadratically affects carbon emission per capita, i.e., technological effect exists; meanwhile, Veblen effect is significant according to (3) - (5), (7), (9), (10). However, some models , (9) - (10), suggests that high ECI values with developed economies in recent years do not enjoy the significantly negative effect of ECI on carbon per capita, with some models suggesting the reverse of it with high ECI. Our results agrees significantly with technological effect Dinda (2004), where development reduces environmental harm, for developing economies. And results agree significantly with the Veblen effect (Veblen and Mills, 2017), while controlling for ECI and development metrics like growth and GDP per capita. Almost all our models under various settings agree with the scale of effects. As for other controlling variables, coefficients are significant and directions of them are as expected, as model (3) suggests. Model (3) - (5) mostly agree with coefficient significance and direction. GDP per capita usually has a significantly positive effect on carbon emission per capita, except for model (9). A possible reason is weak instrument problem, which is also visible if we check the R^2 of model (9). A similar situation happen when growth insignificant effect except for model (9) and (10). We incline to conjecture that a higher individual income leads inevitably to the increase in the carbon emission per capita. And for significantly positive effect of growth on carbon , the scale of effect is 0.03 tons per 1 percentage point, which is economically insignificant. Model (11)-(13) suggest that although in the past increase in average income may lead to some reduction in emission per dollar, this relationship is possibly reversed for developed economy. As for regions and income groups, every model agrees with strong significance some general statements. Ruling out all forces above, all regions emit less than the North America region, and all income groups emit more than the low-income group. With several comparably more fossil-fuel-concentrated economies, Middle East and North Africa region comes in second place and consumes 5 tons less per person each year. Our model recognizes little difference between low-income group effect and lower-middle-income group effect but suggests that a consumer in upper-income or higher-income countries consumes on average 3 to 8 tons more per person on a yearly basis.

As mentioned before, we verify the robustness of our results via different Gini index calculation standards. The above results are still valid in direction and significance. Please see Table 8.

3.2 Cluster Analysis Result

The results of cluster analysis are visible graphically in Figure 8-12. We project the mean of the ECI and the Gini during each period for each country on a Gini-ECI plane, with the size representing the median of emission per capita. In short, developing economies have potential development route allowing carbon emission per capita to go down, economy to develop, without compromising income inequality.

To be more specific, we see clustering of European economies and Japan. The greater majority of developing economies like Asia, Latin America, Middle East, and Africa are often clustered together. We observe, however, some economies trying to break free from the latter to the former in the past decades. From time to time, some rising economies, like Israel, Hong Kong, Singapore, South Korea, India are clustered in between the two clusters mentioned above. We see developing economies moving towards the high ECI, low Gini area where the majority of European economies. However, these economies cannot break free from their position, and ended up back into the low ECI, high Gini area. We can see once an economy realizes higher ECI and lower Gini, they have a better chance

The United States are sometimes clustered with European economies, sometimes clustered with rising economies, sometimes clustered with Canada, and has recently marched onto a path of high

ECI and high Gini. China and Russia are also moving gradually towards the direction of US, with smaller Gini values.

In the most recent decade, we see clustering fractionized. We see Korea joining European's cluster, Japan, the UK and Singapore joins the US for extremely high ECI but moderate Gini group. The greater China area including Hong Kong and Australia, are seen as similar to Argentina and some less wealthy European economies. Some African economies reduced carbon via reduction of Gini index, but fails to realize higher ECI.

Lastly, the negative correlation between the ECI and the Gini described in Hartmann *et al.* (2017) is persistent throughout time.

As will be discussed later, the clustering analysis summarized for several development trajectories in terms of the triplet link.

Table 7: Panel Model Results - Gini Quality-weighted Average

	Emission Per Capita(T/Person)										Emission Per GDP(T/k dollar)		
	OLS					*panel linear*						*panel linear*	
	OLS	LSDV	FE	RE	FE-CR	FE2	FE-HHLD	IV-HHLD	IV-HHLD2	FE-Gov	IV-HHLD3	FE3	FE-Gov2
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
ECI	1.463***	−0.503***	−0.493***	−0.503***	−0.493***	−1.299***	−0.581***	−2.507	−0.271	−0.558*	0.152	−0.105***	0.487***
	(0.122)	(0.128)	(0.129)	(0.128)	(0.088)	(0.124)	(0.210)	(7.043)	(0.480)	(0.284)	(0.143)	(0.036)	(0.080)
Government efficiency										−1.968***			−0.321***
										(0.321)			(0.082)
ECI^2	−0.305***	−0.183*	−0.215***	−0.183*	−0.215***		0.316***	−6.171	1.146***	0.287	−0.268***	−0.165***	−0.276***
	(0.078)	(0.071)	(0.072)	(0.071)	(0.080)		(0.099)	(23.542)	(0.205)	(0.223)	(0.061)	(0.020)	(0.051)
Gini	0.005	0.058***	0.053***	0.058***	0.053***			−12.217	0.629***	0.048*	−0.163***	−0.024***	−0.002
	(0.013)	(0.013)	(0.013)	(0.013)	(0.012)			(42.637)	(0.156)	(0.022)	(0.047)	(0.004)	(0.004)
GDP growth	1.972***	0.751	0.911	0.751	0.911	1.537***	−0.177	−19.816	1.693*	3.688***	−1.174***	−1.233***	−0.717***
	(0.623)	(0.513)	(0.602)	(0.513)	(0.970)	(0.583)	(0.850)	(68.038)	(0.712)	(1.105)	(0.213)	(0.169)	(0.135)
GDP per capita	0.187***	0.098***	0.103***	0.098***	0.103***	0.134***	0.020*	−0.182	−0.091***	0.180***	0.031***	−0.016***	0.012***
	(0.007)	(0.006)	(0.008)	(0.006)	(0.015)	(0.008)	(0.009)	(0.760)	(0.014)	(0.011)	(0.004)	(0.002)	(0.003)
North America		6.409***											
		(0.779)											
Household loan and debt							0.016***						
							(0.005)						
Europe and Central Asia		−2.277***	−8.713***	−8.686***	−8.713***	−8.238***	−9.565***	−56.870		−8.634***		−0.232+	
		(0.636)	(0.439)	(0.436)	(0.196)	(0.525)	(0.341)	(163.842)		(0.762)		(0.123)	
East Asia and Pacific		−2.407***	−8.827***	−8.816***	−8.827***	−8.213***	−9.140***	−11.067		−6.798***		−0.225+	
		(0.662)	(0.464)	(0.464)	(0.250)	(0.553)	(0.363)	(8.380)		(0.807)		(0.130)	
Sub-Saharan Africa		−2.531***	−8.849***	−8.941***	−8.849***	−8.628***	−11.238***	122.233		−8.140***		−0.812***	
		(0.676)	(0.558)	(0.557)	(0.209)	(0.602)	(0.689)	(464.231)		(0.967)		(0.157)	
Middle East and North Africa		0.834	−5.583***	−5.576***	−5.583***	−3.456***	−5.311***	57.521		−4.241***		−0.310*	
		(0.719)	(0.493)	(0.493)	(0.379)	(0.563)	(0.515)	(231.364)		(0.847)		(0.138)	
Latin America and Caribbean		−4.313***	−10.681***	−10.722***	−10.681***	−8.870***	−12.635***	71.629		−11.139***		−1.232***	
		(0.720)	(0.482)	(0.482)	(0.124)	(0.558)	(0.447)	(297.549)		(0.826)		(0.136)	
South Asia		−2.540***	−8.938***	−8.949***	−8.938***	−7.808***	−11.006***	29.073		−8.435***		−0.903***	
		(0.723)	(0.586)	(0.586)	(0.188)	(0.665)	(0.612)	(144.742)		(1.035)		(0.165)	
Lower middle income		0.397	0.529	0.397	0.529***	−0.146				0.747		0.374***	
		(0.416)	(0.417)	(0.416)	(0.108)	(0.357)				(0.791)		(0.117)	
Upper middle income		3.671***	3.786***	3.671***	3.786***	3.027***	4.013***	33.639		4.548***		0.969***	
		(0.439)	(0.440)	(0.439)	(0.140)	(0.384)	(0.365)	(106.100)		(0.843)		(0.124)	
High income		8.228***	8.304***	8.228***	8.304***	8.868***	5.325***	−20.387		9.310***		0.157	
		(0.470)	(0.477)	(0.470)	(0.187)	(0.434)	(0.417)	(86.862)		(0.980)		(0.134)	
Efficiency*ECI										−2.402***			−0.159*
										(0.286)			(0.073)
Efficiency**ECI*^{2}										0.640***			0.044
										(0.148)			(0.042)
Constant	3.397***			6.409***									
	(0.583)			(0.779)									
N	3,972	3,972	3,972	3,972	3,972	5,188	1,644	1,518	1,518	1,554	1,518	3,970	1,552
R^2	0.293	0.734	0.524	0.525	0.524	0.493	0.611	0.039	0.004	0.575	0.016	0.199	0.128
Adjusted R^2	0.292	0.733	0.516	0.523	0.516	0.487	0.595	−0.004	−0.084	0.566	−0.072	0.185	0.037
Residual Std. Error	5.212	4.278											
F Statistic	328.294***	727.733***	306.682***	4,367.405***	306.682***	415.547***	190.726***	7.389	89.943***	121.117***	96.212***	69.135***	25.731***

