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GREEN PENSION INVESTMENT: A DYNAMIC RELATIONSHIP AND EFFICIENCY FOR THE GREEN ECONOMY IN INDONESIA

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ABSTRACT

Introduction/Main Objectives: This study aims to propose alternative investments from pension funds that are integrated with renewable energy productivity to boost green economic growth in Indonesia.To see the ideal efficient proportion of this investment and renewable energy on a regional scale, the efficiency of green economic performance is also identified**. Background Problems:** Investments in the green sector are less attractive to pension fund institutions while they have great potential financial sources. These investments should be promoted to support Indonesia's commitment to strengthening multilateral financing to support climate action in developing countries. **Novelty:** This study will be the first to simulate a green-based investment scheme involving pension funds for green economic growth, as well as capture its level of efficiency in a regional context. **Research Methods:** Two methods were conducted: the generalized method of moment (GMM) and the data envelopment analysis (DEA). Panel data from 34 provinces in Indonesia were used covering the period of 2016-2022. **Finding/Results:** The first finding revealed the short and long-term relationship between the green economy, green pension investment, and renewable energy. The second finding revealed that green economy efficiency in Indonesia has a moderate score with the highest score obtained by DKI Jakarta province. **Conclusion:** Green pension investment could promote the green economy and its efficiency in Indonesia, especially through active integration with the productivity of renewable energy

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INTRODUCTION

The green economy has gained popularity as a new economic mechanism worldwide (Feng et al., 2022). This is mainly because of its advantages as a low-carbon, energy-efficient, and socially inclusive economy (Doğan et al., 2021; Fareed et al., 2020). Several researchers have paid attention to green economic development in terms of investment and financing, such as through government spending (Feng et al., 2022; Huang et al., 2022), foreign direct investment (Ali et al., 2022; Tawiah et al., 2021), fintech (Metawa et al., 2022; Zhou et al., 2022), as well as insurance (Shi et al., 2023). One financial instrument that is less considered in green economic development—despite having great potential—is pension funds; these have investment management funds consisting of up to hundreds of trillions of dollars (Kaminker & Stewart, 2012). Unfortunately, investment in the green sector is less attractive to institutional investors such as pension funds (Rosiana, 2022). Long-term investment horizons make pension fund managers set up portfolios that tend to lead to high-carbon investments (Egli et al., 2022). The United Kingdom government started an initiative in October 2022 whereby it invested 80% of its workers' pension funds in investment schemes that tackle climate risk by allocating these substantial funds to green sustainability initiatives (Government UK, 2022). However, pension fund institutions are showing reluctance towards the UK government's initiative since they are seeking increased incentives to back high-risk sectors and a broader array of investment opportunities for their capital (Financial Times, 2023). Therefore, pension fund investment portfolios in green projects need to be formulated appropriately, one example of which is by linking them to established green securities.

In Indonesia, the contribution of pension funds to the economy as a whole is still low and only accounts for 6.03% of GDP (Huda & Kurnia, 2022). The Financial Service Authority (OJK) also noted that the total investment value of pension funds in Indonesia reached IDR 322.51 trillion in July 2022. This amount increased by 0.31% compared to the previous month when it was IDR 321.5 trillion. This number is also 5.16% higher when compared to the same period in the previous year. As of July 2021, the total pension fund investment was IDR 306.69 trillion (Info Dana Pensiun, 2022). When examined more deeply, according to OJK data, the net assets of most Indonesian employer pension funds (such as DPPK, PPMP, and PPIP)are placed in government securities (SBN) at 34.29% and corporate bonds at 22.63% (Huda & Kurnia, 2022). An investment strategy that complies with the mandate of OJK Regulation No.1/2016 concerning SBN Investment for Non-Bank Financial Services Institutions—where pension funds are mandatory—places a minimum of 30% of its assets under a managed investment portfolio (Seran et al., 2023). Given the potential for expansion and diversification of pension assets, this source of cash might be significantly larger if emerging markets are examined (Gökçen et al., 2020). This means that there is an untapped potential for a large portion of the pension funds in Indonesia to be immediately diverted into investments based on net-zero carbon emissions. Using pension funds for green investment could also be a manifestation of Indonesia's commitment to the 2016 Paris Climate Change Agreement which proposed strengthening green climate funds and multilateral financing to support climate action in developing countries (Amighini et al., 2022).

