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Generating Green Growth

GREEN TRANSFORMATION IN THE GLOBAL SOUTH AND ROLES OF DEVELOPMENT FINANCE

YAN WANG, YINYIN XU

ABSTRACT

This working paper examines the relationship between 'green natural capital' (GNK), carbon dioxide (CO_2) emissions and economic development with a special focus on the roles of various forms of external finance. The new contribution of this paper is the examination of a new GNK dataset in simultaneous equations model (SEM) for a panel of 96 developing countries from 1995-2018. The results of this study confirm an inverted N-shaped environmental Kuznets curve (EKC) relationship between CO_2 emissions and per capita gross domestic product (GDP), which is statistically significant and robust. Second, GNK has a negative and significant association with CO_2 emissions, indicating a robust "biological carbon sequestration" effect. Third, all three kinds of external financing have a significantly positive association with GDP per capita. The net transfer of bilateral lending (including China) and foreign direct investment (FDI) inflows are also associated with lower CO_2 emissions, while this effect is not significant for multilateral development banks. Finally, Chinese development finance in the energy sector is associated with lower CO_2 emissions but is detrimental to GNK formation. The results of this paper indicate a need to enhance investment and regulations in augmenting GNK, including land, forests, fisheries, mangroves and protected areas.

Keywords: Environmental Kuznets curve (EKC); green transformation; green natural capital; development finance

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INTRODUCTION

Three years since the onset of the COVID-19 pandemic, multiple extreme weather disasters have pushed millions of people to the brink of hunger and poverty. Progress in achieving the United Nations 2030 Sustainable Development Goals (SDGs) has been rolled back in many countries due to multiple overlapping crises, or poly-crises: the health crisis, the global climate crisis and humanitarian crises caused by war.

Crises provide opportunities to reflect on humankind's relationship with nature, and to rethink development strategies by returning to the basics. A country needs at least three kinds of capital for development: human capital, natural capital and produced capital. Natural capital can be further divided into renewables and non-renewables. In the past, economists placed too much stress on the accumulation of physical or produced capital, while underinvesting in human capital and over-exploiting natural and environmental capital (Grossman and Kruger 1995; Thomas 2000; World Bank 2003). In this day and age, a global consensus has formed on the critical importance of natural and environmental capital, and on the urgent need for green transformation to reduce carbon dioxide emissions and to protect the planet.

As countries in the global economy are highly heterogeneous in terms of their contributions to the cumulative carbon dioxide (CO_2) stock and the unequal distribution of harm and damage due to global warming, emerging markets and developing economies (EMDEs) are seeking a balance between growth, poverty reduction and sustainability through green transformation.

This working paper builds on the authors' previous studies on structural transformation and moves further to utilize a novel panel dataset of 96 EMDEs. This paper explores the relationship between renewable natural capital, CO_2 emissions and economic development, with a special focus on various forms of development finance, such as the lending from bilateral development banks, multilateral development banks (MDBs) and foreign direct investment (FDI). Questions this paper wishes to answer include:

- Why is natural capital so critical in green transformation?
- What kind of interaction can be seen between green or renewable natural capital, CO_2 emissions and per capita gross domestic product (GDP)?
- What roles do various forms of development finance play? Are there differences between finance from bilateral development banks, MDBs and foreign direct investment (FDI)?
- What roles did Chinese development finance play in the past decade (2008-2018), for which only limited data is available?

The first section presents a conceptual framework of three dimensions: natural resource endowments, the real economy and CO_2 emissions. The second section presents a descriptive analysis: green natural capital (GNK) per capita and CO_2 emissions per capita. The third section discusses this paper's methodology and use of simultaneous equations modeling (SEM). The fourth section provides interpretation of results, while the fifth section presents a brief assessment of China's development finance. The sixth section concludes the paper.

A CONCEPTUAL FRAMEWORK

Green transformation may have different definitions in academic papers with different research scopes. A previous study by this paper's authors focused only on pollutant emissions, green transformation in the real economy and employment (Tong, Wang and Xu 2020). This paper attempts to address the more challenging problem of green transformation in the Global South, which is much broader and highly complex considering the nexus between the real economy and emissions. To limit the scope of this paper, green transformation is narrowly defined as a process of building on and upgrading the nation's existing green natural capital (GNK), such as land, forests, fisheries, mangroves and protected areas,[1] to add their value for resilience and to counterbalance CO_2 emissions. This definition places green endowment at the center of the analysis and utilizes novel data as the dependent variable. In short, green transformation is a process of investing in a country's green endowment, improving economic development and reducing CO_2 emissions, a process that is more inclusive, climate-friendly and sustainable.

The relationship between income growth and environmental degradation has been central to many seminal economic works. In the early 1990s, Grossman and Krueger found evidence that some pollutants rise with income at low-income levels. However, after reaching a certain level in income, CO_2 emissions and other pollutants start to decline (Grossman and Krueger 1995). This stylized fact has been confirmed using various datasets from industrial and developing countries, although turning points vary. Panayotou (1995) calls this inverted U-shaped pattern an environmental Kuznets curve (EKC). In many later studies, the basic EKC equation has been specified in the following form:

$$E_{it} = (\alpha + \beta_i F_i) + \delta Y_{it} + \emptyset (Y_{it})^2 + k_t + \varepsilon_{it} \tag{1}$$

In this equation, E_{it} denotes the environmental indicator in per capita form (including CO_2 emissions), Y_{it} denotes the per capita income, F_i denotes the country-specific effects, and k_t denotes the year-specific dummies.

In the Global South, it is well recognized that traditional economic models such as this single equation model need to be revamped to address broader environmental issues related to climate change, pollutants and emissions, while simultaneously addressing key social and economic challenges such as income growth and poverty reduction. Some even find that data from developing countries does not fully support the hypothesized EKC model (He 2007; Stern 2004), noting that the relationship between development and the environment varies not only between developed and developing countries, but also within developing countries.

New thoughts and economic theories from the Global South are gaining more attention. New Structural Economics (NSE) stresses the importance of the changing structure of endowments, which affects the comparative advantage of an economy. NSE considers that the optimal industrial structure in an economy at a specific time is endogenous to its comparative advantage, which in turn is determined by the economy's given endowment structure at that time (Lin 2011). Based on the NSE theory, Lin and colleagues have developed a discipline of New Structural Environmental Economics (NSEE), which attempts to understand the relationship between the environmental system, the broader socioeconomic system and other structural factors. In the framework of NSEE, households are not just consumers but also owners of factor endowments, producers of eco-services and emitters of pollutants (i.e., CO_2 and others). Households and firms interact to serve as producers and emitters, as well as consumers of the factor endowments including land, forests, protected areas and other resources. In addition, firms also serve as investors and innovators of green technology (Lin, Fu and Zheng 2021).

According to NSE, it is the country's resource endowment and its structure that determines industrial structure, which in turn influences the energy consumption pattern, leading to heterogeneity of CO_2 emissions across economies. As economies transform from primary (agriculture and resources) sectors to secondary industries, energy consumption usually relies on coal and fossil fuels, and thus CO_2 emissions increase. As economies adopt cleaner and more efficient technologies and move

[1] The source of this variable is the World Bank's The Changing Wealth of Nations (CWON), 2022.

