Role of Innovation on Green Economic Growth: Empirical Analysis from the Countries of the Western Balkans

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Abstract. The impact of innovations on the growth of the green economy is a crucial aspect for a country's economy. The promotion of these innovations and investments is also vital for sustainable and long-term development. This paper aims to present the role of innovation on green economic growth in the countries of the Western Balkans (Kosovo, Albania, North Macedonia, Montenegro, Bosnia and Herzegovina and Serbia) over a 13-year period, from 2010 to 2022.Data for the research were obtained from the World Bank and the Global Economy Database, where the study data type is Panel. The econometric models used are: the ordinary least squares (OLS) model, the Fixed Effect (FE) model, the Random Effect (RE) model and the Hausman Taylor (HTH) model. The dependent variable is green economic growth, while the independent variables include the innovation index (INV), research and development expenditures (R&D), information technology exports (ITE), patent applications from residents (PA), manufacturing output (MAN), business freedom index (BFI), investment freedom index (IFI), and economic freedom index (EFI). The findings of this paper show that the countries of the Western Balkans should promote key factors such as: innovation as an important driver, with a positive impact on green economic growth; research and development expenses; patent applications, and favorable business and economic environments to facilitate long-term green economic growth and promote environmental sustainability. The results indicate that the coefficient for innovation is positive (B=0.41) and statistically significant at the 1% level, supporting the hypothesis that the increase in innovation has a positive impact on green economic growth in the countries of the Western Balkans.
Keywords: Green economic growth, Innovation, Research and Development, Western Balkans.

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1. Introduction

Global climate change and environmental pollution are the challenges presented at the global level and the demand for their management encourages more and more countries to use the growth of the green economy. Considering the importance of environmental health, it is necessary to know the impact of innovation, policy reforms and institutional quality on green economic growth. The more the countries of the Western Balkans take steps to stimulate and expand innovations in green economic growth, the healthier their environments will be, reducing exposure to the effects of global climate change. Economists have addressed a wide variety of topics related to the green economy and have made important analyzes of how innovations and changes in global environmental management policies can reduce the negative impact of humans on the environment and thus, in the first place, improve healthy lives and promote well-being in general. A clean environment means a better life on our planet and sustainable green development. Another study recently conducted by Ge et al. (2023) also pays attention to the fair distribution of resources, because the objectives of economic growth on the one hand promote the ways of green development, but on the other hand they can inhibit the effects of green development. Therefore they point out that the productivity of the total green factor can be improved, but the intensity of pollution emissions can be increased. They reveal that outcomes can be affected by green innovation and resource misallocation, as well as strategic interaction.

The main objective of this paper is to present the impact of innovation on green economic growth in the countries of the Western Balkans, where the research provides an empirical statistical analysis through secondary data.

The research question of this paper is: What is the impact of innovation on green economic growth in the countries of the Western Balkans? While the hypothesis of the research is: The increase in innovation has a positive impact on green economic growth in the countries of the Western Balkans.

This paper investigates the impact of innovation on green economic growth in the Western Balkans. These countries possess significant untapped green potential, but face challenges such as institutional limitations, inconsistent government support, mismanagement, brain drain, and limited existing innovation.Our aim is to shed light on the crucial role of innovation in driving a green economic transition in the region. We believe this research will raise awareness among policymakers and stakeholders of the positive impact that increased green innovation can have. Ultimately, focusing on green innovation can contribute to mitigating climate change and fostering a healthier planet.

This study fills a critical gap in the existing literature by providing an empirical analysis of the impact of innovation on green economic growth specifically within the Western Balkans region. These findings will be of significant interest to policymakers, industry professionals, and other stakeholders seeking to promote sustainable development in the region.

In order to investigate the impact or effect of innovation on green economic growth, quantitative methodology was used, which is based on secondary data. The econometric

models that were executed are; first the ordinary least squares (OLS) model, then the Fixed Effect (FE) model, the Ranom Effect (RE) model and the Hausman Taylor (HTH) model. The reason for using the Hausman-Taylor model, unlike most of the conducted research, also solves the problem of endogeneity.

This paper is divided into a total of six chapters, the following chapter presents the literature review, the third chapter explains the methodology and data collection procedure, the fourth chapter of the paper presents the empirical results, the fifth chapter presents the discussion of results and the last chapter presents the conclusion and recommendations.