Furthermore, increased investment in the green sector has also opened up greater access to financing in other related sectors, such as renewable energy, which is a major recipient of green bond yields (IRENA, 2020). Renewable energy has the potential to replace fossil energy usage while also promoting green economic growth (Xie et al., 2020). Although slow in its development, Indonesia has several potential renewable energy options (Greeneration Foundation, 2022). With a transition to renewable energy, energy efficiency is created (Chien et al., 2023) which then encourages the achievement of a sustainable green economic ecosystem (Feng et al., 2022). Through green pension funds, investments can be set aside for financing enterprises that encourage renewable energies, such as producing technologies that reduce environmental pollution (Rempel & Gupta, 2020). Investments can also be made in companies that produce clean energy, such as hydroelectric, biomass, wind, or solar generators, with the earnings reinvested upon retirement. Thus, these pension funds can facilitate businesses focused on developing renewable energy (Chen et al., 2017; González et al., 2020).

While several studies have captured the initial motives of pension fund institutional investors in investing in low-carbon (Boermans & Galema, 2019; Egli et al., 2022) and the policy and political issues surrounding pension funds and green transition (Natali et al., 2022), to the best of our knowledge, none have specifically assessed the investment capacity of pension funds in terms of the organized development of a green economy in developing countries. Also, as we mentioned in the previous paragraph, the performance of green investment pensions needs to be strengthened by renewable energy, but this concept has still not been considered in the existing studies or in policy directions. Some researchers also measure the green economy separately through environmental performance based on carbon emission levels (Sajid et al., 2023; Zheng et al., 2022), and efficiency yield based on resource inputs and environmental cost outputs (Duan et al., 2022; Wang & Peng, 2021), but they have not examined these two measurements together to obtain a more straightforward analysis of which factors affect both. This paper aims to empirically simulate a green-based investment scheme in pension funds for green economic growth, and capture how optimizing green pension fund investments in generating renewable energy productivity can drive overall green economic efficiency. Thus, this research will contribute in at least three ways. First, it provides low-carbon pension fund investment scenarios, involving the productivity of renewable energy, and how these factors shape a dynamic relationship in the short and long term to a green economy. Second, this study also elucidates the attainment of green economic efficiency at the provincial level, incorporating inputs from green pension investments and renewable energy. This is undertaken to provide a comprehensive analysis of cross-provincial disparities in Indonesia, often stemming from the diverse allocation of resources within the geographical expanse of each province (Setyawan & Wardhana, 2020). Third, to generate contributions to the two previous points, a two-stage approach is used, namely dynamic panel regression and data envelopment analysis (DEA). Examination through this two-stage method may provide richer and more in-depth results on the potential for green pension investment and renewable energy in increasing green economy capacity in emerging country markets, which in this study are represented by the Indonesian market.

LITERATURE REVIEW

1. Conceptualize the Green Pension Investment

Pension funds and green investments have a close relationship. Pension funds are collected from workers' contributions while working and used to finance their financial needs after retirement (Boermans & Galema, 2019). Meanwhile, green investment is an investment that aims to promote environmentally friendly and sustainable economic growth (Wang et al., 2022). Green investment can be an attractive investment option for pension funds because it can provide long-term benefits for pensioners and, at the same time, support sustainable development goals. In addition, by choosing green investments, pension funds can contribute to efforts to mitigate climate change and reduce greenhouse gas emissions (Fan et al., 2021; Wang et al., 2022).

Green pension investment is a type of investment that aims to promote sustainable economic growth and considers the social and environmental impact of investment decisions (Hoepner & Schopohl, 2020). Green pension investment can be made by government and private pension schemes that consider the environmental and social impact of their investments. In this case, better incentives and heterogeneity reduction in actual returns are needed (Natali et al., 2022). Therefore, green pension investment involves selecting investment assets related to projects focused on reducing carbon emissions and promoting renewable energy. These assets may include stocks or bonds of companies engaged in renewable energy, environmentally friendly transportation, or green technology (Boermans & Galema, 2019).

In addition, like other green investments that focus on waste management, energy efficiency, and environmentally friendly technology (Al-Roubaie & Sarea, 2019; Mo et al., 2023), pension funds also need to invest in similar projects. The goal of green pension investment is to create an investment portfolio that balances long-term financial returns and the reduction of the negative social and environmental impact of investment activities (Hoepner & Schopohl, 2020). The concept of green pension investment also takes into account long-term investment risks, including environmental and social risks that can affect investment performance and the sustainability of the investment portfolio in the future (Chen et al., 2017; González et al., 2020). Overall, the conceptualization of green pension investment encourages sustainable economic development, considers environmental and social sustainability, and seeks to earn long-lasting, competitive returns for pension funds and individual investors.