Notes:
***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.
FE,CR refers to FE with cluster robust standard error. FE2 skips *ECI*^{2} and gini. FE-HHLD uses household loan and debt (HHLD) to proxy for inequality-induced consumption emulation. IV-HHLD uses HHLD as instrument for gini, with only time FE. IV-HHLD2 and IV-HHLD3 uses HHLD as instrument for gini, with time and individual FE. FE-Gov adds governmen efficiency and uses time FE. FE-Gov2 adds governmen efficiency and uses time and individual FE. IV-HHLD3, FE3 and FE-Gov use emission per dollar as the dependent variable.

Table 8: Panel Model Results - Gini Quality-weighted Average

	Emission Per Capita(T/Person)										Emission Per GDP(T/k dollar)		
	OLS					*panel linear*						*panel linear*	
	OLS (1)	LSDV (2)	FE (3)	RE (4)	FE-CR (5)	FE2 (6)	FE-HHLD (7)	IV-HHLD (8)	IV-HHLD2 (9)	FE-Gov (10)	IV-HHLD3 (11)	FE3 (12)	FE-Gov2 (13)
ECI	1.459***	−0.506***	−0.497***	−0.506***	−0.497***	−1.299***	−0.581***	−0.832	−0.263	−0.566*	0.149	−0.103***	0.486***
	(0.121)	(0.128)	(0.129)	(0.128)	(0.089)	(0.124)	(0.210)	(3.385)	(0.449)	(0.283)	(0.138)	(0.036)	(0.080)
Government efficiency										−1.971***			−0.322***
										(0.321)			(0.082)
*ECI*²	−0.305***	−0.183*	−0.215***	−0.183*	−0.215***		0.316***	−5.320	1.138***	0.285	−0.266***	−0.165***	−0.277***
	(0.078)	(0.072)	(0.072)	(0.072)	(0.079)		(0.099)	(16.770)	(0.192)	(0.223)	(0.059)	(0.020)	(0.051)
Gini	0.005	0.057***	0.052***	0.057***	0.052***			−9.985	0.572***	0.047*	−0.148***	−0.024***	−0.0001
	(0.013)	(0.013)	(0.013)	(0.013)	(0.012)			(28.394)	(0.133)	(0.022)	(0.041)	(0.004)	(0.004)
GDP growth	1.972***	0.751	0.912	0.751	0.912	1.537***	−0.177	−15.575	1.576*	3.688***	−1.143***	−1.234***	−0.713***
	(0.623)	(0.513)	(0.602)	(0.513)	(0.970)	(0.583)	(0.850)	(43.737)	(0.656)	(1.106)	(0.202)	(0.169)	(0.135)
GDP per capita	0.187***	0.098***	0.103***	0.098***	0.103***	0.134***	0.020*	−0.135	−0.090***	0.180***	0.031***	−0.016***	0.012***
	(0.007)	(0.006)	(0.008)	(0.006)	(0.015)	(0.008)	(0.009)	(0.487)	(0.013)	(0.011)	(0.004)	(0.002)	(0.003)
North America		6.435***											
		(0.781)											
Household loan and debt							0.016***						
							(0.005)						
Europe and Central Asia		−2.254***	−8.715***	−8.689***	−8.715***	−8.238***	−9.565***	−48.136		−8.651***		−0.232+	
		(0.637)	(0.439)	(0.436)	(0.195)	(0.525)	(0.341)	(108.683)		(0.761)		(0.123)	
East Asia and Pacific		−2.374***	−8.819***	−8.808***	−8.819***	−8.213***	−9.140***	−12.972		−6.800***		−0.228+	
		(0.662)	(0.464)	(0.464)	(0.250)	(0.553)	(0.363)	(11.278)		(0.807)		(0.130)	
Sub-Saharan Africa		−2.493***	−8.838***	−8.928***	−8.838***	−8.628***	−11.238***	97.142		−8.133***		−0.817***	
		(0.677)	(0.558)	(0.557)	(0.208)	(0.602)	(0.689)	(306.962)		(0.967)		(0.157)	
Middle East and North Africa		0.872	−5.572***	−5.563***	−5.572***	−3.456***	−5.311***	43.749		−4.237***		−0.315*	
		(0.720)	(0.492)	(0.492)	(0.379)	(0.563)	(0.515)	(149.399)		(0.848)		(0.138)	
Latin America and Caribbean		−4.274***	−10.669***	−10.709***	−10.669***	−8.870***	−12.635***	55.089		−11.137***		−1.237***	
		(0.721)	(0.482)	(0.482)	(0.125)	(0.558)	(0.447)	(195.436)		(0.826)		(0.135)	
South Asia		−2.509***	−8.932***	−8.943***	−8.932***	−7.808***	−11.006***	19.615		−8.440***		−0.906***	
		(0.724)	(0.586)	(0.586)	(0.188)	(0.665)	(0.612)	(91.156)		(1.035)		(0.165)	
Lower middle income		0.398	0.530	0.398	0.530***	−0.146				0.753		0.374***	
		(0.416)	(0.417)	(0.416)	(0.108)	(0.357)				(0.791)		(0.117)	
Upper middle income		3.675***	3.790***	3.675***	3.790***	3.027***	4.013***	25.853		4.563***		0.967***	
		(0.439)	(0.440)	(0.439)	(0.141)	(0.384)	(0.365)	(64.369)		(0.843)		(0.124)	
High income		8.231***	8.305***	8.231***	8.305***	8.868***	5.325***	−16.756		9.319***		0.156	
		(0.470)	(0.477)	(0.470)	(0.187)	(0.434)	(0.417)	(60.495)		(0.980)		(0.134)	
Efficiency*ECI										−2.403***			−0.157*
										(0.286)			(0.073)
Efficiency**ECI*²										0.644***			0.045
										(0.148)			(0.042)
Constant	3.434***			6.435***									
	(0.585)			(0.781)									
N	3,972	3,972	3,972	3,972	3,972	5,188	1,644	1,518	1,518	1,554	1,518	3,970	1,552
R^2	0.293	0.734	0.524	0.525	0.524	0.493	0.611	0.042	0.007	0.575	0.015	0.198	0.128
Adjusted R^2	0.292	0.733	0.516	0.523	0.516	0.487	0.595	−0.001	−0.081	0.566	−0.073	0.185	0.037
Residual Std. Error	5.212	4.278											
F Statistic	328.280***	727.565***	306.603***	4,365.997***	306.603***	415.547***	190.726***	11.130	102.639***	121.081***	103.357***	69.022***	25.697***