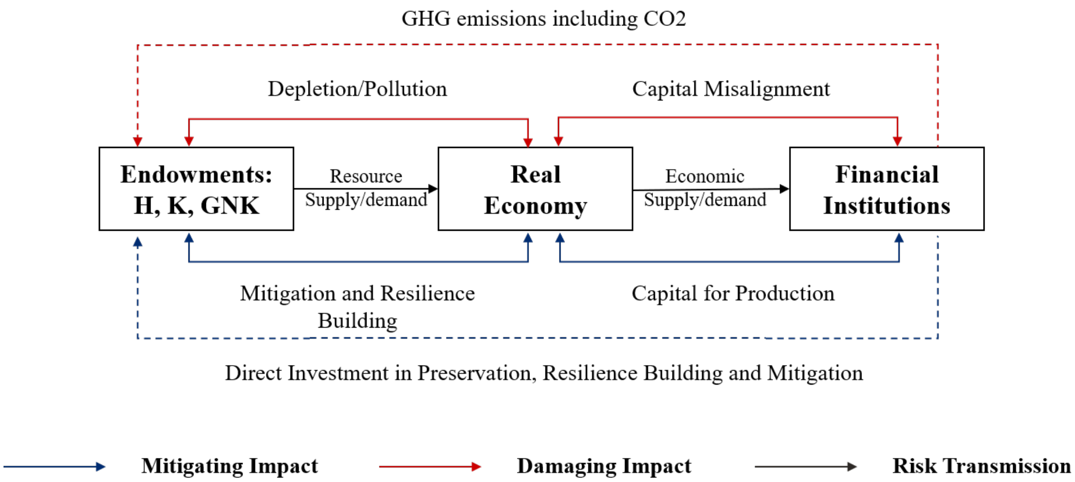
from second to tertiary (service) sectors, the economy becomes technologically intensive, which in turn changes the energy consumption structure and reduces CO_2 emissions. Therefore, a nonlinear, inverted U-shaped relationship seems to exist between CO_2 emissions and structural change.

Following the same logic, a previous study by the authors of this paper utilized a system dynamic model to examine the importance of the structure of endowments. The structure of endowments has a strong impact on the structures of industries and employment. To make a structural transformation "green," a country must start with what it has, including green endowments. If a country manages to have a better accounting of its natural capital, and invests in green natural capital and human capital, it can increase investment returns and attract more physical/financial capital, making these green assets more sustainable (Tong, Wang and Xu 2020).

However, the above framework has not incorporated the third dimension that we are interested in: development finance in the financial sector. Here, we present an illustration of a simple framework where all three dimensions - the natural endowments, the real economy and the financial sector - are intertwined and they produce goods and services, as well as some negative outcomes such as the emission of greenhouse gases (GHG), including CO_2.

Figure 1: Three Dimensions are Intertwined: Endowments, the Real Economy and the Financial System.

Source: Modified by authors based on Kepler Cheuvreux, December, 2022.



Note: H: human capital, K: produced capital, GNK: green natural capital.

The structure of endowments, including natural capital, determines the industrial structure and level of emissions. Meanwhile, emissions of GHGs and pollutants can negatively impact the value of land, forests, fisheries and protected areas (representing a disinvestment in green natural capital). Conversely, if governments and financial institutions want to reduce emissions of CO_2 and other pollutants, they could foster the growth of green natural capital (GNK) including an appreciation of land values (Lord, Krabben and Dong 2022). Thus, a virtuous cycle of sustainable economic development is likely to emerge in the long run.

Notably, physical or financial capital, from private sector or international development financing, can have a direct or indirect impact, as well as a mitigating and/or increasing impact. Documented empirical evidence, while mostly done at a small scale, has verified the aforementioned process, in addition to the fact that green financial flows tend to favor countries with higher human development scores (Yuan and Gallagher 2018) and good national governance systems and capabilities (Wang et al. 2022).

In sum, all three dimensions - endowments, the real economy and the financial sector - are intertwined, and two-way or three-way causalities exist. The impact of green natural capital (GNK) on CO_2 emissions is called "biological carbon sequestration." The complexity of such a multi-dimensional framework requires an understanding of general equilibrium and interrelation, leading this paper to utilize a system of simultaneous equations.

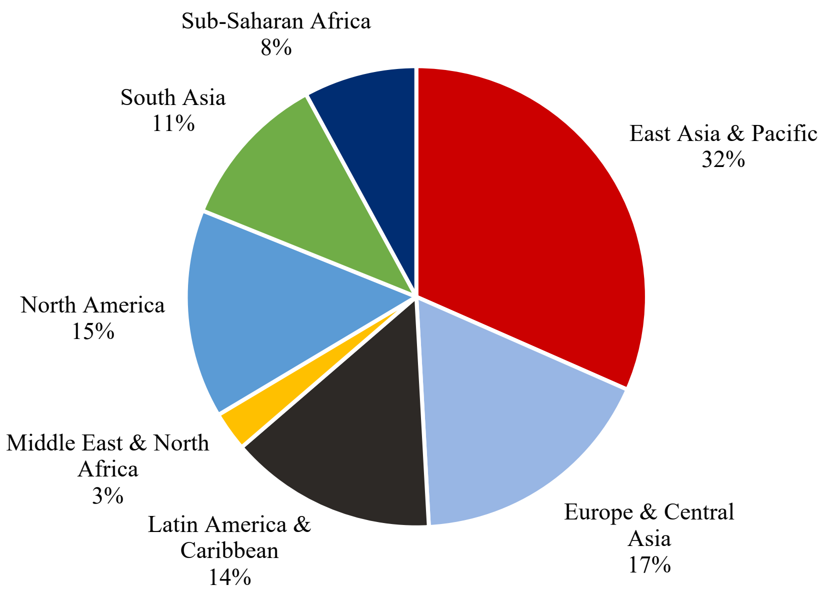
DATA DESCRIPTION AND REASONS TO FOCUS ON DEVELOPING COUNTRIES

Recognizing the difference between developing and developed countries, this paper first presents the heterogeneity between them in terms of green natural capital accumulation and CO_2 emissions. The following descriptive analysis is conducted with countries that have available data regarding GNK (105) and CO_2 emissions (145).

Middle-income countries have roughly the same level of per capita renewable natural capital abundancy as high-income countries, although renewable natural resources are not a large proportion of the national wealth of middle-income countries. In comparison, the per capita renewable natural capital of low-income countries is lower than their counterparts. Natural resource endowment, especially green natural capital (GNK), refers to the stock of natural resources and ecosystems that yields a flow of benefits to people.

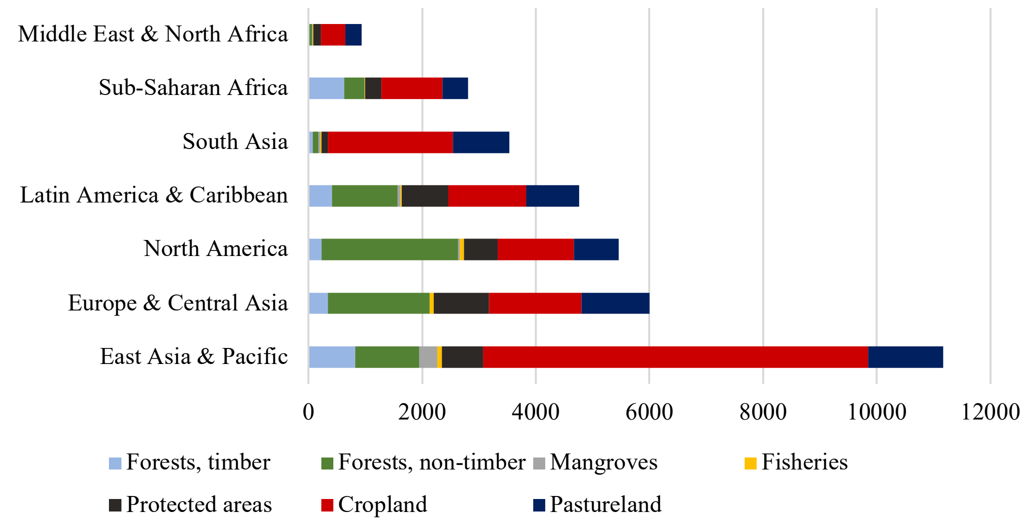
Regionally, the value of green or renewable natural resources in East Asia and Pacific countries is the highest among all the regional groups, and the total value of cropland in East Asia and Pacific countries is much higher than that of other regions (Figure 2 and Figure 3). Figure 4 shows the heterogeneity of the distribution of GNK among African countries.