2. Literature review

In this part of the paper, the empirical evidence of the impact of innovation on green economic growth is presented, and the paper is linked with the opinions of other authors. A significant number of authors researching the green economy suggest that any innovation in growing the green economy will create a better environment by reducing the negative effects of environmental pollution and slowing global climate change, which are the biggest challenges of our time. In addition to technological innovation, there is also a special emphasis on the institutional quality in the management of these policies, as well as carbon reduction, as a promoter for sustainable development (Obobisa et al., 2022).

Ahmed et al. (2022) during the study on the role of green innovation in the economy of South Asia, emphasize that energy production, innovation and green trade are factors that contribute to the growth of the green economy of these countries. Undoubtedly, one of the main requirements that the authors highlight that contribute to high-quality economic development is green innovation and institutional constraints that should advance the market system and increase support from governments (Li et al., 2021).

Anwar et al. (2024) emphasize the importance of comprehensive policy frameworks for fostering green economic growth and sustainable development. Their research identifies economic policy uncertainty, green innovation, and financial development as key drivers of a green economy. Building on this, Degbedji et al. (2024) find that institutional quality varies across countries, and strong institutions are crucial for achieving green economic growth.

The countries of the Western Balkans, like many others, face challenges in managing the risks posed by natural disasters, which are exacerbated by climate change. Their green economy is also less developed compared to EU countries. Therefore, our focus in this paper is to make the findings of how many authors use research on how innovations affect the growth of the green economy that these countries undertake, with a relatively low rate of utilization of green resources compared to European countries. Licastro and Sergi (2021) assert, that the countries of the Western Balkans deserve more attention in the reviews of academic literature, because their untapped green potential can be an indicator for policy makers to policies for their countries to progress as greener countries. Merko et al. (2019) emphasize that the construction of green GDP indicators is of particular importance, which shows how much it is to face the cost of ecological and environmental

degradation, taking Albania as an example. So, any innovation or push towards a green economy has the cost consequences of releasing pollutants into the environment such as CO2 and depleting natural resources. Another paper is analyzed by Kaldellis et al. (2018) where the relationship is revealed as to how the speed of the green transition is affected by migrations and especially the possible brain drain, which would greatly contribute to the acceleration of the green transition. But the authors, based on European integrative perspectives, give a promising signal that the involvement of young scientists in green research may be a solution.

Like many other countries in the Western Balkans, Kosovo, a relatively new nation, struggles to create robust job sectors. This lack of strong job markets, coupled with high levels of mismanagement and governance issues, hinders the development of a green economy and fosters brain drain, a major obstacle to progress. Brain drain, the emigration of highly skilled individuals, weakens a country's innovation potential, which is crucial for a successful green transition.

Using panel data techniques, Zhang et al. (2021) examined that promoting a sustainable green economy is done through public spending on human resources and green technology development. Similarly, some researchers have found that the favorable strategies for developing countries are increased investment in human resources and technological development as well as green industries (Wang et al., 2022).

Fang et al. (2022) analyze how technology can help minimize CO2 emission levels and improve industrial practices. Their research suggests that developing countries might benefit more from these advancements compared to developed countries. Furthermore, Soundarrajan and Vivek (2016) have found that it is important to green growth while keeping carbon low, through green finance as an investment or lending program. Kwilinski et al. (2023) strongly emphasize the importance of available resources, desired outcomes, and undesired outcomes during study. The paper shows that compared to green investments, economic openness and governance efficiency as a factor with a positive impact on green economic growth, green innovations are limited by asymmetry in technological progress. Zeraibi et al. (2023) emphasize the importance of the industrial sector actively investing in renewable energy and environmental quality to reduce environmental degradation. Maradana et al. (2017) find a complex relationship between innovation and economic growth per capita. The causality can be unidirectional (driven by supply or demand) or bidirectional. The type of innovation indicator also affects the observed causality. Jacobs (2012) analyzes green growth by describing the term green economy as a sister concept to sustainable development. Jacobs analyzes three forms of claims of environmental policy as a driver of growth: the Keynesian argument in recession for what he calls "green incentives", growth from natural capital and correcting the failures of market and theories of comparative advantage and long waves of capitalism. Author Barbier (2011) carries out the research that sustainable development will not occur through green growth as long as we face ecosystem loss. And this is accomplished by overcoming financing challenges through international payments. While Popok et al. (2020) emphasize that the modern approach to the green economy must take into account all sectors of the economy.

