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The Impact of Official Development Assistance on Carbon Emissions in Developing Countries: Implications for Mongolia

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ABSTRACT

Using comprehensive panel data covering 110 developing countries over four decades (1981–2020), this study asks the following questions: (1) Will carbon emissions naturally decrease as income levels in developing countries rise? and (2) How do financial resources reduce those emissions? The study finds that: 1) major carbon emissions are expected to decrease after countries reach a certain income threshold level, confirming the so-called Environmental Kuznets Hypothesis, with the turning point occurring between $26,884 and $38,674; and 2) both official development assistance (hereafter, ODA) disbursement in the energy sector and private investment are more effective in relatively lower income developing countries (a threshold of $6,343 and $7,806) where higher temperatures prevail. This means that, in colder and relatively higher-income (rapidly growing, *per se*) economies, ODA and private investment should serve as strategic complements to each other, facilitating multi-stakeholder partnerships, including public-private partnerships, to address environmental degradation. In this regard, this article discusses the case of Mongolia.

Keywords: carbon emission, environmental Kuznets curve, official development assistance, private investment, panel data, marginal effect

INTRODUCTION

The Paris Agreement, adopted in December 2015 and implemented in November 2016, was the first international agreement regarding climate change to bring developed and developing countries together under the common goal of limiting global warming to below 2℃ from pre-industrial levels. To achieve this goal, countries aim to reach the global peak of greenhouse gas (GHG, hereafter or carbon, informally speaking) emissions as soon as possible—recognizing that doing so will take longer for developing countries—and to achieve a climate-neutral world by 2050.

GHG emissions consist of 3 major components —carbon dioxide (CO_2), methane, and nitrous oxide (N_2O)—as well as hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride (United Nations Framework Convention on Climate Change [UNFCCC], 2022a). As the primary GHG, CO_2 accounts for the largest percentage of all GHG (Intergovernmental Panel on Climate Change [IPCC], 2014). Hence, international agreements regarding climate change have focused on CO_2.

Ahead of the 25th UN Climate Change Conference (known as COP25 or Conference of the Parties) (COP25, 2022), the Net Zero Challenge report warned that the net-zero goal governments had previously committed to was insufficient. At the time, excluding the top five emitters, only 67 countries had committed to this goal (World Economic Forum [WEF], 2019), rising to 121 in 2019. This made carbon neutrality a global agenda; nevertheless, it still lacked the necessary impact because the committed countries represented less than 25 percent of global emissions (World Economic Forum [WEF], 2020). As of November 2021, over 130 countries including big emitter countries such as India, China, the EU, Brazil, and the United States have now committed to carbon neutrality, marking some progress in this regard (COP26, 2021).

It took 6 years from the signing of the Paris Agreement and 25 years from the signing of the Kyoto Protocol for developed and developing countries to achieve consensus regarding climate change. Still, the net-zero goal remains biased toward developed countries that have already reached the global GHG emissions peak, and lower-level income countries continue to be neglected in the discussion. The international community (including developing countries) has recognized the urgency of tackling climate change in a manner that aligns with the notion of “Common but Differentiated Responsibilities,”; in line with this notion, the Glasgow Climate Pact highlighted the need for “accelerated action in this critical decade, on the basis of the best available scientific knowledge and equity, reflecting common but differentiated responsibilities and respective capabilities and in the context of sustainable development and efforts to eradicate poverty” (United Nations Framework Convention on Climate Change [UNFCCC], 2021).

Meanwhile, although the UNFCCC and the Paris Climate Agreement both treated climate finance as a core agenda item, it emerged as an issue at the COP26 when rich countries again failed to generate the annual $100 billion climate finance fund promised by 2020. Global climate finance was estimated to be $722 billion over the last four years, and as of 2019, developed countries had provided only $79.6 billion to developing countries. Meeting existing pledges thus requires more than $20 billion in financial resources. In the COP26 negotiations, developed countries made a new financial pledge of over $600 million for the Least Developed Countries Fund (LDCF) to help accelerate adaptation.

Against this backdrop, this study asks two main questions: Will carbon emissions naturally decrease as income levels in developing countries rise? How do financial resources reduce those emissions? To state the conclusion up front, major carbon emissions are expected to decrease after countries reach a certain income level threshold, confirming the so-called Environmental Kuznets Hypothesis, with the turning point occurring between $26,884 and $38,674. However, since achieving this range is too challenging for most developing countries to expect a natural decrease, mobilizing financial resources should be emphasized to expedite the process of reducing carbon emissions. Regarding the specific impacts of these financial resources, both public ODA disbursements in the energy sector and private investment are more effective in relatively lower income developing countries where higher temperatures prevail. This means that, in colder and relatively higher-income (*per se* rapidly growing) economies, ODA and private investment should strategically complement each other to facilitate multi-stakeholder partnerships, including public-private partnerships, to address environmental degradation. In this regard, this study discusses the case of Mongolia.