Figure 2: Share of Global Green or Renewable Natural Resources by Region, 2018



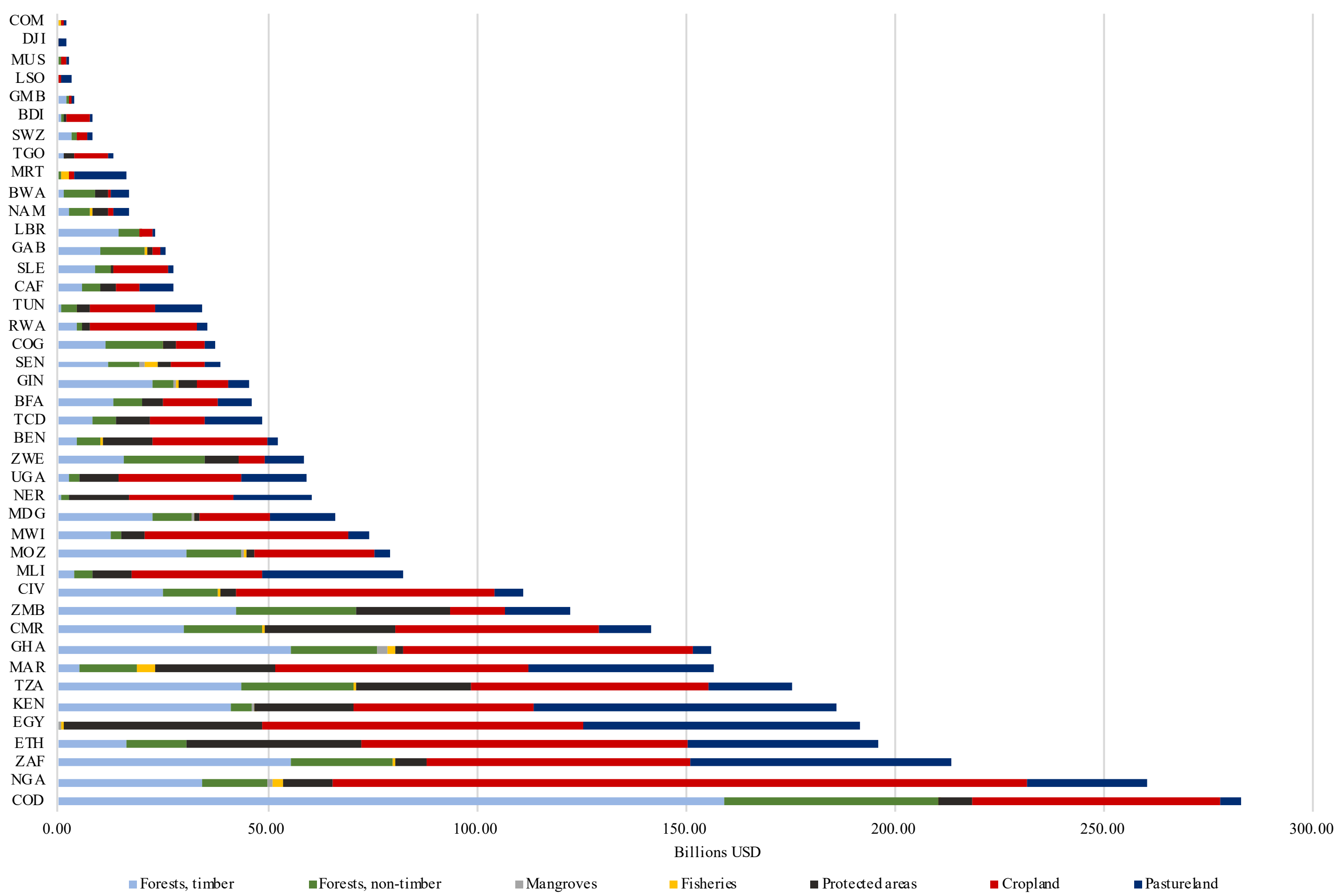
Source: World Bank, the Changing Wealth of Nations, 2021.

Figure 3: Decomposition of Green or Renewable Natural Resources by Region in 2018, USD Billions



Source: World Bank, the Changing Wealth of Nations, 2021.

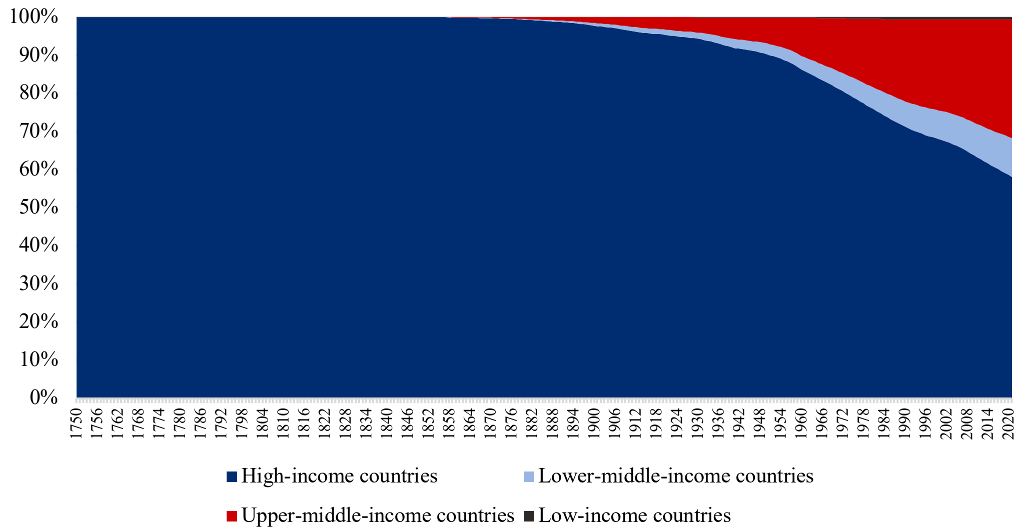
Figure 4: Heterogeneity of Green or Renewable Natural Resources in African Countries in 2018, USD Billions



Source: World Bank, the Changing Wealth of Nations 2021.

It is well known that CO_2 emissions are highly unequal between countries, both in historically cumulative terms and current per capita terms. Historically, rich and developed countries have been the largest contributors to CO_2 emissions. It is estimated that their attributed historic emissions approach (or even exceed) allocated shares for future emissions (Raupach et al. 2014). This trend is observable by adding up each country's annual CO_2 emissions over time. Notably, the contribution of low-income and most middle-income countries to global historical accumulation is negligible (Figure 5).

Figure 5: Cumulative CO_2 Emissions by Income Group Based on Consumption, as Percent of Global Total

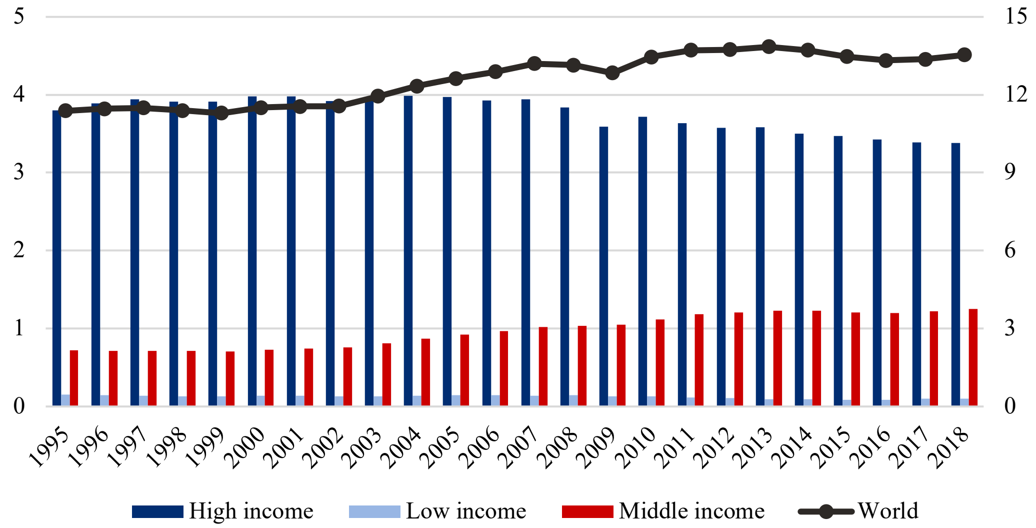


Source: Global Carbon Project, 2022.