Gurtowski (2011) potentially the reference between the challenges of innovation and traditional polluting industry is inevitable. In general, the authors refer to the challenges of improving green economic efficiency. Also Chen et al. (2024) notes that green economic efficiency is enhanced by technological, structural and energy effects.

It is more than clear that countries to achieve green development rates and reduce long-term pollution, must manage energy reduction and strengthen technology investments, through which the objectives are achieved as the authors Lin and Ullah (2024) point out. In addition to the management and advancement of the use of technologies, the use of appropriate renewable energy technologies has an important impact. Gibson et al. (2017) examine the functioning of renewable energies and highlight some strategies for mitigating their negative effects such as wind, solar and water energy. Wind energy has a lower impact, solar energy is better if it is designed with advanced technology, water energy has greater risks in ecological environments. These technologies are growing globally and are an influential indicator in the growth and use of green energies. Song et al. (2019) highlight the need for increased and regionally-adapted investments in research and development (R&D) to achieve green economic growth. Aydin and Degirmenci (2024) suggest a link between investment freedom and environmental quality, citing examples from Belgium, Croatia, Denmark, Italy, and Spain. Oyebanji et al. (2022) emphasize the importance of promoting patenting, as strong patent protection can encourage environmentally friendly technologies and economic development (e.g.,reducing CO_2 emissions). Fedajev et al. (2024) recent study finds that Western Balkan countries lack innovation compared to Central and Eastern European (CEE) countries. This puts them at a disadvantage. The study recommends adopting best practices from other countries to improve innovation in the region.

3. Research methodology and data

In order to investigate the impact or effect of innovation on green economic growth, quantitative methodology was used, which is based on secondary data. The data for the research includes the six countries of the Western Balkans (Kosovo, Albania, Montenegro, Serbia, North Macedonia and Bosnia and Herzegovina), while the research period is 13 years, specifically from 2010 to 2022, so The data consists of panel data type.

Since the region of the Western Balkans is characterized by a lack of statistical data, then the study period is only 13 years (2010-2022), limitations in the data have also determined some of the variables of the study along with the measurement units.

The econometric models that were executed are; first the ordinary least squares (OLS) model, then the Fixed Effect (FE) model, the Ranom Effect (RE) model and the Hausman Taylor (HTH) model(Clark & Linzer, 2015).The reason for using the Hausman-Taylor model, unlike most of the conducted research, also solves the problem of endogeneity, since it is considered that green economic growth can be influenced by the variable itself in the following year (Baltagu& Bresson, 2012).

The model, Hausman - Taylor, is defined as follows:

$$Yit = c + \beta 1\ (yit-1) + \beta 2\ (INV) + \beta 3\ (R\&D) + \beta 4\ (ITE) + \beta 5\ (PA) + \beta 6\ (MAN) + \beta 7\ (BFI) + \beta 8\ (IFI) + \beta 9\ (EFI) + uit$$

Where yit is the dependable variable, which in this case is green economic growth, i = 1….6 (countries), t = 2010…2022 (years); c is constant; the explanatory variables include: $yit-1$, which is the first lagged of dependent variable, *INV* (Innovations index); *R&D* (rResearch and development expenditure); *ITE* (Information technology exports); *PA* (Patent applications by residents); *MAN* (Manufacturing); *BFI* (Business freedom index); *IFI* (Investment freedom index); *EFI* (Economic freedom index) and *uit* is the exogenous disturbance.

Table 1. Definition of variables

Nr	Variable	Abbreviations	Unit
1	Green Growth	GGDP	%
2	Innovations	INV	Index (0-100)
3	Research and development	R&D	Percent of GDP
4	Information technology exports	ITE	percent of total goods exports
5	Patent applications	PA	By Residents
6	Manufacturing	MAN	Percent of GDP
7	Business freedom	BFI	Index (0-100)
8	Investment freedom	IFI	Index (0-100)
9	Economic freedom	EFI	Index (0-100)

3.1. Descriptive statistics

The data in table 2 offers insights into various economic indicators for Western Balkan countries over the period of 2010-2022. Firstly, the mean value of Green Growth Domestic Product (GGDP) indicates an average growth rate of 4.07%, reflecting the region's overall economic performance in terms of environmentally sustainable economic activities. This suggests a positive trend towards environmentally friendly economic development within the Western Balkans.