The remainder of this study is organized as follows. Section 2 overviews existing literature to outline the theoretical background for this study. Section 3 describes the study's research design, including the data profile and methodologies. Section 4 summarizes the findings of the empirical tests. Lastly, Section 5 concludes the study and discusses the Mongolian case to address the main findings from the previous section.

REVIEW OF EXISTING STUDIES AND THEORETICAL BACKGROUND

The so-called Environmental Kuznets Hypothesis has been a dominant approach in empirical examinations of the relationship between countries' income and environmental degradation levels. Like Kuznets (1955)'s original hypothesis, which argued that a quadratic relationship exists between countries' inequality and income levels, the environmental version of the Kuznets Curve predicts that the relationship between income and environmental degradation levels will take the form of an inverted U curve, as shown in Figure 1. Throughout the years, the number of studies that have addressed the EKC hypothesis and its extensions theoretically and empirically has grown significantly (Purcel, 2020). Grossman and Krueger (1991) first tested the EKC Hypothesis with data covering 32 countries for the years 1977, 1982, and 1988, identifying the turning point at around $4,772–5,965. Later, numerous studies set out to prove that environmental degradation tends to worsen as modern economic growth occurs until average incomes reach a certain point in the course of development.

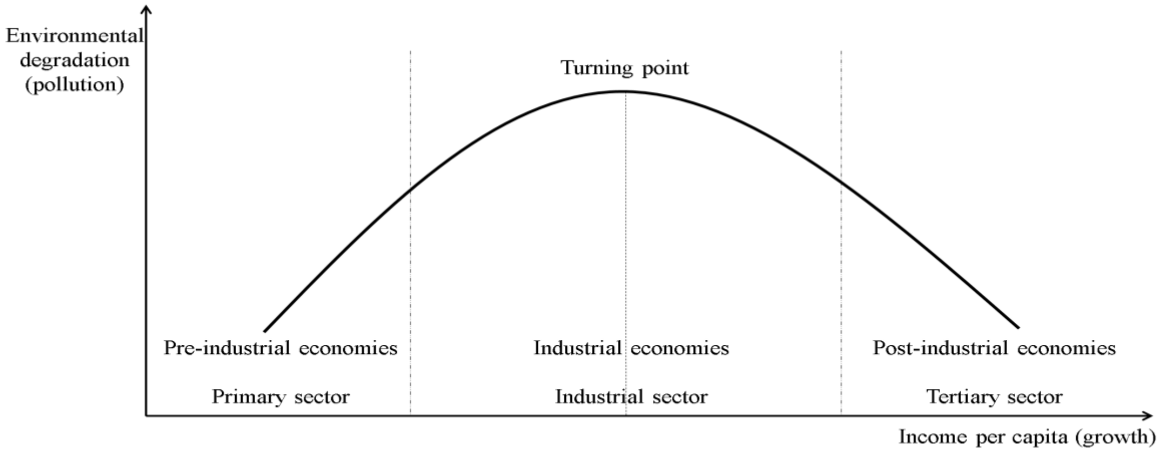
Shafik and Bandyopadhyay (1992) pointed out that the empirical evidence supporting the EKC hypothesis at a macro-economic level remains scarce and that efforts to generate said evidence have been constrained by the absence of data from numerous countries. Since the 1990s, EKC studies first adopted time-series and cross-country evidence, and Shafik (1994) later improved their approach by applying it to a panel dataset covering 31 countries for 17 years (1972–1988), identifying $4379 as the turning point. Selden and Song (1994) analyzed data covering 30 countries including 22 OECD countries and 8 developing countries for 9 years (1973–1975, 1979–1981, and 1982–1984), and identified the turning points at around $10,000–22,000 and $6,000–12,000 in the random and fixed effects models, respectively.

Grossman and Krueger (1995) broadened the period under analysis from 3 years (1977, 1982, and 1988) to 12 years (1977–1988) (1992) and identified turning points at $4,000 and $6,000 for SO2 and smoke. Cole et al. (1997) used panel data covering OECD countries for an average of approximately 20 years, from the 1970s up to the early 1990s.