High-income countries have contributed to about 40 percent of the world's annual CO_2 emissions, with a total of over ten metric tons per capita between 1995-2018, annually. However, high-income countries only represent 16 percent of the world's population. In comparison, the rest of the world, which is home to about 84 percent of the world's population, emits the remaining 60 percent of CO_2 emissions. Middle-income countries, on average, emitted around 2.1 to 3.7 metric tons per capita annually during the same period. The per capita emissions from low-income countries account for two percent of the world's total emissions (Figure 6).

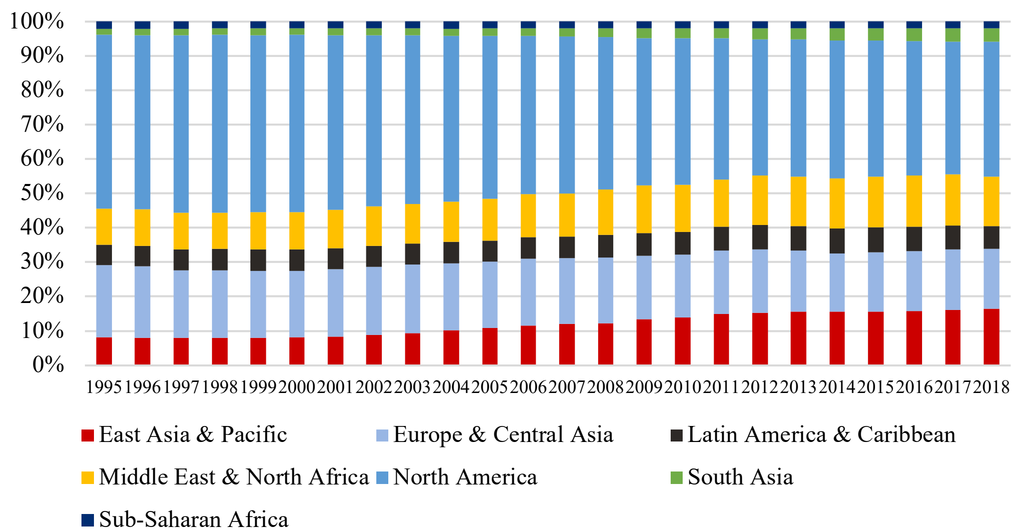
From a spatial perspective, North America has emitted substantially more than the rest of the world. On average, the region emitted more than 15 metric tons per capita during the observed period, despite decreasing at a rate of 0.9 percent annually. Sub-Saharan Africa's per capita emissions are the lowest at about 0.7 metric tons. In addition, the region's per capita emissions decreased during the observed period, at a rate of 0.1 percent. South Asia's per capita emissions have increased by 3.6 percent annually, which is the largest growth in all regions (Figure 7).

Figure 6: CO_2 Emissions (Metric Tons Per Capita), by Income Group



Source: World Bank, World Development Indicators.

Figure 7: CO_2 Emissions (Metric Tons Per Capita), by Region



Source: World Bank, World Development Indicators.

This paper focuses on emerging markets and developing economies (EMDEs) to investigate the role of development finance and options for developing countries to address emissions in an equitable way. High-income countries are not recipients of development finance and including them in the following regression analysis would lead to biased estimates. Historically accumulated and current per capita data on CO_2 emissions also reveal worldwide disparities between developed and developing countries and provide strong evidence to call for fair distribution of the burden of mitigating climate change (MRF 2018). Given structural differences between low- and middle-income countries, and high-income countries, placing them in the same empirical study would be problematic.

MODEL SPECIFICATION, SIMULTANEOUS EQUATIONS MODEL (SEM)

Most researchers found a non-linear relationship between country income and environmental degradation in the EKC studies, among which the inverted U-shape relationship is most extensive. Earlier, Grossman and Krueger (1995) proposed the environmental Kuznets curve (EKC) hypothesis that CO_2 emissions and income level show an inverted U-shaped curve. Tahvonen and Salo (2001) established a theoretical model, in which economies could switch back and forth from non-renewable to renewable energy and found that CO_2 emissions have an inverted-U relationship with income level. Based on the theory of New Structural Economics (NSE), the work of Zhu, Zheng, Zhao and Kou (2020) investigated the heterogeneous role of economic growth on energy structure transition and CO_2 emissions. Using a joint quadratic function model with panel data for 67 economies worldwide from 1990-2018, they examined the effect of economic growth on energy structure transition and CO_2 emissions. The results showed that energy transition and economic growth have a U-shaped relationship, while CO_2 emissions and economic growth have an inverted U-shaped relationship, which to a certain extent confirms the EKC hypothesis on a global scale. More inverted U-shape results are documented in Culas (2012) and Duan et al. (2016).

In more recent studies, scholars tend to re-consider EKC models and more frequently add the cubic function of income to the model (Lee et al. 2009; Allard et al. 2018). In addition, the aforementioned studies have addressed a nonlinear relationship between environmental degradation and economic growth or renewable energy adoption. There is a gap in using green natural capital (GNK) as one of the dependent variables. Nonetheless, the prior model specifications provided inspiration for this study.

Based on this previous literature, this paper begins by formulating a simultaneous equations model (SEM), which is frequently used in empirical studies of the EKC relationship. Such preference is due to how natural endowments act as a major factor in production functions while environmental quality is likely to have a feedback effect on income growth in reality, thus giving no direction of causality (Borghesi 1999). As an extension of the EKC relationship between income and pollutant emissions, this paper uses a cubic function form, and further examines the impact of development financing as an additional focus.

Thus, the simultaneous equations model can be given as equations 2-4.

$$\begin{aligned} lnCO2_{it} = {} & a_0 + a_1 lnGNK_{it} + a_2\, lnGDPpc_{it} + a_3 lnGDPpc_{it}^2 + a_4 lnGDPpc_{it}^3 \\ & + a_5 lnMLTpc_{it} + a_6 lnBLTpc_{it} + a_7 lnFDIpc_{it} + IV_{it} + \theta_{it} + \varepsilon_{it} \end{aligned} \tag{2}$$

$$\begin{aligned} lnGDPpc_{it} = {} & \beta_0 + \beta_1\, lnGNK_{it} + \beta_2 lnGNK_{it}^2 + \beta_3\, lnCO2_{it} + \beta_4\, lnMLTpc_{it} \\ & + \beta_5\, lnBLTpc_{it} + \beta_6\, lnFDIpc_{it} + IV_{it} + \theta_{it} + \mu_{it} \end{aligned} \tag{3}$$

$$\begin{aligned} lnGNK_{it} = {} & \gamma_0 + \gamma_1 lnGDPpc_{it} + \gamma_2 lnGDPpc_{it}^2 + \gamma_3 lnGDPpc_{it}^3 + \gamma_4 lnCO2_{it} \\ & + \gamma_5 lnMLTpc_{it} + \gamma_6 lnBLTpc_{it} + \gamma_7 lnFDIpc_{it} + IV_{it} + \theta_{it} + \tau_{it} \end{aligned} \tag{4}$$

Where $\boldsymbol{CO2}$, $\boldsymbol{GNK}$, $\boldsymbol{GDPpc}$, $\boldsymbol{MLT}$, $\boldsymbol{BLT}$, $\boldsymbol{FDI}$ denote per capita CO_2 emissions, the green part of the natural capital per capita (i.e., the green natural capital), per capita GDP, per capita net transfer of concessional lending from Multilateral Development Banks(MDB)s,[2] per capita net transfer of concessional lending from bilateral development agencies and FDI inflows per capita, respectively. ε, μ, τ are error terms and $\boldsymbol{i}$ and $\boldsymbol{t}$ stand for country index and time index. $\boldsymbol{\theta}$ is a vector of control variables, which cover the country and year fixed effect, small island developing states (SIDS) status, etc. IV stands for the instrumental variables.