The Index of Inovation (INV) stands out with a mean value of 33.85, which shows a value below the average of this index and that the countries of the Western Balkans should try to offer more innovations that are related to green economic growth.

Thirdly, Research and Development (R&D) expenditure, with a mean value of 0.41% of GDP, highlights the region's investment in innovation and technological advancement. While this figure may seem relatively low compared to more developed economies, it signifies a growing emphasis on fostering innovation within the Western Balkans.

Additionally, Information Technology Exports (ITE) as a percentage of total goods exports, with a mean value of 0.54, suggest a modest yet noteworthy contribution of the IT sector to the region's export portfolio. This indicates a potential for further growth and

development in the technology sector, driving future economic expansion. Patent Applications (PA) by residents in the region, with a mean value of 52.33, reflect a moderate level of innovation activity. This indicates a budding entrepreneurial spirit and a willingness to protect intellectual property rights within the Western Balkans.

Manufacturing (MAN) as a percentage of GDP, with a mean value of 8.57, underscores the significance of the manufacturing sector in the region's economy. This indicates a diverse economic base with substantial contributions from the manufacturing industry.

Business Freedom (BFI), Investment Freedom (IFI), and Economic Freedom (EFI) indices, with mean values of 78.11, 67.48, and 63.10 respectively, reflect the overall regulatory environment and ease of doing business within the Western Balkans. While these indices show a relatively favorable business climate, there may still be room for improvement to attract more investment and foster economic growth.

Table 2. Descriptive statistics of variables

Variable	Obs	Mean	Std. Dev.	Min	Max
GGDP	78	4.076	1.648	1.18	7.04
INV	78	33.859	3.243	27.1	41.2
R&D	78	.413	.203	.19	.92
ITE	78	.547	.466	.02	2.13
PA	78	52.333	61.717	1	290
MAN	78	8.573	4.509	2.34	16.119
BFI	78	78.115	80.786	46	777
IFI	78	67.487	6.958	50	83
EFI	78	63.103	5.832	45	78

4. Empirical results

In this part, the empirical results are presented, where first the correlation analysis is presented to present the relationship between the variables of the study. Based on the presented data of the correlation coefficient (Table 3), there is a positive relationship between innovation and economic growth with coefficient r=0.22. So, in addition to the growth of innovation in the countries of the Western Balkans, we also have green economic growth.

Table 4 displays findings derived from various regression models, including Ordinary Least Squares (OLS), fixed effects, random effects, and the Hausman-Taylor model with instrumental variables (IVs). Appendix Table A1 contains the results of the Hausman test. The Hausman test statistic is reported as 60.64, yielding a p-value of 0.0006. This indicates a rejection of the null hypothesis (H0) in favor of the alternative hypothesis (Ha). Consequently, both the random effects and fixed effects models are dismissed in favor of the Hausman-Taylor model, which is deemed more efficient. Moreover, Hausman-Taylor IVs are employed to address the issue of endogeneity in the analysis.

Table 3. Correlation results

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) GGDP	1.00								
(2) INV	0.22	1.00							
(3) R&D	0.29	0.30	1.00						
(4) ITE	0.34	0.42	0.82	1.00					
(5) PA	0.60	0.18	0.74	0.72	1.00				
(6) MAN	0.62	-0.02	0.48	0.45	0.66	1.00			
(7) BFI	-0.04	0.09	-0.07	-0.06	-0.09	-0.18	1.00		
(8) IFI	-0.06	-0.07	-0.03	-0.11	-0.11	-0.23	0.12	1.00	
(9) EFI	-0.28	0.06	-0.02	-0.05	-0.15	0.11	0.13	0.21	1.00