This study follows a classification used by Shahbaz and Sinha (2019) for single country and cross-country contexts. Since the 2000s, some EKC studies have also adopted regional approaches in areas such as the EU, the Middle East and North African (MENA, hereafter), OPEC, and Asian countries (Apergis & Ozturk, 2015; Arouri et al., 2012; Dehnavi & Haghnejad, 2012; Musolesi et al., 2010) or in specific countries such as Sweden, Canada, Geneva, Switzerland, China, Algeria, Indonesia, Turkey, and USA (Aslan et al., 2018; Lacheheb et al., 2015; Lantz & Feng, 2006; Lindmark, 2002; Ozatac & Gokmenoglu, 2017; Panayotou, 2003; Sugiawan & Managi, 2016; Zhang, 2011). Musolesi et al. (2010) examines EKC for CO_2 emissions in 109 countries for 43 years (1959–2001) and identifies a clear EKC shape in EU countries with turning points at $16,105 while some signs of an EKC in less developed countries. Arouri et al. (2012) uses panel data for 12 MENA countries for 25 years (1981–2005) and finds a distinct EKC shape for CO_2 in the regional level, but poor evidence for EKC in the country level owing to very low or high turning points. Dehnavi and Haghnejad (2012) utilizes a panel of 8 selected OPEC countries for 38 years (1971–2008) and confirms an N-shaped

Figure 1

Environmental Kuznets Curve (EKC)



Note. Adapted from "An Approach to the Effect of Energy Innovation on Environmental Kuznets Curve: An Introduction to Inflection Point" by D.B., and A., 2016, *Bulletin of Energy Economics, 4*(3), 224–233. Copyright 2016 by Danial Balsalobre Lorente and Agustin Alvarez, and "Emissions, Renewable Energy and the Environmental Kuznets Curve, a Panel Cointegration Approach" by Z. Zoundi, 2016, *Renewable and Sustainable Energy Reviews, 72*, 1067–1075. (https://doi.org/10.1016/j.rser.2016.10.018.). Copyright 2016 by Zakaria Zoundi.

relationship for CO_2 and identified the turning points at about $15,000 and $25,000. Apergis and Ozturk (2015) confirms the EKC hypothesis using a dataset containing 14 Asian countries for 22 years (1990–2011). Lindmark (2002) investigates the EKC of Swedish CO2 emissions for 128 years (1870–1997) and by dividing the periods, found that time-specific technological clusters may affect EKC patterns. Like this, some EKC studies with regional approaches utilize control variables that take regional characteristics into consideration.

The default criticism frequently raised for the EKC Hypothesis is that it only looks at a bright future that we hope for, not the one that we face, and the argument that GHG naturally decrease as a country's income level rises may work only in theory without strong empirical evidence. In this regard, some studies have attempted to identify external factors that may curb GHG emissions, particularly in developing countries.

One such factor is official development assistance (ODA). It is one of major financial resources that developing countries can receive from the global community and several studies have measured ODA's impact on the environment. Although the ODA disbursement hypothetically reduces GHG emissions, empirical results in this regard have been mixed. For example, while Lee et al.. (2020) found that ODA has a mitigating impact in the recipient countries, Wang et al.. (2022) found the opposite, stating that increased ODA leads to *increased* carbon emissions, especially in low-urbanization areas; meanwhile, Li et al. (2021) concluded that, although green ODA overall has no direct relationship with carbon emissions, it works *conditionally* in countries with strong institutional capacities.

Taking these mixed findings into consideration, this study revisits the EKC, seeking to determine whether the inverted U curve can be confirmed such that the GHG emission problem is automatically resolved as countries' income levels rise. In addition, this study examines whether mobilizing external forces will reduce emissions, first checking ODA and then considering private sector investment.

A literature survey of EKC (Mitić et al., 2019) says that a number of EKC-related studies and many studies in other areas have measured the extent to which external financial resources reduce GHG emissions. However, very few studies have examined both using up-to-date datasets and taking into account marginal effects. Moreover, this study conducts an in-depth case study of Mongolia, with a reasonable ground. It thus makes several substantial contributions to the literature.

DATA AND METHODOLOGY

The hypothetical inverted U curve explains the theoretical mechanism of increasing and decreasing inequality, particularly in developing countries, which is stated in the beginning of the previous chapter, backed up by Figure 1. In order to test whether this theory works, this study constructs comprehensive cross-national panel data for 110 developing countries over a 40-year period (1981–2020). The 110 countries are selected based on data availability, and countries with income levels exceeding US$12,695—identified using the World Bank's income level classification (constant at 2020 gross national per capita income)— are excluded from the data. To examine the relationship between developing countries' income, financial resources, and environmental degradation levels, the regression equation applied in this study is as follows:

$$m_{it} = \beta_0 + \beta_1 GDPpc_{it} + \beta_2 GDPpc^2_{it} + \beta_3 Finance_{it} + X_{it} + \varepsilon_{it} \quad (1)$$