[2] This study uses Public and Public Guaranteed (PPG), bilateral concessional (net transfer) and PPG and multilateral concessional lending (Net transfer) data throughout the paper.

In terms of model selection, a Hausman test is deployed for the selection between the fixed-effects and random-effects estimation. The test results reject the hypothesis of the random-effects model. We adopted a similar approach as Shen (2006) by examining the endogeneity of the explanatory variables in the single polynomial equation estimation within the system. The Hausman test and Wald test results confirm that it is necessary to employ the cubic term (as shown in the technical annex). This study also examines a model in which the GDP per capita enters the model as itself and in quadratic form, but it was not statistically stable or robust (see the Appendix for more detailed results).

The hypotheses of this paper are as follows:

1. GDP per capita has a nonlinear relationship with GNK and CO_2 emissions;
2. "Biological carbon sequestration" exists and GNK has a negative relationship with CO_2 emissions;
3. The per capita net transfer of MDBs and that of bilateral financial institutions are positively related to GDP per capita, whereas their relationship with CO_2 and GNK is an empirical question;
4. FDI inflow per capita is positively related to GDP per capita, whereas its relationship with CO_2 and GNK is an empirical question.

Based on the discussions in the second section, this paper compiles a panel dataset of 96 countries[3] for the period 1995-2018 with the following sources: green natural capital (GNK) based on the World Bank's *The Changing Wealth of Nations* (CWON); CO_2 emissions per capita from the World Bank's World Development Indicators; net transfer of MDBs; net transfer of bilateral development institutions (including those from China) based on the World Bank's International Debt Statistics (IDS) database; foreign direct investment (FDI) inflows from the United Nations Conference on Trade and Development (UNCTAD) data and the China's Global Energy Finance (CGEF) Database by the Boston University Global Development Policy Center (Table 1).

Table 1: Descriptive Statistics of Variables (1995-2018)

	Sample Mean	Standard Deviation	Sample Minimum	Sample Maximum	N
lnGNKpc	8.324	0.704	4.574	10.542	2170
lnGDPpc	8.539	0.902	6.151	10.251	2170
lnCO2pc	-0.158	1.481	-6.917	2.731	2170
lnMLTpc	2.388	0.897	0.000	3.620	2170
lnBLTpc	3.951	1.407	0.000	4.850	2170
lnFDIinpc	6.239	0.114	5.945	6.795	2170
lnCGEFpc	0.154	0.593	0.000	4.333	1768
Emp.	58.169	13.164	23.742	86.063	2170
SIDS	0.088	0.283	0.000	1.000	2170
HDI	0.590	0.135	0.238	0.851	2170
LQ	0.937	0.386	0.161	1.966	2170

Source: Authors' elaboration. See Appendix for detailed sources.

3 This panel is not balanced and there are 68 countries with data of the full-time range between 1995-2018. The regressions in this paper adopt the fixed effects model which accounts for time and country fixed effect.

EMPIRICAL RESULTS

The key concerns are the shape of the empirical model, as well as the turning points in the EKC models. The turning points for U-shaped (quadratic functional income) and N-shaped (cubic functional income) EKC from cross-country and single-country studies vary substantially among different observance of pollutants or environmental degradation (Borghesi 1999). Using different techniques of estimation, researchers have found the turning points (in terms of per capita income) range from hundreds to tens of thousands (Holtz-Eakin and Selden 1995; Maradan and Vassiliev 2003), while others found an absence of EKC (Selden and Song 1994; Gangadharan and Valenzuela 2001; Arouri 2012). However, few are concerned with international development finance. Meanwhile, studies found that the inclusion of trade variables raises substantially the turning point of the curve (Kaika and Zervas 2013). Table 2 presents the paper's empirical results.

Table 2: Estimated Results for Equations 2-4 in a Simultaneous Equations Model (SEM) 3SLS with Fixed Effect

	ln(CO_2)	ln(per capita GDP)	ln(per capita GNK)
ln(per capita GDP)	-41.426*** (5.549)		-71.827*** (7.627)
(ln(per capita GDP))^2	5.271*** (0.67)		8.948*** (0.921)
(ln(per capita GDP))^3	-0.216*** (0.027)		-.363*** (0.037)
ln(per capita GNK)	-0.504*** (0.021)	-13.077*** (1.769)	-
(ln(per capita GNK))^2	-	0.865*** (0.114)	-
ln(per capita MLT)	-0.012 (0.014)	0.032* (0.016)	-0.01 (0.016)
ln(per capita BLT)	-0.031*** (0.006)	0.019** (0.007)	-0.027*** (0.007)
ln(per capita FDIin)	-0.167** (0.08)	0.575*** (0.087)	-0.319*** (0.094)
SIDS	1.58*** (0.112)	-5.61*** (0.666)	2.57*** (0.135)
ln(CO_2 per capita)		0.632*** (0.053)	-0.902*** (0.072)
Employment Rate	-	0.027*** (.003)	-
Constant	109.064*** (15.042)	52.041*** (6.517)	197.288*** (20.627)
Turning Points	1st, 763.98[a] 2nd, 15214.03	1917.85[b]	1st, 1062.84[c] 2nd, 12896.62
N	2170	2170	2170

*** p < .01, **p < .05, *p < .1

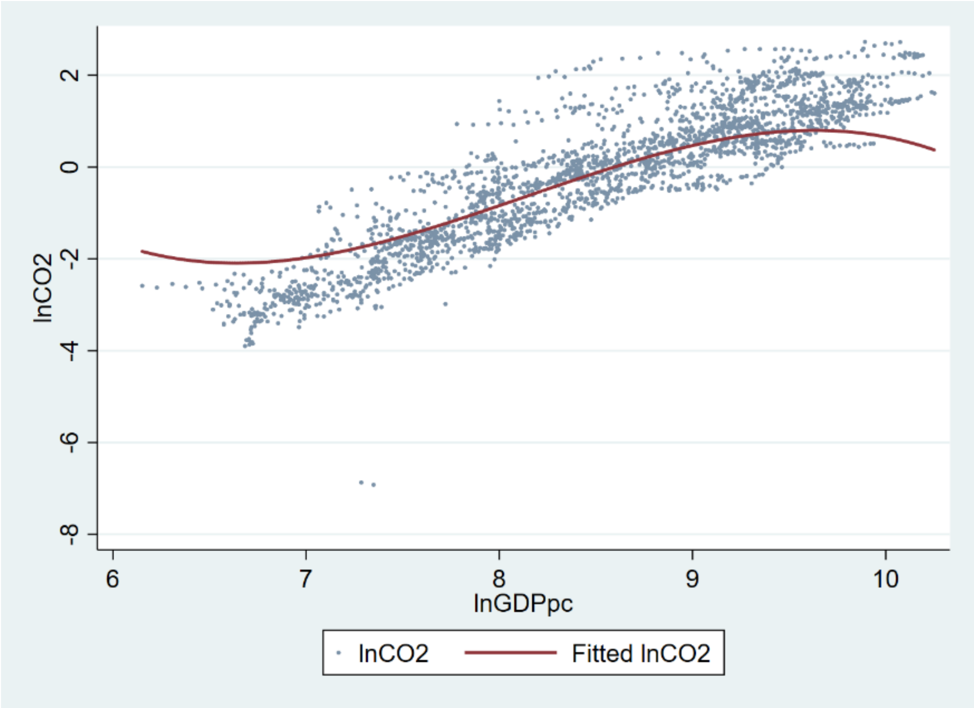
Source: Authors' elaboration, based on regression analysis.