However, like any other kind of investment, green investing also has risks that pension funds must carefully calculate. Green investments may have higher liquidity risks than traditional investments (Chen et al., 2017; González et al., 2020). This can make it difficult for pension funds to sell green investment assets in difficult market situations. In addition, government policies can vary in favor of green investment. If governments limit or reduce their support for green investments, this can negatively impact the performance of green investments. If a green investment funded by a pension fund violates environmental or social standards, this could damage the reputation of the pension fund and the impact on future investment performance (Andonov et al., 2018). Therefore, before deciding to make a green investment, pension funds need to carry out a risk analysis and ensure that the investment aligns with pension participants' long-term goals and risk tolerance (Chen et al., 2017; González et al., 2020). By anticipating these issues, pension funds can conceptualize green pension investment and create a sustainable investment portfolio that balances financial returns with social and environmental impact.

Some technical steps can also be taken to ensure the success of green pension investment. The first step is to define the purpose and objectives of the investment. This includes identifying the target returns, risk appetite, and sustainability goals (Chen et al., 2017; González et al., 2020). The second step is to identify the relevant environmental and social factors that need to be considered. This may include analyzing the environmental and social impact of potential investments, assessing the risks associated with climate change and natural resource depletion, and evaluating the social impact of investments (Alda, 2018; Zhao & Zhao, 2018). The third step is to select suitable investment options that align with the sustainability goals and risk profile of the pension fund. This may include investing in renewable energy, sustainable infrastructure, or socially responsible companies (Alda, 2018; Woods & Urwin, 2010; Zhao & Zhao, 2018). The fourth step is to develop investment policies and guidelines that incorporate the sustainability goals of the pension fund. This includes defining investment criteria, establishing environmental and social screening processes, and monitoring and reporting on sustainability performance (Chen et al., 2021). The final step is to engage stakeholders and communicate the investment strategy. This may include communicating the sustainability goals and investment strategy to beneficiaries, engaging with investee companies on sustainability issues, and collaborating with other investors to promote sustainable investment practices (Sciarelli et al., 2021).

2. Renewable Energy Productivity

Renewable energy, often referred to as green energy, is characterized by its capacity to lower energy consumption by promoting energy efficiency (Y. Li et al., 2022). The productivity of renewable energy can be achieved by promoting the efficiency and effectiveness of all eligible technologies (Ogunrinde & Shittu, 2023) and sources, such as solar, wind, hydro, geothermal, and biomass, that are harnessed and utilized to produce energy (Bergman, 2018). Since renewable energy is gaining prominent popularity as an important growth factor in various countries, its productivity needs to be maintained to reduce traditional energy consumption more intensively (Solarin et al., 2022). At the same time, the renewable energy market is also approaching the maturity stage and is therefore becoming attractive for many investors (Voronova et al., 2023). This investment, which is part of the green investment ecosystem, is aimed at providing financing for renewable energy projects and supporting the development of renewable energy infrastructure. Green investment can also support the development of energy storage solutions, which can help to address the intermittency of renewable energy sources and improve renewable energy productivity (Chien et al., 2023). The green investment will help overcome the challenges associated with improving renewable energy productivity, such as limited access to financing and regulatory barriers (Chen et al., 2021), thereby accelerating the transition to a more sustainable energy system (Maolin & Yufei, 2020).

In Indonesia, green investment in renewable energy has been growing in recent years, with several green investment funds and initiatives focused on renewable energy development.

For example, the Indonesia Green Finance Institute (IGFI) was established in 2020 to promote sustainable finance and green investment in Indonesia. The IGFI provides technical assistance, training, and research to support the development of green investment in Indonesia, including in the renewable energy sector (Seran et al., 2023). Green investments from pension funds can also be used as an alternative financing source to support renewable energy productivity. As these energy sources become more productive and widespread, they could replace fossil fuels in various sectors, such as power generation, transporttation, and heating. By reducing dependence on fossil fuels and increasing the use of renewable energy, greenhouse gas emissions can be reduced significantly(Y. Li et al., 2022; Xu et al., 2023). This is an important step in combating climate change and its negative impacts to promote green economy growth.

3. Green Economy and Efficiency

The green economy model emphasizes the procedure of converting to an economic development model that consumes less energy, emits less pollution, and has a more harmonized economic environment (Wang et al., 2022). A green economy and efficiency are two interconnected concepts that aim to promote sustainable development and address environmental challenges (Maolin & Yufei, 2020). The green economy is an economic system that prioritizes sustainable development and the preservation of natural resources, while efficiency refers to the efficient use of resources, including energy, water, and materials (Fan et al., 2021). Efficiency is an important aspect of the green economy, as it helps to reduce waste and increase productivity while minimizing environmental impact (Ozturk, 2010; Raberto et al., 2019). By improving efficiency, businesses and industries can reduce their resource consumption, lower their operating costs, and improve their environmental performance. Efficiency can be achieved through various measures, such as the use of energy-efficient technologies, the implementation of waste reduction and recycling programs, and the use of sustainable materials and practices (Bergman, 2018; Linquiti & Cogswell, 2016). In the context of the green economy, efficiency measures can be applied across all sectors of the economy, including energy, transportation, agriculture, and manufacturing (Schumacher et al., 2020).