Table 4. Regression results

Variables/Models	OLS	FE	RE	HTH
INV	0.172***	-0.0334	0.172***	0.416***
	(4.41)	(-1.44)	(4.41)	(-4.74)
R&D	2.630*	-0.424	2.630*	0.341**
	(2.54)	(-0.53)	(2.54)	(2.45)
ITE	-0.431	-0.288	-0.431	-0.367
	(-0.92)	(-1.28)	(-0.92)	(-1.57)
PA	0.990**	0.11	0.990**	0.244**
	(2.88)	(0.43)	(2.88)	(3.11)
MAN	0.258***	0.00317	0.258***	-0.0101
	(6.99)	(0.05)	(6.99)	(-0.17)
BFI	0.186	0.129*	0.186	0.147**
	(1.33)	(2.09)	(1.33)	(2.36)
IFI	0.465**	-0.116	0.465**	0.849***
	2.73	(-1.20)	(2.73)	4.87
EFI	0.114***	0.432	0.114***	0.268
	(5.38)	(0.34)	(5.38)	(2.21)**
GGDP_ln_Lag				0.146**
				(2.81)
CountryID				0.687**
				(2.58)
_cons	0.775	5.866***	0.775	3.417**
	(0.41)	(5.26)	(0.41)	(2.59)
N	78	78	78	78
VIF	2.35			
Breusch-Pagan Test	P=0.7381			
Hausman Test	P=0.0006			

t statistics in parentheses

* p<0.05, ** p<0.01, ***p<0.001

The innovation coefficient (B=0.41) shows a positive impact on green economic growth. So, for every 1 additional value in the innovation index, we will have green economic growth for 0.41% on average. Impact of innovation is statistically significant on green economic growth in 1% level.

Research and development expenditures have a positive impact (B=0.34) on green economic growth. So, for every 1% of the value of the gross local production, an increase in research and development expenses, we will have a green economic growth of 0.34% on average. The impact of research and development expenditures is statistically significant for green economic growth at the 5% significance level.

The application of patents, which is related to the variable of expenses for research and development and innovation, also has a positive impact on green economic growth (B=0.24). So, for every 1 application more for patents from the citizens of the countries of the Western Balkans, we will have a green economic growth of 0.24% on average. Patent application is statistically significant at the 5% level for green economic growth.

All three indices (Index of doing business B=0.14, Index of investments B=0.84 and Index of economic freedom B=0.26) have a positive impact on green economic growth. So, the growth of these indices has a positive impact on green economic growth, where the impact is greater on the investment index, while the smallest positive impact is on the doing business index. The doing business index and the economic freedom index are statistically significant at the 5% significance level, while the investment index is statistically significant at the 1% significance level.

5. Discussion

The analysis highlights several key factors that contribute to green economic growth in the Western Balkans. Notably, innovation emerges as a significant driver, with a positive impact on green economic growth. This underscores the importance of fostering a culture of innovation and investing in technological advancements within the region. Additionally, research and development expenditures are found to positively influence green economic growth, indicating the value of allocating resources towards scientific and technological research to support environmentally sustainable initiatives. Moreover, the positive impact of patent applications further emphasizes the role of intellectual property rights and innovation in driving green economic development.

The study identifies three indices—business freedom, investment freedom, and economic freedom—that also play a crucial role in promoting green economic growth. These indices serve as indicators of the regulatory environment, ease of doing business, and overall economic policies within the region. The positive impact of these indices suggests that favorable business conditions, coupled with investment-friendly policies and economic freedom, contribute significantly to fostering green economic growth in the Western Balkans. Notably, the strongest impact is observed in the investment index, highlighting the critical role of investment in driving sustainability initiatives.

Our findings highlight innovation as a critical driver of green economic growth in the Western Balkans. Its statistically significant impact demands that policymakers and stakeholders prioritize initiatives that foster innovation, research, and development. By nurturing an innovation-friendly environment through R&D incentives, patent support, and collaborative ecosystems, countries in the Western Balkans can unlock long-term green growth. Furthermore, fostering favorable business environments with supportive regulations for entrepreneurship, accessible green capital, and academia-industry-government collaboration will be crucial for maximizing the impact of innovation.

Our findings, aligned with theory and evidence from other contexts, underscore the universal importance of innovation for driving economic growth, especially in environmental sustainability sectors. Innovation acts as a catalyst, fostering green technologies, processes, and practices that boost resource efficiency, reduce environmental impact, and propel green industries. This robust relationship underscores the critical need to prioritize innovation policies for effective sustainable economic development in the Western Balkans.