Note: The SEM estimation is conducted using Stata's Reg 3 (3SLS) with fixed effects. For a and c, the turning points are calculated for GDP per capita in PPP constant 2017 international dollars; for b, the turning point is calculated for green natural capital, constant 2018 dollars.

In the first equation of CO_2, (Column 2), the model presents an inverted N-shaped or flattened S-shaped relationship with income. Per capita GDP, and the quadratic and the cubic term of per capita GDP, which are expressed in logarithmic form, are statistically significant. There is a trade-off between GDP level and CO_2 emissions up to the turning points. The first and second turning points are 763.98 and 15214.03 constant 2017 international dollars using purchasing power parity (PPP) rates, respectively. Such a relationship can be pictured as an inverted N-shaped curve or flattened S-shaped curve (Figure 8).

The second equation tells a story that the real economy uses GNK as an input initially, so the GNK declines as the economy grows in early stages. Only when the economy is developed to a certain extent (i.e., above the turning point where GNKpc = 1917.75) do governments start to invest in GNK, which rises thereafter. In the third equation of GNK (Column 4), GDP per capita has a nonlinear and inverted N-shaped relation with GNK per capita, and all three coefficients are statistically significant, with the first and second turning points at 1062.84 and 12896.62 PPP constant 2017 international dollars, respectively.

Figure 8: An Inverted N-Shaped Relationship Between CO_2 Emissions and GDP Per Capita, Both in Logarithmic Form



Source: Authors' elaboration, based on regression analysis.

One of the most interesting cross-equation findings is the validation of the "biological carbon sequestration" effect, that is, the natural ability of ecosystems to store carbon, demonstrated by the negative and significant relationship between green natural capital and CO_2 emissions. The coefficient is -0.504, which implies that a one percentage increase in a country's GNK would potentially lead to a reduction of CO_2 emissions by 0.5 percentage point. This confirms the second hypothesis.

Another cross-effect we found is that the natural log of CO_2 emissions per capita has a negative and significant effect on the natural log of green natural capital per capita, with a coefficient of -0.902. This implies that CO_2 emissions and other kinds of GHG emissions would reduce the value of land, forests and other kinds of GNK. This is consistent with the findings of the Lincoln Institute of Land

Policy that pollutant emissions reduce the value of land and real estate in China (Lord et al. 2022).[4] It is also consistent with numerous studies considering the impact of pollutants on people's health and quality of life.

On development financing, findings indicate that:

- All three kinds of financing have significant positive impact on GDP per capita, which is expected and consistent with previous studies. In particular, FDI inflow per capita has a positive and statistically significant relationship with GDP per capita. This confirms the fourth hypothesis.
- Bilateral lending and FDI inflows, on average, have a good performance in terms of reducing emissions (negative and significant).
- The model does not report a statistically significant relationship between net transfer of multilateral lending on CO_2 emissions, nor a support for green natural capital. This could be explained by a policy of "do no harm," which was found by previous studies.
- None of these development financing mechanisms have a positive impact on green natural capital accumulation. Bilateral lending and FDI inflows, however, are shown to have a negative and significant relationship with the log form of GNK per capita, indicating a certain degree of over-exploitation of green natural capital such as through deforestation, over-grazing, over-fishing and, in some cases, desertification.

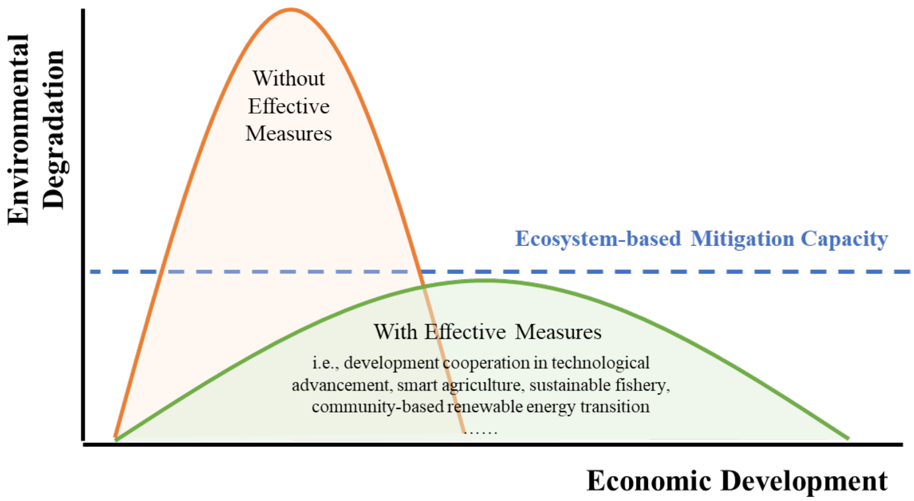
Such a relationship fits within the structural development process described in NSE and the previous sections. In the early stage of economic development when the endowment structure is dominated by land and labor, its endogenously-determined optimal industrial structure is dominated by land and labor-intensive sectors such as agriculture and livestock. The environmental characteristics of such sectors are of low energy consumption and pollution intensity. Thus, the environmental constraints on such sectors are weak and have less impact. In general, economic growth in this stage is relatively slow due to low productivity, and there is a steady decrease in emissions until the economy reaches the first threshold. With economic development and a changing structure of endowments, the optimal sectoral structure becomes increasingly capital-intensive, where capital plays an increasingly essential role in development along with both a mitigating impact and a damaging impact on the real economy. The environmental characteristics of this kind of industrial structure are often high-energy and pollution-intensive, thereby leading to the depletion of natural endowments. Meanwhile, with the tightening of environmental constraints, there will be strong demand for green transformation from society, and capital can impact the real economy with mitigating forces to accelerate the green transformation away from a pollution-intensive industrial structure, consequently reaching the overall goal of mitigation and building resilience. Thus, the economy reaches the second turning point where its emissions start to drop.

The estimated turning points are merely estimates since this paper uses data from 1995-2018 due to the unavailability of GNK data in more recent years. In particular, progress in environmental protection is notable in developing countries and effective policies are in place, which could have flattened the upward sloping part of the EKC and not been captured by the data of this study, which ends in 2018. There have been research and policies pursuing a "faster" downturn, figuring out the income level at which the turning point will occur and speed up in reaching such a peak. In addition, as Munasinghe (1998) notes, equivalent attentions need to be paid to "tunneling through" the curve by bridging the upward and downward parts of the curve. In EMDEs, if the environmental and climate

[4] The paper by Lord et al. builds a spatio-temporal model that makes an association between the effects of changes in air quality on land values. By applying this model to three Chinese case study cities – Shenzhen, Suzhou and Zhengzhou – they are able to present financial estimates of the impact of improved air quality on the value of development land.

problems are not taken seriously during the upward sloping part of the curve, it could reach a point of being nonreversible. This paper argues that policy actions and technological advancements will help developing countries reach a moderate peak, where international development cooperation can play an important role in knowledge sharing and addressing bottlenecks. Figure 9 illustrates how policies can "flatten the curve."

Figure 9: A Conceptual Interpretation of "Flattening the Curve"



Source: Authors' elaboration, based on Munasinghe (1998).

In addition to the results presented, there is a concern that countries highly reliant on importing agricultural products might have advantages accumulating green natural capital, given that it does not deploy domestic land as input to the real economy. This paper thus uses the following robustness test by controlling for the reliance on importing agriculture products. The test results are presented in Table 3.