where m_{it} is a dependent variable, measured by major air pollutants (CO_2, N_2O, and PM 2.5) for a given country *i* at time *t*. Most previous studies have confirmed the inverted-U relationship between economic development and CO_2 emissions (in metric tons per capita). Other than CO_2 emissions, N_2O emissions is a pollutant consisting of GHG which is 300 times more impactful than CO_2 emissions (Intergovernmental Panel on Climate Change [IPCC], 2007) that Selden and Song (1994); Panayotou (2003); Aguado and Oh (2021) also examined. Meanwhile, PM2.5 air pollution is another pollutant closely related to urbanization that, because of the spatial distribution of global urbanization, many regional studies have examined (Yang et al., 2018). $GDPpc_{it}$ is GDP per capita and its square term for the countries examined in this study, and $Finance_{it}$ is the financial resources that each country can utilize (ODA and private investment). X_{it} is a group of several control variables to identify other significant indicators of economic growth, population density, trade volume, and investment in energy with private participation or ODA in the energy sector. ε_{it} is the error term. All the variables are taken from the World Bank's *World Development Indicator.*

In the first round of analyses, this study tests the EKC Hypothesis with three major air pollutants[1]—CO_2, N_2O, and PM 2.5—to check the robustness of the hypothesis. With these major pollutants as dependent variables, the analyses focus on GDP per capita and its square term. The inverted-U hypothesis predicts that the coefficients for the linear term and the square term of GDP per capita are positive and negative, respectively. As for control variables, this study follows previous studies in using population density, trade volume, and investment in energy with private participation.

In the second round of analyses, the study focuses on the impact of financial resources, conducting an in-depth examination of $Finance_{it}$ from Equation (1) based on three major sources—the total amount of ODA, ODA disbursement in the energy sector, and private investment (the same variable used in the above-mentioned analyses). In addition, it only considers CO_2 as the dependent variable and does not use as many control variables as in the first round.

All the variables are log-transformed and tested a VIF to minimize multicollinearity. Based on the results of the Hausman Test[2] (Hausman, (1978), this study puts more weight on the fixed effects analyses to tackle any potential endogeneity

[1] Although CO_2 emissions are the most commonly used measurement, N_2O emissions are allegedly 300 times more impactful than CO_2 emissions (IPCC, 2007), and PM 2.5 has emerged recently as a major pollutant (Yang et al., 2018). Data regarding PM2.5 is limited; this study analyzes PM2.5 data for the years 1990, 1995, 2000, 2005, and from 2010 to 2017.

[2] Test of Null Hypothesis: Difference in coefficients not systematic chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B) = 96.24 Prob > chi2 = 0.0000 (V_b-V_B is not positive definite)

issues, although it also provides results from the random effects for sensitivity checks.

FINDINGS

Table 1 shows the results for the first round of analyses—testing the EKC Hypothesis. The results confirm the inverted-U pattern for all major pollutants—CO_2 emissions as well as N_2O emissions and PM2.5 air pollution. The GDP per capita coefficients are all positive for the linear terms and negative for the quadratic terms, with statistical significance. Based on these coefficients, the inverted-U curve peaks, known as the turning points, are calculated: CO_2 emissions are expected to peak when countries' per capita income levels reach between $26,884 and $38,674;[3] N_2O emissions are expected to peak between $31,650 and $50,036; and PM2.5 air pollution is expected to peak at the relatively earlier income level of between $1,791 and $2,531.

Population density is significantly positive only for N_2O emissions, while the analyses show that trade, as well as private sector investment, fails to generate any significant outcomes. The private investment variable is reused and given priority in the next-round analyses, which measure the impact of financial resources.

Table 1

Estimation Results: Testing EKC Hypothesis

	$LnCO_2$		LnN_2O		LnPM2.5	
	FE	RE	FE	RE	FE	RE
LnGDPpc	2.917***	3.021***	0.829**	0.844***	0.815***	0.794***
	(0.771)	(0.791)	(0.315)	(0.326)	(0.277)	(0.261)
$LnGDPpc^2$	-0.143***	-0.143***	-0.040*	-0.039*	-0.052***	-0.053***
	(0.046)	(0.048)	(0.020)	(0.021)	(0.018)	(0.017)
LnDensity	0.252	0.048	0.655***	0.578***	-0.135	-0.038
	(0.176)	(0.088)	(0.109)	(0.100)	(0.120)	(0.054)
LnTrade	-0.010	-0.011**	0.000	-0.000	0.006	0.007
	(0.006)	(0.006)	(0.004)	(0.004)	(0.005)	(0.005)
LnInvestment	0.007	0.008	-0.002	-0.001	-0.004	-0.004
	(0.007)	(0.008)	(0.004)	(0.003)	(0.004)	(0.004)
Constant	-14.925***	-14.833***	2.521**	2.113*	0.842	0.698
	(3.057)	(3.184)	(1.214)	(1.280)	(1.109)	(1.012)
Turning Point	$26,884	$38,674	$31,650	$50,036	$1,791	$2,531
# Observation	520	520	520	520	244	244
Goodness of Fit	0.424	0.634	0.628	0.627	0.122	0.114

Note. ***, **, and * respectively notes significance levels at 1%, 5%, and 10%. White heteroskedasticity-consistent errors are provided in parentheses. Variables are log-transformed. FE stands for Panel Fixed Effect and RE, Random Effect.