By emphasizing the pivotal role of innovation, our research underscores the need for targeted efforts to foster a culture of innovation and entrepreneurship within the region. Policymakers can accelerate innovation-driven growth by strategically investing in research and development, particularly in [targeted areas], fostering supportive regulations and collaboration between various stakeholders. These endeavors hold the potential not only to spur economic prosperity but also to propel the Western Balkans toward a more sustainable and resilient future.

These results provide empirical support for the hypothesis that the increase in innovation positively impacts green economic growth in the countries of the Western Balkans. Policymakers and stakeholders in the region can use these findings to inform strategies aimed at fostering innovation ecosystems, investing in research and development, and promoting entrepreneurship to drive sustainable economic growth and address environmental challenges.

6. Conclusions

While innovations and the growth of the green economy are closely related to each other, the research shows that any increase in innovations in the Western Balkan countries results in the growth of the green economy in general. So the impact of innovation is statistically significant in green economic growth at the level of 1%. This paper analyzed the main determinants of the growth of the green economy in order to create certain investment policies that will help in its growth. The results of the analysis of the econometric models complement the results of the literature and are in line with the expectations. According to the results of the econometric models and the reviewed literature, the greatest impact is observed in the index of investments, which play an important role in promoting the green economic growth.

The average rate of the Domestic Product of Green Growth (GGDP) is expressed with values of an average growth rate of 4.07%, contributing to a positive trend of economic

development activities in the countries of the Western Balkans.From the data analysis, innovation, research and development, patent applications, and favorable business and economic environments all contribute to sustainable economic development in the Western Balkans. Stakeholders in the region and policymakers can use these findings to make strategies aimed at promoting innovation, investment in research and development and promoting entrepreneurship to foster sustainable green economic growth and addressing environmental challenges.

The empirical analysis underscores the pivotal role of innovation in driving green economic growth within the countries of the Western Balkans. The positive impact of innovation, as evidenced by the statistically significant coefficients derived from various regression models, highlights the importance ofm prioritizing policies and initiatives that foster innovation across different sectors.Additionally, the findings suggest that increased investment in research and development (R&D) activities, promotion of patent applications, and improvements in the overall business and investment climate can significantly contribute to sustainable economic development in the region. Moreover, the emphasis on regional collaboration and knowledge sharing underscores the potential for leveraging collective resources and expertise to address common challenges and maximize the impact of innovation-driven strategies on green economic growth.

The study acknowledges several limitations. Firstly, while the Hausman-Taylor model is employed to address endogeneity concerns, residual endogeneity may still persist, particularly regarding variables such as innovation and research and development expenditure. Despite efforts to mitigate this issue, the potential influence of unobserved factors remains a concern and could introduce bias into the estimated relationships. Moreover, the model may not fully capture the complex interplay between variables, such as simultaneous causality, which could affect the robustness of the findings and undermine the validity of the conclusions drawn. Secondly, the study may suffer from omitted variable bias due to the exclusion of important factors that could influence green economic growth, such as environmental regulations, energy prices, or political stability. The failure to account for these variables could limit the explanatory power of the model and lead to biased estimates. Additionally, measurement errors in key variables, such as the innovation index and green economic growth, may affect the accuracy of the results. Further validation of the selected variables through additional references or detailed explanations of the methodological procedures from data providers could enhance the credibility of the findings. Overall, while the study provides valuable insights into the relationship between innovation and green economic growth in the Western Balkans, these limitations should be carefully considered.

Based on these results, policymakers are recommended to prioritize the formulation and implementation of evidence-based policies aimed at promoting innovation-led green economic growth in the Western Balkans. This includes allocating resources towards R&D initiatives, providing incentives for patent applications, and implementing reforms to enhance the business and investment climate. Moreover, efforts should be made to strengthen regional collaboration and knowledge sharing mechanisms to facilitate the exchange of best practices and promote growth among countries within the region. By

adopting these recommendations, policymakers can effectively harness the potential of innovation to drive sustainable economic development and improve the overall well-being of the citizens in the Western Balkans.

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Data source links

https://www.theglobaleconomy.com/indicators_list.php
https://data.worldbank.org/

Appendix

Table A1. Hausman (1978) specification test

Hausman Test	Coef.
Chi-square test value	60.64
P-value	0.0006