Controlling for a country's dependence on importing agriculture products, it is notable that the GNK is still negatively associated with CO_2 emissions, along with an increase in the magnitude of such an impact. Thus, the biological carbon sequestration effect of green natural capital holds. In terms of the other interested variables, the expected signs for the coefficients do not change with the inclusion of new control variables, HS2, HS3 and HS4, and the magnitude of changes in coefficients is not remarkable. Thus, the overall model can be regarded as robust.

Table 3: Estimated Results for Equations 2-4, Controlling for Import of GNK

	ln(CO_2)	ln(per capita GDP)	ln(per capita GNK)
ln(per capita GDP)	-12.891*** (2.99)		-30.697*** (6.942)
(ln(per capita GDP))^2	1.742*** (0.362)		4.071*** (0.838)
(ln(per capita GDP))^3	-.071 (0.014)		-0.168*** (0.033)
ln(per capita GNK)	-.511*** (.013)	-1.267*** (0.491)	-
(ln(per capita GNK))^2	-	0.109*** (0.032)	-
ln(per capita MLT)	0.005 (0.013)	-.005 (0.012)	0.003 (0.022)
ln(per capita BLT)	-0.024*** (0.006)	0.02*** (0.006)	-0.04*** (0.01)
ln(per capita FDIin)	-.375*** (0.07)	0.438*** (0.062)	-0.555*** (0.123)
SIDS	1.314*** (0.092)	-1.574*** (0.212)	2.682*** (0.165)
ln(CO_2)		.811*** (0.031)	-1.788*** (0.081)
Employment Rate	-	0.007*** (0.002)	-
HS2	-	-	0.054*** (0.02)
HS3	-	-	0.058* (0.03)
HS4	-	-	0.073* (0.039)
Constant	34.069*** (8.068)	8.399*** (1.852)	81.379*** (18.764)
N	1832	1832	1832

*** p < .01, **p < .05, *p < .1

Source: Authors' elaboration, based on regression analysis.

Note: HS 2-4 are defined as second, third and fourth quantile in terms of reliance on importing agriculture products by two-digit HS code. The lowest quantile dummy variable is omitted during the construction with a concern of multicollinearity. The same estimation process is used as in Table 2.

CHINA'S ROLE IN SOUTH-SOUTH GREEN COOPERATION: WHAT THE DATA SAYS SO FAR

China has emerged as the largest bilateral provider of development finance since 2008. Thanks to several research initiatives,[5] World Bank staff have incorporated China's development finance lending from the Export-Import Bank of China (CHEXIM) into its IDS database.[6] Therefore, the BLT variable in the fourth section includes the net transfers of these official Chinese entities. In comparison to the total net transfers of the bilateral lending documented in the IDS database, China's part is relatively small, although its contribution has increased in the last decade.

Here, this paper takes an experimental approach and uses the China's Global Energy Finance (CGEF) Database dataset produced by the Boston University Global Development Policy Center to replace bilateral development finance in the above SEM model, and see if using this dataset makes a difference in the overall model. In particular, the review of the CGEF Database seeks to provide insight regarding whether projects financed or co-financed by China have helped accelerate green energy transformation in host countries. However, the dataset itself has limitations compared to the dataset used in the above SEM model since it only documents China's financing for global energy projects by China's two global development finance institutions, the China Development Bank (CDB) and CHEXIM, and there is no information on repayment or net transfer. The two banks have issued a total of 331 loans to 68 foreign governments and associated entities in the energy sector since 2000, totaling $234.6 billion (Ma, Springer and Shao 2022). The SEM regression using CGEF data is shown in Table 4.

Table 4 shows that the findings in the fourth section hold true for this model that substitutes bilateral lending with China's global energy financing per capita. The estimated signs of coefficients remain unchanged. Energy financing from China is associated with reduced CO_2 emissions in developing countries with the coefficient (-0.019) negative and significant. This mitigation may be related to the building of energy projects in low-income countries, such as large-scale hydropower generation projects, where the emissions are low. Meanwhile, CGEF is negatively associated with the GDP per capita and green natural capital (GNK). These negative but significant estimates may be explainable by the structure of these investments (Springer, Lu and Chi 2022) and the long-term characteristics and complexity of an infrastructure project, as suggested by previous studies reviewed.

Although Chinese investments in developing countries have significantly bridged the infrastructure gap, there are observable negative socio-economic impacts. The OECD (2012) notes that China's investment in infrastructure "has helped develop infrastructure in fragile and low-income states, which may otherwise not have had access to market finance or even to donor funding which tends to focus on social sectors in these countries." Other studies found that Chinese investment in Africa is fraught with issues such as risky loans, moral hazards and environmental concerns rooted from informal operations (Hou et al. 2020). Dreher et al. (2022) pointed out that "socioeconomic impacts of Chinese development projects are comparable with, if not superior to, those generated by the World Bank." In the CGEF Database dataset, there are a growing number of low-carbon energy projects for hydropower generation and renewable energy in recent years. In addition, it is notable that China's new coal-fired power plants follow strict rules for conventional emissions standards while maintaining high efficiency in power generation (CAP 2017). However, Chinese development projects may also have negative externalities, such as corruption, political instability and environmental degradation (Dreher et al. 2022, 228). Bräutigam's recent study (2022) on China and Zambia reveals that

[5] These research initiatives include but are not limited to China Africa Research Initiative (CARI) led by Deborah Bräutigam, the China's Global Energy Finance (CGEF) Database managed by the Boston University Global Development Policy Center and the AidData research initiative at the College of William and Mary.

[6] The definition of bilateral concessional lending excludes the China Development Bank.

Table 4: Estimated Results for Equations 2-4 in a Simultaneous Equations Model (SEM) 3SLS with Fixed Effect, with CGEF instead of BLT

	$\ln(CO_2)$	ln(per capita GDP)	ln(per capita GNK)
ln(per capita GDP)	-46.622*** (6.051)		-100.83*** (12.785)
$(\ln(\text{per capita GDP}))^2$	5.888*** (0.728)		12.615*** (1.548)
$(\ln(\text{per capita GDP}))^3$	-0.216*** (0.027)		-.512*** (0.062)
ln(per capita GNK)	-0.24*** (0.029)	-9.4*** (1.374)	-
$(\ln(\text{per capita GNK}))^2$	-	0.639*** (0.091)	-
ln(per capita MLT)	-0.001 (0.011)	-0.014 (0.016)	0.002 (0.02)
ln(per capita CGEF)	-0.019** (0.008)	-0.02* (0.011)	-0.03** (0.014)
ln(per capita FDIin)	-0.075 (0.063)	0.272*** (0.09)	-0.066 (0.119)
SIDS	1.597*** (0.084)	-4.84*** (0.593)	3.298*** (0.186)
$\ln(CO_2$ per capita)		0.75*** (0.059)	-1.67*** (0.132)
Employment Rate	-	0.017*** (.003)	-
Constant	121.238*** (16.492)	39.748*** (4.992)	267.749*** (34.455)
N	1768	1768	1768

*** $p < .01$, **$p < .05$, *$p < .1$

Source: Authors' elaboration, based on regression analysis.

Note: The SEM regression is conducted using Stata's Reg 3 (3SLS) with fixed effects.

the multiplication of stakeholders has created fierce and unregulated competition for infrastructure contracts in the host country. In addition, some research documents a large proportion of informal Chinese small-scale mining operators in the extractive sector with their activities exacerbating the already high mining-induced environmental problems (Ofosu et al. 2020; Crawford and Botchwey 2017). Yang et al. (2021) found that China's development projects, particularly within the energy sector, pose greater socio-ecological risks to biodiversity on Indigenous peoples' lands than those of the World Bank.