[3] These turning points are from the fixed and random effects models. They are found using the following equations. $y = ax^2 + bx + c$, $dy/dx = 2ax + b = 0$, x^* (turning point) = $-b/2a$. Lastly, since all variables are log transformed, the command "exp" is used to do exponential root transformation: exp ($-b/2a$).

The estimated turning points from the previous table are too high for most developing countries to expect a natural decrease. Given this, mobilizing financial resources should be emphasized to expedite the process of reducing carbon emissions. Table 2 shows the results for the second-round analyses—the impact of financial resources on reducing carbon emissions. While the sector-blind total amount of ODA does not help reduce CO_2 emissions, that amount specially targeted to the energy sector works consistently in both the fixed and random effects analyses, when controlled by per capita GDP. However, the results could also be interpreted as indicating that the carbon emissions problem becomes more serious as the income levels rise. Although the results in Table 3 show that CO_2 emissions will eventually peak and decrease thereafter, all the developing countries are on the left side (i.e., the increasing stage) of the inverted-U curve, which represents a positive correlation between per capita GDP and emissions levels. Meanwhile, private investment in energy turns out to have an insignificant effect on carbon emissions reductions.

Private investment in energy turns out to be insignificant in reducing carbon emissions. Last but not the least, the random effects analysis of the cold climate dummy reveals a significantly positive coefficient, while the fixed effects is inapplicable due to its time-invariant characteristics. This study estimates that countries with cold climates—average annual temperatures below 12-degree Celsius—emit, on average, seven[4] times more CO_2 than countries with warmer climates. This implies that the carbon emissions issue is particularly important in countries with colder climates as their income levels rise.

This finding raises another series of questions: Will these financial resources work *conditionally* depending on countries' income levels and climates? More specifically, are these resources more effective in the so-called "easy-to-handle" countries with lower income levels and "not-very-cold" climates that may generate carbon emissions? If this is the case, how should those resources be managed to improve their effectiveness for rapidly growing (*per se* higher income) countries with colder climates? To answer these questions, this study further examines the dataset by interacting financial resources with per capita GDP and breaking down the dataset into two groups by climate level. In so doing, it pays extra attention to CO_2[5], and considers the marginal effect by partially differentiating it with respect to private investment in energy or ODA in the energy sector, after interacting these variables with income level. Since both fixed and random effects analyses provide similar results in this case, the fixed effects results are reported here.

As shown in the first column of Table 3, the private investment seems to be effective in reducing CO_2 as the coefficients for CO_2 emissions are all negative. Interestingly, however, when interacted with GDP per capita, the coefficients become significantly positive, implying that the marginal effect switches its direction depending on a country's income threshold. To examine the exact turning point for this threshold, this study partially differentiates the dependent variable (CO_2) with respect to investment and locates the derivative on the vertical axis, matching GDP per capita on the horizontal axis. The turning point occurs where the line crosses the x-axis, which is made at \$6,343[6]; below this point, private investments addressing environmental issues effectively reduce CO2 emissions, but such investments cease working above that point. The left graph in Figure 2 depicts this process.

[4] Exp (1.971) = 7.178

[5] Results for N_2O and PM2.5 can be provided upon request, as can results for the random effects analyses.

[6] $\partial y / \partial LnInvestment = -0.429 + 0.049\ GDPpc = 0, GDPpc = 8.755. \exp(8.755) = \$6{,}343$

This study repeats the same process for ODA disbursement to confirm whether external public financial resources and internal private spending are at all consistent. As the second column of Table 3 shows, the result is very similar to the first one. Public ODA effectively reduces CO_2 emissions, and this effect is particularly meaningful in lower income countries. The turning point in this case occurs at $7,808[7]; the right graph in Figure 2 illustrates this.