Notes:
***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.
FE,CR refers to FE with cluster robust standard error. FE2 skips ECI^2 and gini. FE-HHLD uses household loan and debt (HHLD) to proxy for inequality-induced consumption emulation. IV-HHLD uses HHLD as instrument for gini, with only time FE. IV-HHLD2 and IV-HHLD3 uses HHLD as instrument for gini, with time and individual FE. FE-Gov adds government efficiency and uses time FE. FE-Gov2 adds governmen efficiency and uses time and individual FE. IV-HHLD3, FE3 and FE-Gov use emission per dollar as the dependent variable.

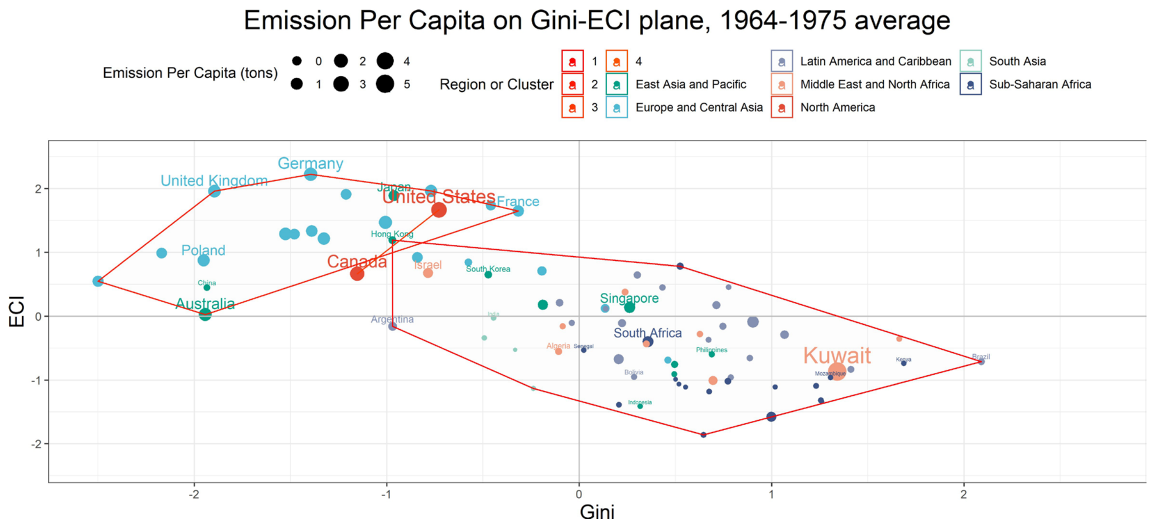

Figure 8: 1964-1975

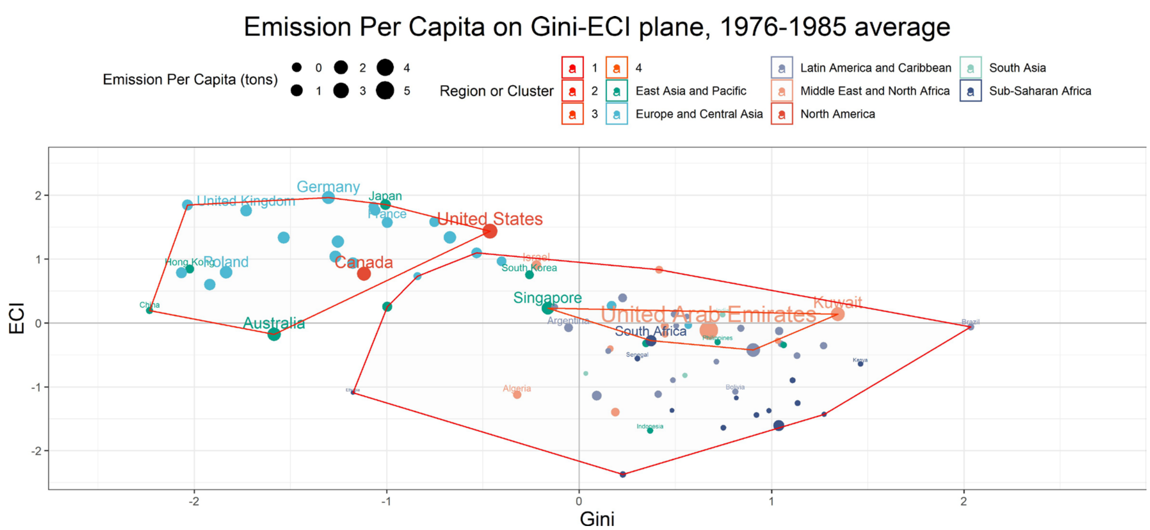

Figure 9: 1976-1985

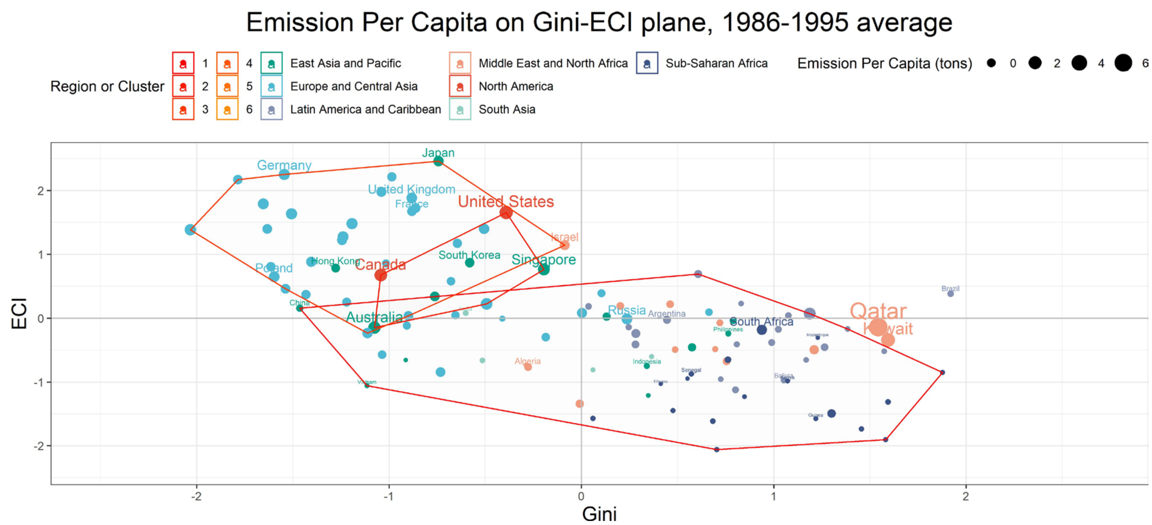

Figure 10: 1985-1995

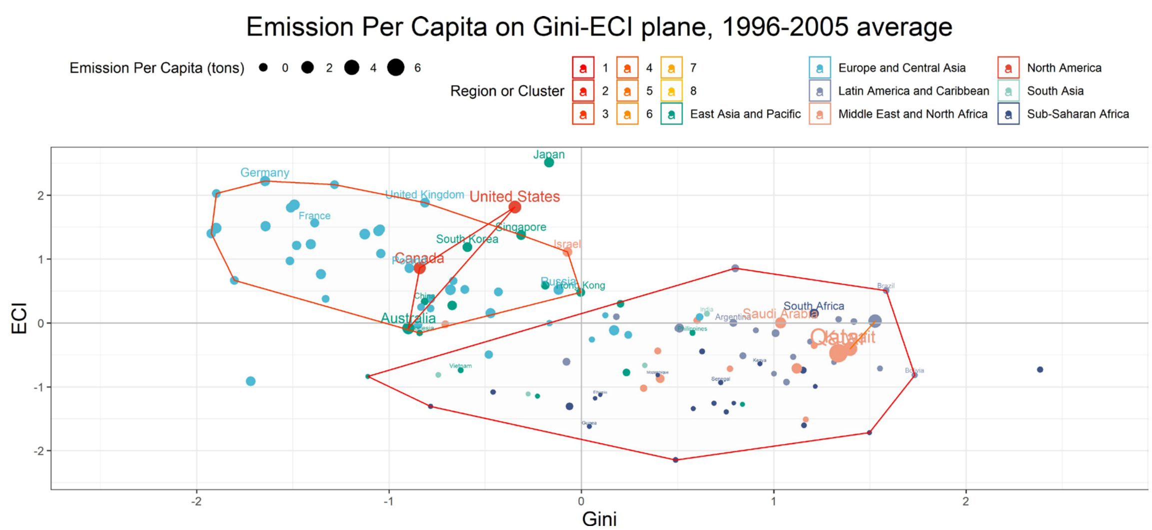

Figure 11: 1996-2005

4 Discussions

4.1 Carbon Reduction in Combination with Economic growth and Promoted equality

The empirical results from model (3) - (10) suggest that ECI and Gini have separate effect on the carbon emission per capita, justifying the triplet link, indicating a possible route for the coexistence

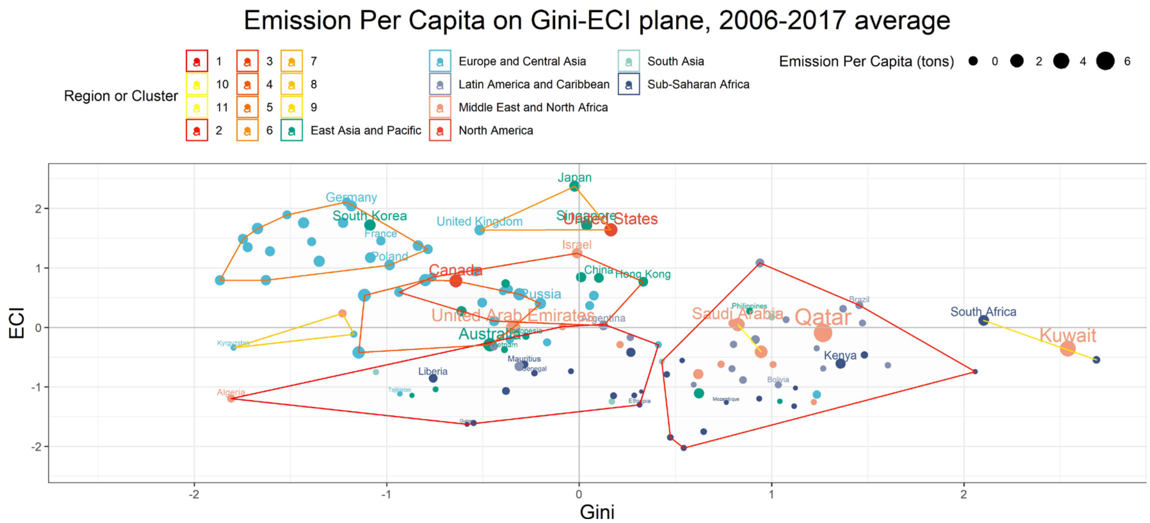

Figure 12: 2006-2017

of development and carbon reduction for the developing world. What matters is perhaps not the negative correlation between the ECI and the Gini by Hartmann *et al.* (2017), but the potential for countries to optimize both in development by improving ECI for development resilience and in income inequality to evade the Veblen effect. These measures will contribute positively to economic development while reducing carbon emission. Economic complexity will help drastically reduce carbon emission per consumer and is not done directly through reducing income inequality, since its effect is still present after we control for the presence of Gini index.