Much more work needs to be done to safeguard Chinese investment against unintended socio- ecological and environmental impacts. The selection of projects should follow the host country's development agenda and be consistent with their Nationally Determined Contributions (NDCs). China's policymakers and practitioners should try to learn from the positive and negative lessons from the past, follow ESG principles and comply with host government regulations, to provide technology and financing for green transformation. Rather than capital-intensive infrastructure projects, small mitigation and conservation projects, such as Grain for Green, community-level renewable biomass and microgrids, are equally worth worldwide support.

CONCLUSION AND POLICY RECOMMENDATIONS

This paper attempts to explore the challenging problem of green transformation in the Global South, and the roles of various forms of development finance and FDI. Green transformation is defined as the augmentation of renewable or green natural capital (GNK), which is a novel variable to enter the simulations equation model (SEM) as one of the dependent variables.

Using SEM and fixed effect, this paper's results confirm an inverted-N or flattened S-shape curve between CO_2 emissions and per capita GDP, which is statistically significant and robust. Second, building on and upgrading a nation's existing green natural capital (GNK), such as land, forests, fisheries and protected areas, could have a "biological carbon sequestration" effect on CO_2 emissions and have some positive effect on GDP per capita (after the turning point). In EMDEs, economic agents use GNK as an input initially in agriculture, animal husbandry, fishing and manufactural industries, so the GNK declines as the economy grows in early stages. Only when the economy is developed to a certain extent do people start to invest in GNK.

On limitations, the authors of this paper echo the recent views of the accounting and measurement of renewable natural capital by researchers and the World Bank's *The Changing Wealth of Nations*, that the current classification of GNK is quite narrow and not consistent with the definition of green assets that economists have proposed in earlier works, holding an environmental-constraints views. This particular interpretation of the natural capital concept aims to incorporate natural constraints into economic analysis, through the use of the term "capital," but endowing this capital with particular characteristics. It is necessary to update this view in the future, by including energy sources such as wind, solar and hydro energy and biomass as various forms of natural capital services, and the emergence of sustainable industries (Hart and Ahuja 1994; Russo and Fouts 1997; Russo 2003; Ekins et al. 2003; Fenichel and Abbott 2014). Another limitation is that due to the unavailability of GNK, this study is limited to the period between 1995-2018.

On development financing, this study finds that all three kinds of development financing of interest have significantly positive association with GDP per capita. Bilateral lending (including China) and FDI inflows, on average, perform well in reducing emissions. The results do not show a significant association between multilateral lending and CO_2 emissions, nor a support for green natural capital. However, the two forms of development financing mechanisms examined in this study, multilateral and bilateral lending, either have a weak or absent association with green natural capital accumulation.

These results point to a neglected area of investment by multilateral and bilateral development financiers, and that is renewable or green natural capital (GNK). Investing in forests, land, fisheries and protected areas and augmenting their values, could reduce CO_2 emissions and improve people's income and welfare. This is consistent with previous studies which show the negative impact of pollution on land value and people's health. However, neither multilateral nor bilateral development financiers have provided adequate financing in these areas of investment.

Investing in renewable or green natural capital requires long term "patient capital," which can be provided by multilateral and bilateral development banks, as well as host countries' fiscal resources and national development banks. An advantage is that this area of investment is labor-intensive, which will consequently create employment, promote rural development and reduce poverty. In practice, these investments tend to have a clear socio-economic and environmental goal to achieve, making them a good match for life-cycle environmental management frameworks based on a common understanding among bilateral and multilateral creditors (CCICED 2020).

These investments are not as risky and lumpy as infrastructure projects such as power generation and transportation. Therefore, it is hopeful that EMDEs can invest in these areas without incurring large amounts of debt and can subsequently be the priority areas for boosting sustainable development. Governments and development banks may consider various forms of incentive schemes such as "ecological service subsidies" and work with local communities to invest in agriculture (crop land), forestry, animal husbandry (pastureland), fishery and protected areas and related small-scale and affordable renewable energy projects such as mini grids and agricultural biomass. This will also be a direction for future research.

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APPENDIX 1: TECHNICAL NOTE

Hausman Test for Fix Effect vs. Random Effect

This paper uses a Hausman test to decide whether to apply a fixed or random effects model to the panel data. The test is performed separately for each of the three equations in the set of equations, and the following are the results of the test.

Annex Table 1: Hausman Test for Each of the Equations Within the System

	Eq. (2)	Eq. (3)	Eq. (4)
Chi-square test value	13.868	151.207	22.429
P-value	0.054	0	0.002

Source: Authors' elaboration, based on regression analysis.

Inclusion of quadratic and cubic term

This paper uses the Wald test to compare the simple linear regression model without quadratic and cubic terms with the regression model with the inclusion of quadratic and cubic terms to decide whether quadratic and cubic terms should be introduced. The test results show that it is necessary to include quadratic and cubic terms in the model.

Annex Table 2: Wald Test for Quadratic and Cubic Terms

lnCO2	Coef.	St.Err.	t-value	p-value	Sig
lnGNK	-.03	.019	-1.62	.105	
lnGDPpc	-12.797	3.466	-3.69	0	***
lnGDPpc2	1.922	.415	4.63	0	***
lnGDPpc3	-.085	.016	-5.16	0	***
lnMLTpc	-.263	.023	-11.33	0	***
lnBLTpc	-.014	.013	-1.13	.26	
lnFDIinpc	.187	.139	1.34	.179	
SIDS	-.258	.036	-7.20	0	***
Constant	21.785	9.598	2.27	.023	**
Mean dependent var	-0.159		SD dependent var		1.495
R-squared	0.850		Number of obs		2234
F-test	1946.175		Prob > F		0.000

*** p < .01, **p < .05, *p < .1

Source: Authors' elaboration, based on regression analysis.

Note: H0: lnGDPpc2 = 0, lnGDPpc3 = 0; F (2, 2225)=103.67, Prob>F=0.0000

Endogeneity Test

In a system of simultaneous equations, the endogeneity is caused by the simultaneity. This endogeneity is reflected in the endogeneity tests below. There are three endogenous variables identifiable in the equation system, which are lnGNK, lnCO2 and lnGDPpc. Because of the existence of endogenous variables, it is necessary to adopt instrumental variables, for which employment rate, urbanization location quotient and human development index are used as instruments.

Annex Table 3: Endogeneity Test for Equations 2 and 3

Linear regression 1

lnGDPpc	Coef.	St.Err.	t-value	p-value	Sig
lnMLTpc	-.008	.007	-1.05	.294	
lnBLTpc	.011	.003	3.37	.001	***
lnFDIinpc	.241	.038	6.29	0	***
SIDS	.864	.053	16.22	0	***
Emp	.004	.001	2.74	.006	***
HDI	5.055	.172	29.32	0	***
LQ	-.109	.057	-1.93	.054	*
Constant	3.806	.278	13.69	0	***
Mean dependent var		8.539			
R-squared		0.983			
F-test		956.735			

Linear regression 2

lnCO2	Coef.	St.Err.	t-value	p-value	Sig
lnGNK	-.068	.025	-2.74	.006	***
lnGDPpc	-10.597	2.31	-4.59	0	***
lnGDPpc2	1.553	.279	5.56	0	***
lnGDPpc3	-.068	.011	-6.16	0	***
lnMLTpc	-.015	.014	-1.09	.274	
lnBLTpc	-.03	.006	-4.80	0	***
lnFDIinpc	.027	.083	0.33	.74	
SIDS	.739	.119	6.21	0	***
gdp_res	-.33	.084	-3.93	0	***
Constant	20.134	6.311	3.19	.001	***
Mean dependent var		-0.158			
R-squared		0.976			
F-test		666.631			

Source: Authors' elaboration, based on regression analysis.
Note: H0: gdp_res = 0; F (1, 2043) =15.43, Prob>F=0.0001

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