Table 2

Estimation Results: The Impact of Financial Resources on Carbon Emissions

	FE			RE		
$LnCO_2$	**(1)**	**(2)**	**(3)**	**(1)**	**(2)**	**(3)**
LnODA_Total	0.089			0.081		
	(0.063)			(0.061)		
LnODA_Energy (Lag)		-0.022*	-0.049***		-0.023**	-0.049***
		(0.012)	(0.015)		(0.011)	(0.014)
LnInvestment			-0.012			-0.011
			(0.017)			(0.018)
LnGDPpc		1.424***	-4.512***		1.457***	-4.415***
		(0.264)	(1.362)		(0.251)	(1.315)
$LnGDPpc^2$			0.400***			0.395***
			(0.095)			(0.090)
Cold climate						1.971***
						(0.578)
Constant	1.814***	-9.000***	12.904**	1.919***	-9.286***	12.060**
	(0.345)	(2.108)	(4.916)	(0.408)	(1.946)	(4.829)
# Observation	1,649	1,467	502	1,649	1,467	495
Goodness of Fit	0.0424	0.3405	0.3981	0.0424	0.3404	0.5249

Note. ***, **, and * respectively notes significance levels at 1%, 5%, and 10%. White heteroskedasticity-consistent errors are provided in parentheses. Variables are log-transformed except for Cold Climate, a time-invariant dummy variable where developing countries with an average yearly temperature below and over 12.05 ºC are 1 and 0 respectively. LnODA_Total is log-transformed total ODA disbursement and LnODA_Energy is log-transformed ODA disbursement in energy sector, which is lagged by 1 year to avoid endogeneity issues. FE stands for Panel Fixed Effect and RE, Random Effect. The cold climate dummy is time-invariant and does not allow FE as an analytic tool.

[7] $\partial y / \partial LnODA\_Energy = -0.242 + 0.027\, GDPpc = 0, GDPpc = 8.963. \exp(8.963) = \$7,808$

Table 3

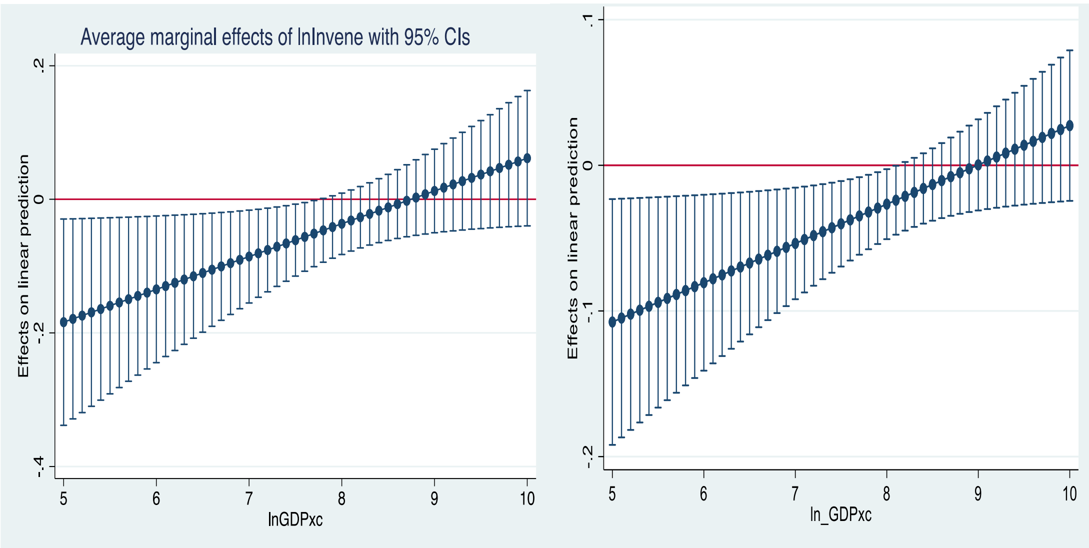
Further Estimation: Interaction and Results by Climate

	Interaction (1)	Interaction (2)	Cold	Non-cold
LnODA_Energy		-0.242**	-0.015	-0.024**
		(0.107)	(0.042)	(0.011)
LnInvestment	-0.429**			
	(0.198)			
LnGDPpc	0.728*	1.387***	1.636***	1.363***
	(0.429)	(0.256)	(0.536)	(0.196)
LnODA_Energy X LnGDPpc		0.027**		
		(0.013)		
LnInvestment X LnGDPpc	0.049**			
	(0.024)			
Constant	-2.734	-8.689***	-8.963**	-9.000***
	(3.234)	(2.035)	(4.098)	(1.494)
#Observations	844	844	342	1,093
Goodness of Fit	0.369	0.369	0.4688	0.4284

Note. ***, **, and * respectively note significance levels at 1%, 5%, and 10%. White heteroskedasticity-consistent errors are provided in parentheses. In the first two models, each financial resource (private investment and public ODA disbursement) is interacted with GDP per capita. In the last two models, the dataset is broken into two groups by cold weather and otherwise.