As our data shows, many economies are entering the technological effect, where development helps reduce carbon outlets, matching EKC hypothesis. It may seem awkward since technological effect was predicted to occur with highly developed economy. The occurrence technological effect can be a result of technological spillover, where rising economies enjoys the positive externality of technological product of the developed world. Simply diversifying the production activities makes an economy resilient towards unexpected shocks and allows for various means of energy consumption, reducing the reliance on fossil fuels, therefore the carbon. As we can see in the rising Asian economies like Japan, China, South Korea, India, Hong Kong, Singapore, Vietnam, and Malaysia, ECI have been raised drastically, accompanying reduction in carbon emission per capita, a couple of them without Gini changing drastically.

Our models also suggest that technological effect may be drying up for the developed economies, reconciling in part with previous findings (Can *et al.*, 2020; Doğan *et al.*, 2019, 2021; Li *et al.*, 2021), but remains effective for the developing economies. Model (7)-(10) help us draw a similar conclusion as these predecessors in that for developed economies of ECI higher than 0, the punishment of development kicks in. These models uses household debt as instrument so the consequence of consumption emulation on carbon is more cleanly controlled. The drawback for this method is the lack of such household debt data for many developing economies. Nevertheless, we see that for developed economies, technological effect used to exist in the past years in general (model (3)-(6)), but it functions no more.

Inequality is a useful answer to the question whether there are ways for the developed economies to contain carbon emissions without the help of technological effect. Though regional researches suggested that a left-skewed income distribution reduces the source of energy consumption (Baloch *et al.*, 2018; Coondoo and Dinda, 2008; Heerink *et al.*, 2001; Nikodinoska and Schröder, 2016; Ravallion, 2000), our global picture suggests that a comparably unequal economy can always find its way to emit carbon less efficiently. The underlying results can be the negligence on improving energy consumption efficiencies of the people due to unequal social status induced by income gap. The Veblen effect (Veblen and Mills, 2017) stands to be a more realistic explanation for inequality-carbon dynamics. Were the phenomenon that consumers consume referencing not only their income

(Campbell and Mankiw, 1989), but rather comparison of higher social status (Bagwell and Bernheim, 1996; Basmann *et al.*, 1988; Frank *et al.*, 2014) the truth, then carbon will be the least of their concerns, while unnecessary consumption leads to waste and further emission. The leverage is also a proxy for consumers' capacity to care for externality. People have way less attention to focus on externality and public issues such as environment protection when they are struggling to earn a living and change their lives, or repaying the debts due to emulation.

We can see also that Veblen effect may have functioned more in developed economies. In model (9) where we use household debt as an instrument for income inequality, we see that every percentage point increase in Gini index raises average carbon emission by 0.629 tons, compared to around 0.055 tons in model (3) - (5). Keeping in mind that the data reflects generally the case in developed countries, we can argue that debt as a measure of consumption emulation and thus a measure of Veblen effect predicts that unequal social status will greatly promote inefficient consumption and carbon outlets. Thus the solution seems valid that the developed economies can rely on reducing social inequality to reduce the Veblen effect, thereby reducing emission.

The results of the model (6) with only the ECI but no Gini also help clarify a myth between development and environmental protection. Some fear that rapid development is achieved at the cost of carbon emission, which is correct according to the significantly positive contribution of pure economic growth to carbon outlet in models. The models (3) - (5), where ECI and Gini joins the picture, do not fully agree with the strong causality found by Zhang and Cheng (2009) between GDP growth and energy consumption. We observe generally growth does not boost carbon emission per capita, since it is not growth that changes one's consumption habits, but income and waste due to unnecessary expenditures and pursuit of status. Model (9)-(10) illustrates, however, significantly positive effect of growth on carbon. The first argument is that these data covers the recent trend in developed economies, and is thereby consistent with Zhang and Cheng (2009). The second argument is that we can add to our assurance if we have even stronger micro-level consumption data or instruments to proxy for Veblen effect in both developing and developed economies to measure the effect of growth. What policymakers in the developing world should know is that once ECI and income inequality are in check, the global panel model suggests that growth will not necessarily lead to a worsen environment.

Our model is prone to the theory that the diversification of production and exports, combined with more equalitarian income distribution, have more significant impact on carbon footprints for the less-developed economies. Also, our model generally agree that Veblen effect is present on the emission per capita level, no matter we observe Gini or household debts as instrument for the consequence of consumption emulation, which is one of our main contribution to the study. The developing world can enjoy the benefit of both technological effect and the whole world can benefit by containing Veblen effect. The next pertinent question is whether there are specific road maps to follow in this optimization for the developing world.

4.2 Development Trajectories and the Carbon Dilemma for the Late Starters

To put the above finding in perspectives, we studied the development track of all countries and economies in the past five decades on a Gini-ECI plane, attempting to see how economies balance between the triplet of emission, ECI, and Gini, i.e., development and environment. Here we further employed cluster analysis to identify the situation where countries can simultaneously maintain a certain degree of economic development while decreasing carbon emissions. The countries in the high ECI, low Gini zone has relatively lower emission, locally, since we cannot project income per capita on the graph. There are exceptions, e.g., some developing countries have low ECI, high Gini, but lower emission compared to those with close but not as bad ECI and Gini. The carbon emissions of these exceptions are often characterized by low average income levels. Though the emission per capita will go up eventually as the average income amounts, ceteris paribus, there are chances to slow the pollution along the way to economic development.

The k-means cluster analysis provides an angle for our conjectures. For the most part of the five decades in question, the developed world hovers more often in the high ECI, low Gini zone, whereas the developing world spend most of the five decades in, or trying to escape, the low ECI, high Gini zone. Equilibrium with higher ECI, lower Gini, and lower carbon emission is the general goal for every economy, as our model suggests. In reality, Europe and Central Asia regions are full of economies characterized as such for most of the five decades. They are usually separated from the developing world, including Sub-Saharan African, Middle East and North African, Latin American and Caribbean, South Asian countries. Most of these developing countries can be observed with little movements in the high ECI, low Gini areas. Once they improve on both factors, their emission level drops accordingly. Although this is not to say Europe and Central Asia have reached the most efficient equilibrium, they still constitute encouraging goals for developing world in terms of the triplet. Also, the reason why developed economies do not all have extremely high ECI is that the technological effect may have tapped off for the most developed economies.

The story for East Asia and Pacific area is yet an uncanny one. The clusters of these countries have shifted several times along the decades. During the first decade between 1964 and 1975, most East Asian countries are regarded as equals of the developing world, with a few exceptions, Japan and China. It was a time when they maintain an unremarkable ECI and Gini level. The next decade they witnessed better economic performances, with improved ECI and sequentially lower

Gini. Among them, Hong Kong, Singapore, South Korea, and New Zealand are clustered either with the European area, or with some upper-middle income or thriving peers like Spain, Ireland, Israel, Argentina, South Africa. In the following decade, most of them are on par with the European area and Central Asia, surpassing Canada, Russia and Australia, leaving the developing world behind. From 1996 to 2005, this trend persists while Japan become the exception, as we will show afterwards. This is a period during which the world is roughly divided into the Europe-US-East-Asia centered cluster and rest-of-the world cluster.

We can see that this area is a golden example of the development path. The economies in this category usually started plain, but found their way into a higher level of ECI, and maneuvered their way out of undesirable inequality to cash in the Veblen effect right after or even alongside the ECI boost. All the process started with an improvement in ECI and an increased level of carbon emission due to sudden income surge. The ECI boost is usually accompanied by technological effect that reduces carbon emission. This effect explains the coexistence of development and stable average carbon outlet of East Asian economies.

The clusters display Veblen effect on a macro scale, and the growth of ECI slows down. The regional increment of per capita emission in the East Asia and Pacific area, accompanied by stable ECI and increment in Gini, can be viewed as a long-term attempt to meet the existing consumption standards, or life standards in a sense, in the two comparably developed areas, North America, Europe and Central Asia. The absolute level of average emission suggests that the North America, Europe and Central Asia have been maintaining a relatively high amount of per capita carbon outlet given the relatively small population. Albeit effort to reduce carbon emission through stably high ECI and relatively low Gini index, their higher emission signals a more luxurious mode of consumption standard. The emulation of developing countries towards developed economies exists, since after ECI of the East Asia and Pacific economies stabilizes in the recent decade, the carbon footprint still increases with Gini. The carbon footprint of some gradually lowers as they settled near the high ECI, low Gini zone.

Some exceptions like China and Japan are paving their way towards the USA, which harms their environmental health inevitably. The United States, rather than being viewed as a peer in the Europe cluster, is constantly isolated as one cluster of its own. Its biggest distinction between other high ECI, developed European peers is an observed deterioration in income inequality, with some fluctuations. As it moves along this path, its carbon footprint follow the reasonable trend and increases. The phenomenon is a sign of existence of Veblen effect, where inequality motivates emulation and inefficient consumption. What cautions the reader is that China and Japan, are having similar problems, with elevated but stabilizing ECI, elevated Gini, and elevated carbon outlets. As the previous paragraphs mentioned, the worst end of this trend is the Veblen effect taking place on a truly global scale, where income inequality induced, inefficient consumption drives high carbon emission.