Figure 2

Visual Illustration of Marginal Effects



IMPLICATIONS AND THE CASE OF MONGOLIA

Mongolia is one of the most air polluted countries in the world; its average PM 2.5 concentration level of 128 is 9.3 times greater than the World Health Organization (WHO) recommendation (IQ Air, n.d.). The use of solid fuels for heating in urban areas, including in households in the "Ger District" due to the limited availability of electricity and natural gas, is arguably responsible for the air pollution, which threatens public health and causes a number of heart, respiratory, and cardiovascular diseases—among the leading non-communicable diseases in Mongolia over the past 10 years (National Statistics Office of Mongolia, 2021). Children and pregnant women are particularly vulnerable to air pollution, which can lead to premature birth and death, less brain development, and chronic respiratory diseases[8] (Asian Development Bank, 2021).

Measures have been taken to reduce pollutant emissions of solid fuels for residential heating in Ulaanbaatar. These include encouraging fuel switching (away from coal to improved compressed fuels, briquette), banning burning coal, supplying improved briquettes, reducing the price of electricity during night heating, and expanding the use of more efficient heating technologies (improved stoves) and improved housing materials to reduce heat loss in housing. Mongolia's energy sector has also received ODA. For example, the "Capacity Development Project for Air Pollution Control in Ulaanbaatar City" was implemented based on a Japanese loan targeting SMEs engaged in air-quality-conservation projects, including stove upgrades[9], discouraging fossil fuels (e.g., coal briquettes and coke production), and encouraging energy efficiency and renewable energy use (Fujita, 2019).

However, government measures, including the production of improved (fuel) briquettes in Ulaanbaatar, have encountered widespread suspicion and harsh criticism from the public for failing to reduce urban air pollution and creating social and environmental damage. Crucially, because Mongolia is one of the coldest countries in the world—temperatures drop below -20 degrees Celsius in the winter, and the average annual temperature in Ulaanbaatar is -0.8 degrees Celsius (Climate Data, n.d.)—demand for heating is greater than in any other developing countries. At the same time, Mongolia's PPP-adjusted GDP per capita was $11,723 in 2020, one of the highest in the region next to Kazakhstan, making it a very good candidate to examine in this study.

Table 4

2020 GDP per Capita of Selected Countries in Central Asia

Country	Current USD	PPP (2017 Constant USD)
Kazakhstan	9,122	25,363
Kyrgyz Republic	1,175	4,714
Mongolia	4,061	11,723
Tajikistan	859	3,657
Uzbekistan	1,750	7,331

[8] Between 2011 and 2014, the incidence level of respiratory diseases (per 10,000 people) in Ulaanbaatar doubled, increasing from 903 to 1833, and exceeding the national level, which also increased from 1090 to 1612 between 2011 and 2014 (National Statistics Office of Mongolia, 2021). Pneumonia increased from 212 to 351 per 10,000 people between 2011 and 2019 (NSO 2020). Moreover, exposure to smoke and fire, one of the leading causes of death among children aged 1–5 years increased from 5% to 12.4% between 2011 and 2019 (National Statistics Office of Mongolia, 2021).

[9] The following statement highlights the need to upgrade stoves. "Although a number of projects over the last 10 years distributed stoves designed to burn coal more efficiently and reduce emissions, the coverage by these projects was very low, and the vast majority of dwellings still use traditional heating stoves" (Ochir et al., 2014) . In fact, the U.S. Millennium Challenge Corporation (MCC) through its compact with the Mongolian government introduced a program in 2011 to encourage the replacement of traditional stoves with subsidized top lit updraft coal burning lower emission stoves. As part of this compact, approximately 97,230 stoves were distributed (Ochir et al., 2014).

Mongolia joined the Paris Agreement in 2015 and committed to reduce its total greenhouse gas emissions by 22.7% (16.89 million tons of CO2) as a Nationally Determined Contribution (NDC) by 2030 (Government of Mongolia, 2019). As the energy sector bears almost half of the total emissions, it is obliged to have a greater role to reduce the level by 8.34 million tons through increasing renewable energy production and reducing the emissions by 2.97 million tons as well as improving energy efficiency and reducing emissions by 5.37 million tons (Government of Mongolia, 2019).