The attempts of the greater developing world are not as desired for them. Ideally, the developing world aims to follow the example of the East Asia and Pacific area, but the reality constantly disturbs them from realizing the first crucial step, the elevation of their ECI level. Some were close to a success during 1976 and 1985, for instances, Israel, Argentina, India, South Africa, Mexico, Jordan. Their progress was short-lived. By the end of that decade, only Israel made it into the high ECI, low Gini zone, whereas the rest of the front-runners from the Sub-Saharan Africa, Middle East and North Africa, Latin America and Caribbean, South Asia are re-clustered together. It symbolizes the start of two-decade-long struggle to break free from the group for all these countries. Someof them stays emitting the same level of carbon, while some worsens due to a more intense income inequality and a bad ECI, Kenya for example.

The decade from 2006 to 2017 is the new era for the world. While the more developed European economies settled in a high ECI, low Gini zone, together with Japan, Korea, and Israel. Mid-tier developed European and Central Asia economies are mixed with Asia-Pacific economies and a few rising developing economies from Latin America and Caribbean area. Some of the developing world achieved lower emission by coping with inequality, but the vast majority of them are still in the low ECI, high Gini zone, with increased emission compared to themselves a decade ago. It suggests that reducing inequality first is a noble attempt, but a difficult path for ECI improvement or development overall.

4.3 The Role of Government

Model result from (10) and (11) - (13) tell us two stories: first, government intervention may change the way technological effect come into effect; second, government intervention may mean different things on emission per capita level and emission per dollar level, with the former concerning total amounts and the latter concerning energy efficiency. To note the discussion is more valid for developed economies, but can provide guidance for developing economies.

To start, we see that the combined effect for an economy with average government efficiency of 1.5 will have marginal effect of ECI, which is also an increasing function of ECI and government efficiency, at 2 by -0.321 tons per capita. This number will turn positive if ECI increases or government efficiency amounts to 2, which is not uncommon for developed economies in Europe in our sample. What the model suggests darkly is that for government of a negative score and low ECI, the technological effect may disappears as well, meaning there will be a period where ECI increase will lead to increased carbon emission in a developing economy. Fortunately, this finding also points to the fact that for countries with moderately high ECI between 0 and 2, the technological effect is still potentially present even if government efficiency is mildly positive. Still, the economies with ECI higher than 2 or with extremely bad government efficiency will face the loss of technological effect. Government efficiency seems to function as an amplifier in this setting in that, the effect of positive ECI or the effect of the negative ECI can be boosted by the government. Government efficiency itself also has the effect of reducing carbon per capita, which we can understand as general policy guidance.

The story is different for energy efficiency via model (11) - (13) based on emission per dollar. Almost unanimously, these models suggest that ECI, inequality, growth, and government efficiency will lead to the decrease of emission per dollar. The idea can be summarized by the economy of scale. Increased ECI and growth are proxies of technological improvement, production capacity, and manufacturing experience, the accumulation of which sounds like a natural reducer of energy deficiency in production. Gini index as a proxy of inequality can point to the fact that production are centralized, thereby displaying the economy of scale. Government efficiency again amplifies the carbon reducing technological effect via ECI, and reduces carbon directly, possibly via policy directions. A comparison between models with emission per capita and models with emission per dollar draws opposite significance sometimes. Such contrast is due to the fact that energy efficiency improvement does not change that as global average income increases, the dollars spent by each individual goes up inevitably, eroding into the carbon reduction brought by technological effect and government guidance on each dollar. It is important to realize that government guidance on energy efficiency may mean more productive economy, but may not lead to the reduction of carbon per capita or total. If intervention should be placed, carbon per capita should be the more relevant goal.

A nation-level example can tell us a more specific story. Among all economies, Israel realized the threshold of its economy drive via elevating ECI along its development. During its development, the inequality goes up gradually, hedging off the decreasing effect of ECI on the emission per capita. As its economy settles into a good condition in the 21st century, it started lowering the inequality while maintaining a high level of ECI. The achievement is a falling emission from its peak in recent years. The example is a good reference to learn from for countries who try not to rid their people of rights of economic development while maintaining a range of environmentally friendly industrial policies.

To add to our perspective, Silhouette estimation approach constantly separate the countries into two clusters during all periods. Still, it pointed out the Kuwait, Qatar, and United Arab Emirates are the three nations frequently deviating from the rest of the world. Out of the few data points available data on these nations, we usually see low ECI, a natural result of strong reliance on fossil fuels, and high income inequality, accompanied by inevitable differences in social status leading to possible consumption emulation. This finding suggest that these three nations are marked with exceedingly disproportional carbon emission with regard to their low economic complexity and high income inequality. It is possible data selection problem that they are less willing to participate in collecting the relevant data in terms of carbon, albeit renouncing fossil-fuel focused industries not being the only choice. These government can play a more significant role by gradually establishing a positive ECI economic structure and amplify the technological effect from it via efficient government intervention. Given their circumstances in the feature space and the lack of data, they deserve to

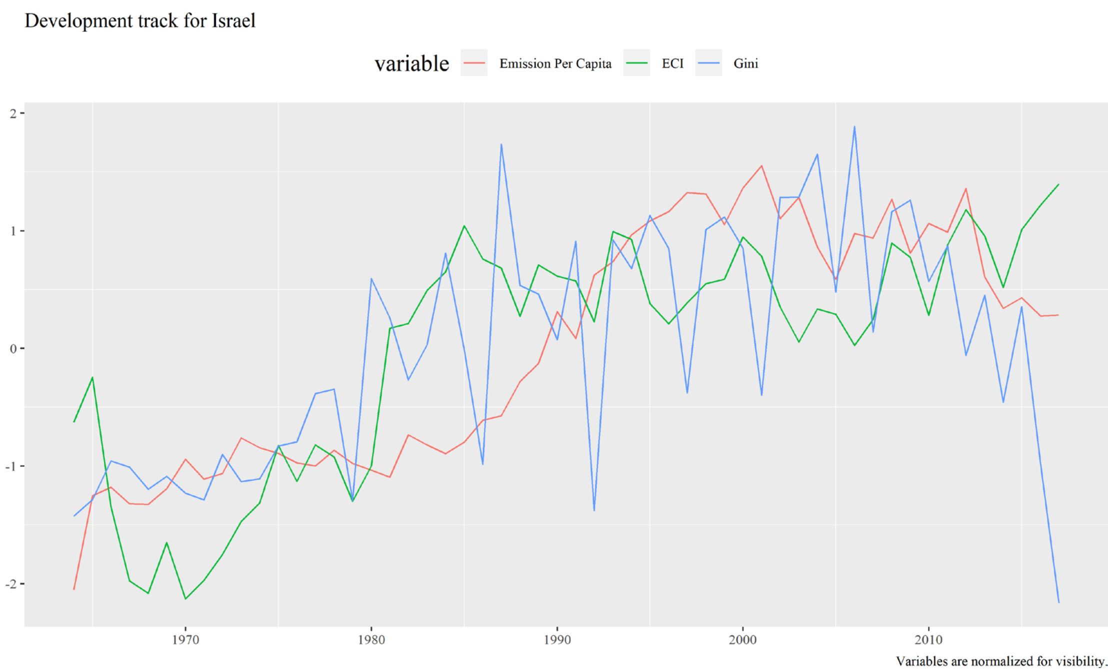

Figure 13: Development track for Israel

be analyzed separately for development strategies and policy suggestions combining more detailed data, which is beyond the scope of this paper.

5 Conclusions and Policy Recommendation

As opposed to the usual perception of trade-offs between development policies and environmentally friendly policies, this paper suggests that increasing the ECI and lowering Gini can help reduce carbon emission via technological effect and Veblen effect. Literature has argued that ECI is now causing more problems to carbon reduction (Can *et al.*, 2020; Doğan *et al.*, 2019, 2021; Li *et al.*, 2021), which can be addressed in two ways: 1. It is not the same as before when ECI reduces carbon emission per capita through the efficiency of energy diversification, and the threshold where technological effect starts to tapper off may have been met by the developed economies. 2. The observed positive impact of ECI on carbon outlets in the past years can be attributed to its effect prevailing its impact on income inequalities by Hartmann *et al.* (2017); Hidalgo and Hausmann (2009). Increase in ECI leads to a reduction in income inequality, thus reduces carbon. This effect is, potentially, fully offset by the extremely large values of ECI. Further, reducing Gini index can help reduce carbon emission via containing the Veblen effect to reduce inefficient consumption and waste. It is thus environmentally beneficial for developed economies to reduce income inequality and for developing economies to increase their ECI and reduce their income inequality at the same time.

The development trajectory agrees with this suggested optimal development path, and the transition are often accompanied with lowered emission on average, if not for the sudden soaring of income. The path is of great value, since it provides an example for countries who have been fighting to get rid of poverty, inequality, and possibly desiring a lower environment externality. The hurdle for this practice lies in lifting the ECI on most occasions, and deserves the maximum focus.

Directly, economic complexity enables an economy to adopt a more diversified range of production, enabling the utilization of more energy source. Earlier literature, through different angles, has argued that merely boosting the GDP growth for the developing world is no solution to their situation in welfare (Alvaredo and Gasparini, 2015; Morelli *et al.*, 2015; Palma, 2011), not to mention carbon emission. As discovered in our cluster models, Kuwait, Qatar, and United Arab Emirates are frequently isolated from the low ECI world during the five decades, mostly because of their skyrocketing emission level per capita. These countries and similar economies are known for skewed focus on fossil-fuel-related industries, which is the reason for that high-rising carbon outlet.

A wider range of production and export is not just about choices of production procedure or energy source, but also about the endogenous capability within an economy to thrive under different shocks, e.g., the Covid-19 crisis. Economic complexity means not just different productive specializations, but also human capital (Pugliese *et al.*, 2017; Carvalho and Rezai, 2016; Ferraz *et al.*, 2018). The capability ensures a more complex source of income, a more sophisticated economic structure for industrialization, as well as nurturing human capital in distinctive industries (Lee and Vu, 2020). In other words, a stably high level of economic complexity gifts an economy with flexibility to expand on its good days and a stronger recovery ability to stand up from short-term shocks.

The flexibility in economic structure enables market participants to engage in different productions, thereby creating various opportunities to reduce poverty and income inequality. Improving the economic complexity is the first step to actually bring up the welfare of a country, and can be achieved environmentally friendly.

What comes following up should be the reduction of income inequality. Many of the Asia-Pacific economies maintained a stable level of carbon while enjoying the benefit of economic growth, due to the technological effect that reduces carbon emission. A number of them, however, were faced with income inequality problems. This is not a problem of their own, but also an existing problem for the USA as well. Veblen effect is, as our model suggests, a due problem for every economy to reach a high ECI, low carbon equilibrium, and the developing world should be prepared for the challenge. What seems to be working in Europe and Central Asia is their welfare system and open government pursuit. A system that rids citizens of critical survival concerns, together with chances to climb higher up on the social ladder, is suggested to be effective in eliminating the need for emulation and status-related consumption. To provide example for the bigger developing world, (Ozturk and

Al-Mulali, 2015) show through a city-level model that municipal governance can be a key to carbon control. The capability of local governance in ruling out corruption and a better management in city planning can be the driving force for carbon reduction in the developing economy. What policy makers should further consider is the urbanization, a moderate level of which is beneficial to emission control (Shah *et al.*, 2020), due to its ability to empower the local economic complexity.

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A Appendix

A.1 Some Extra Descriptive Statistics

First we show the sample counts, where the column name suggests the validity of a sample based on whether it has certain key variables. ceg suggests sample with carbon, ECI and Gini data. cegl adds household loan and debts, while ceglg further adds government efficiency.

Table A1: Sample Count by Year

Year	ceg	cegl	ceglg
1964	48	5	
1965	54	5	
1966	54	6	
1967	56	7	
1968	65	7	
1969	64	8	
1970	71	10	
1971	71	10	
1972	70	10	
1973	65	10	
1974	71	10	
1975	71	11	
1976	69	11	
1977	73	13	
1978	72	13	
1979	71	14	
1980	72	16	
1981	77	16	
1982	76	16	
1983	74	16	
1984	73	16	
1985	73	16	
1986	72	17	
1987	70	17	
1988	70	16	
1989	66	16	
1990	69	19	
1991	70	20	
1992	83	21	
1993	98	21	
1994	91	26	
1995	93	38	
1996	92	39	38
1997	93	39	
1998	96	41	40

Table A1 Continued:

Year	ceg	cegl	ceglg
1999	90	42	
2000	94	42	41
2001	91	50	
2002	92	53	52
2003	86	52	51
2004	93	53	52
2005	88	55	54
2006	90	56	55
2007	88	57	56
2008	90	61	60
2009	91	60	59
2010	91	58	57
2011	80	56	55
2012	91	57	56
2013	86	58	57
2014	83	59	58
2015	77	56	55
2016	70	50	49
2017	60	44	44

Table A2: Sample Count by Country

Country	ceg	cegl	ceglg
Austria	54	23	19
Bulgaria	54	23	19
Canada	54	49	19
Colombia	54	22	19
Denmark	54	24	19
Ecuador	54		
Finland	54	48	19
Germany	54	48	19
Greece	54	24	19
Hungary	54	54	19
Ireland	54	16	16
Israel	54	26	19
Netherlands	54	28	19
Norway	54	43	19
Panama	54		
Spain	54	38	19
Sweden	54	54	19

Table A2 Continued:

Country	ceg	cegl	ceglg
United Kingdom	54	52	19
United States	54	54	19
Kenya	53		
New Zealand	53	28	19
South Korea	53	53	18
Turkey	53	31	19
Singapore	52	25	17
Australia	51	38	16
India	51	17	15
Philippines	51		
Portugal	51	36	19
Indonesia	50	17	16
Iran	50		
Italy	50	50	19
Jamaica	50		
Japan	50	50	15
Poland	50	23	19
South Africa	50	8	8
Malaysia	49	11	11
Argentina	48	24	19
Belgium	48	32	16
Chile	48	10	10
China	48	12	12
El Salvador	48	17	16
Jordan	48		
Venezuela	48		
Bolivia	47		
Dominican Republic	47		
Egypt	46		
Honduras	46	17	16
Hong Kong	46	27	
Mexico	45	19	15
France	44	41	19
Kuwait	44		
Uruguay	44		
Brazil	43	24	19
Costa Rica	43	17	16
Pakistan	43	6	6
Syria	41		
Peru	40	17	16
Morocco	39	10	9
Thailand	39	13	13