Consequently, Mongolia has been implementing two main policy measures to reduce carbon emissions in the energy sector. First, to increase the production of renewable energy, and second, to improve energy conservation and efficiency. These policies are anchored in the “State Policy on Energy” (2015) “In the scope of environmental sustainability and green development: 3.1.6. Reduce negative impact on environment; reduce greenhouse gas emissions; and increase production of renewable energy sources” (Government of Mongolia, 2015). According to the policy, the government set goals to make the share of renewable energy to 20% of the total installed capacity by 2020 and 30% by 2030 (Government of Mongolia, 2015)

As Mongolia is located in one of the coldest parts of the world, the heating season is very long and 9-10 months of the year heating is required. The electricity and heating have been solved by a centralized system from coal-fired Combined Heat and Power (CHP) plants in urban areas as coal is the most common and the cheapest resource in the country. As of 2021, 81% of the total energy consumption is covered by domestic sources and 19% is imported. 89.8% of domestic electricity/energy production is provided by thermal power plants, 9.1% is provided by solar and wind farms, 1% by hydro power plants and 0.01% from diesel sources (Energy Regulatory Commission, 2022). In cities and towns, heating is solved only by sources based on coal-fired technology. The environmental condition, which is as cold as -40 degrees Celsius, and strong fluctuating characteristics of wind and solar sources make it very difficult to adopt renewable energy technology in Mongolia.

There are six solar and three wind power plants operating and connected to the central energy system so far in Mongolia. Entire renewable energy sources are funded by private investments such as ADB (Asian Development Bank) and EBRD (European Bank for Reconstruction and Development).

Mongolia’s power generation system is divided into five regions, namely Central region integrated power grid (CRIPG), Western region integrated power grid (WRIPG), Eastern region integrated power grid (ERIPG), Altai-Uliastai integrated power grid (AUIPG) and Southern region power distribution grid (SRPDG). However, consumers of CRIPG alone covers 84.5% of total consumption and 72.3% of total consumers live in the capital city of Ulaanbaatar as of 2021 (Energy Regulatory Commission, 2022).

Mongolia’s total electricity production has reached 7,963.6 million kWh in 2021 as it has increased by 10.7% compared to 2020. As of 2021, 89.8% of total electricity was supplied by thermal power plants (CHPP), 9.1% from solar and wind farms, 1.0% by hydro power plants, and 0.01% by diesel generators. Total heat energy production has reached 11,092.2 thousand Gcal which is a 3.6% increase compared to 2020.

Total coal consumption in power generation reached 8,100.1 kton in 2021, an increaseof nearly 25% compared to 2016. The total carbon emission level from the CHPPs increased by nearly 13% up to 10.34 million tons from 9.16 million tons between 2018-2021 (Energy Regulatory Commission, 2022).

Total electricity demand has grown by 43% from 968 MW to 1387 MW between 2016-2021 as estimated by the peak load. The number of electricity consumers has grown by 24% from 606,982 to 752,205 between 2016-2021 (Energy Regulatory Commission, 2022). As for the electricity consumer classification, “Ger district” households covers 48.7%, households living in apartments covers 43.7% and industry and offices covers only 7.6% of total consumption (Energy Regulatory Commission, 2022). In 2015, the average yearly electricity consumption of a household was 2,220.5 kWh (kilo-Watt hour) while in 2021, it increased significantly to 3,062.5 kWh by 37.9% (Energy Regulatory Commission, 2022).

According to the Ministry of Energy of Mongolia, the total electricity consumption of Mongolia has been growing by an average of 7-8% in recent years, while domestic energy production has been growing by an average of 6-7%. This means that the capacity of the power producers of the integrated grids has reached its limit and cannot meet the growing demand as it is facing a great challenge regarding energy security. In particular, the capacity to meet the energy demand during the peak winter season has reached its limit and power producers are working without any reserve, while the capacity to meet the winter energy consumption in the coming years, such as 2022-2023 and 2023-2024, is not sufficient. The capital Ulaanbaatar is facing the largest heat supply shortage where the central heat supply system has a shortage of 1400 Gcal/hour (Ministry of Energy of Mongolia, 2022) . The Ministry of Energy estimates that total energy consumption will increase by almost 80% by 2030 and fivefold by 2050 compared to 2018 (Ministry of Energy of Mongolia, 2022). Hence the carbon emissions level is estimated to be 21.5 million tons by 2030. It also claims that there is a possibility of reducing the emissions of energy sector by 8.3 million tons (Ministry of Energy of Mongolia, 2022) as pledged in NDC, but the lack of information on how to secure the funding for the planned projects raises doubts about whether this goal is achievable.

The findings from the previous section imply that developing countries with cold weather and relatively higher income levels (which allegedly produce more pollutants) may need to take further action—securing more global climate financing, blueprinting long-term programs, coordinating public-private partnerships, and so on—to tackle the problems. Mongolia's cold climate and relatively higher income level make it a country where such actions are particularly important, as most funding from the developed world is concentrated on the least developed nations—e.g., LDCF from UNFCCC to tackle climate change (United Nations Framework Convention on Climate Change [UNFCCC], 2022). Strategies for effectively mobilizing different types of financial resources targeting developing countries with relatively higher incomes should therefore be given priority in future studies.

It would be also desirable to add more control variables such as carbon tax and trading as well as FDI (Foreign direct investment), which should be addressed in further studies, as well.

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