Table A2 Continued:

Country	ceg	cegl	ceglg
Tanzania	38		
Tunisia	38		
Guatemala	36		
Sri Lanka	36	11	10
Ghana	35		
Zimbabwe	35		
Madagascar	33		
Senegal	33		
Cote d'Ivoire	32		
Nigeria	31		
Cameroon	30	4	3
Trinidad and Tobago	28		
Zambia	28		
Algeria	27		
Bangladesh	27	2	2
Nicaragua	27	4	3
Croatia	26	23	19
Estonia	26	23	19
Latvia	26	23	19
Lithuania	26	23	19
Moldova	26		
Paraguay	26		
Slovenia	26	23	19
Albania	25	12	12
Belarus	25		
Czech Republic	25	23	19
Macedonia	25	13	13
Russia	25	19	17
Slovakia	25	23	19
Switzerland	25	19	17
Ukraine	25	22	18
Georgia	24		
Oman	23		
Azerbaijan	22		
Kazakhstan	22	15	15
Mongolia	22		
Qatar	22		
Ethiopia	21		
Mozambique	17		
Congo	16	2	2
Togo	16		
Vietnam	15		

Table A2 Continued:

Country	ceg	cegl	ceglg
Yemen	15		
Cambodia	13		
Gabon	13		
Myanmar	12	4	3
Serbia	11		
Angola	9		
Bosnia and Herzegovina	9		
Mauritania	7		
Uzbekistan	7		
Saudi Arabia	6	5	5
Botswana	5		
Guinea	5		
United Arab Emirates	5	1	1
Laos	4		
Sudan	4		
Turkmenistan	4		
Kyrgyzstan	3		
Lebanon	3		
Namibia	2		
Liberia	1		
Malawi	1		
Mauritius	1	1	1
Tajikistan	1	1	1
Uganda	1		

Table A3 gives the mean value of government efficiency and ECI for each country.

Table A3: Efficiency and ECI mean by country

Country	Efficiency	ECI
Libya	-1.833	-1.117
Myanmar	-1.429	-1.081
Turkmenistan	-1.365	-0.922
Liberia	-1.326	-0.851
Togo	-1.311	-1.012
Sudan	-1.263	-1.308
Congo	-1.19	-1.31
Angola	-1.143	-1.544
Zimbabwe	-1.13	-0.214
Yemen	-1.07	-1.046

Table A3 Continued:

Country	Efficiency	ECI
Guinea	-1.054	-1.52
Venezuela	-1.036	-0.498
Nigeria	-1.027	-1.988
Tajikistan	-0.997	-1.105
Syria	-0.978	-0.489
Mali	-0.954	-1.021
Cote d'Ivoire	-0.942	-1.209
Uzbekistan	-0.937	-0.526
Paraguay	-0.922	-0.698
Cambodia	-0.852	-0.596
Cameroon	-0.841	-1.351
Kyrgyzstan	-0.84	-0.349
Belarus	-0.832	0.677
Laos	-0.802	-0.678
Madagascar	-0.791	-1.062
Nicaragua	-0.791	-0.502
Zambia	-0.749	-0.833
Bangladesh	-0.729	-0.891
Papua New Guinea	-0.701	-1.883
Bosnia and Herzegovina	-0.696	0.493
Gabon	-0.69	-1.336
Malawi	-0.684	-0.558
Ethiopia	-0.678	-1.054
Ecuador	-0.674	-0.925
Azerbaijan	-0.67	-0.615
Honduras	-0.647	-0.529
Ukraine	-0.642	0.457
Guatemala	-0.619	-0.095
Pakistan	-0.611	-0.488
Algeria	-0.61	-0.836
Moldova	-0.6	0.014
Mozambique	-0.567	-0.775
Mauritania	-0.561	-1.128
Uganda	-0.545	-0.425
Tanzania	-0.536	-1.116
Kenya	-0.517	-0.654
Iran	-0.498	-1.002
Egypt	-0.494	-0.291
Dominican Republic	-0.493	-0.379
Kazakhstan	-0.481	-0.261
Bolivia	-0.47	-0.888
Mongolia	-0.414	-0.501

Table A3 Continued:

Country	Efficiency	ECI
Russia	-0.392	0.386
Albania	-0.359	-0.151
Lebanon	-0.313	0.328
Senegal	-0.304	-0.664
Indonesia	-0.3	-0.759
Peru	-0.273	-0.549
El Salvador	-0.269	0.15
Vietnam	-0.261	-0.564
Macedonia	-0.19	-0.071
Sri Lanka	-0.166	-0.702
Cuba	-0.143	-0.327
Colombia	-0.134	-0.005
Morocco	-0.121	-0.434
Brazil	-0.096	0.124
Saudi Arabia	-0.089	-0.548
Ghana	-0.084	-1.191
Argentina	-0.062	0.003
India	-0.055	0.145
Serbia	-0.044	0.558
Philippines	-0.025	-0.15
Georgia	0.025	-0.061
Kuwait	0.031	-0.328
China	0.069	0.451
Bulgaria	0.099	0.519
Jordan	0.101	0.344
Namibia	0.117	-0.614
Panama	0.151	0.297
Turkey	0.163	0.005
Jamaica	0.172	-0.293
Mexico	0.199	0.673
Tunisia	0.247	-0.118
Trinidad and Tobago	0.263	-0.098
Thailand	0.287	-0.004
Costa Rica	0.312	0.16
Oman	0.326	-0.483
Croatia	0.485	0.769
Uruguay	0.501	0.201
South Africa	0.514	-0.068
Botswana	0.53	-0.569
Italy	0.532	1.577
Greece	0.568	0.191
Poland	0.598	0.885

Table A3 Continued:

Country	Efficiency	ECI
Latvia	0.677	0.36
Qatar	0.682	-0.243
Lithuania	0.729	0.39
Hungary	0.741	1.042
Slovakia	0.777	1.261
Czech Republic	0.906	1.535
Estonia	0.96	0.6
Mauritius	0.973	-0.628
South Korea	0.991	1.073
Slovenia	0.993	1.422
United Arab Emirates	0.999	-0.16
Malaysia	1.007	0.121
Portugal	1.102	0.679
Chile	1.175	-0.195
Israel	1.224	1.038
Spain	1.269	0.991
Japan	1.428	2.213
France	1.506	1.595
Ireland	1.533	1.261
United States	1.585	1.657
Germany	1.642	2.143
Belgium	1.683	1.401
United Kingdom	1.684	1.833
Australia	1.718	-0.082
Austria	1.727	1.852
New Zealand	1.782	0.304
Canada	1.832	0.782
Netherlands	1.871	1.197
Norway	1.906	0.969
Sweden	1.94	1.982
Switzerland	1.967	2.07
Denmark	2.051	1.409
Finland	2.077	1.623
Singapore	2.152	0.884
Hong Kong	NaN	0.857