In addition to improving environmental sustainability, efficiency in the green economy can also lead to economic benefits, such as increased productivity, reduced operating costs, and improved competitiveness (Raberto, 2018; Tolliver, 2020). By adopting efficient and sustainable practices, businesses and industries can position themselves as leaders in the transition to a more sustainable economy (Bergman, 2018). Furthermore, the efficient use of energy is a critical component of reducing greenhouse gas emissions and mitigating climate change (Bergman, 2018; Linquiti & Cogswell, 2016; Schumacher et al., 2020). Promoting the efficiency of greenhouse gas emissions could also be the first step to achieving net zero carbon emissions.

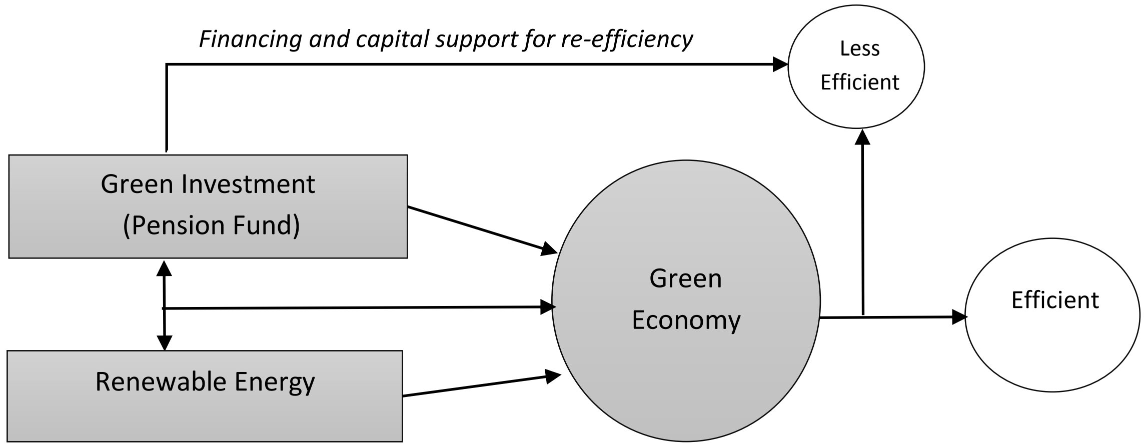
Fan et al. (2021)document that green economy efficiency can be achieved from carbon emission efficiency which is generated from nonhuman sources (such as properties, energy, industrial framework, and resource spillovers) and human sources (such as population number, labor force, and age distribution). Many researchers then use these factors as input and output in the Data Envelopment Analysis model (Geng et al., 2017; Seran et al., 2023; Yang et al., 2015), which is widely used as nonparametric programming in many economy-level energy and environmental efficiency evaluation methods (Geng et al., 2017; Iftikhar et al., 2016). The initial DEA-CCR presentation model served as the foundation for establishing constant returns to scale (Cooper et al., 2000) while accounting for a diverse set of inputs and outputs. Resource input and environmental cost considerations are widely used in a green economy to evaluate efficiency indicators in a country or region, with a focus on two aspects: (1) the effectiveness of input elements in the production process; and (2) the advantages of the green economy after the inclusion of both environmental component inputs and pollution-related factors (Wang & Peng, 2021).

Based on these two aspects, the achievement of sustainable green economic growth and efficiency can be encouraged through the integration of profitable financial sources and alternative energy sources. The financial source can alternatively be chosen from green pension investment, while energy sources in practice can involve renewable energy. Effective collaboration between green pension investments as environmental equity and renewable energy as environmental goals can ultimately drive overall green economic growth (Yang et al., 2015). However, we cannot ignore the fact that the success of a country's green economy also depends on the level of human and social acquisition of green development at the regional level, so that ecological consumption at the regional level can express investment to realize regional sustainable development (Yang et al., 2015). Therefore, by analyzing green economy efficiency in a regional scope, we can select which inefficiency leaks need to be patched, such as by adding pension fund investments for regional green projects so that they can reproduce more efficiently. Based on this argument, we propose a research framework as visualized in Figure 1.

METHOD AND DATA

This study used cross-sectional data from 34 provinces in Indonesia with an observation period from 2016 to 2022. The research approach is quantitative with a two-stage research method. The first method is dynamic panel data regression using the Generalized Method of Moment (GMM) Arellano-Bond. GMM (Arellano & Bond, 1991) provides a generalized differential moment estimation method based on the instrumental variable method that uses the lagged term of the dependent variable up to period t-1 as the first-order differential lagged term of the dependent variable, thus providing consistent and more efficient estimation results. The advantage of the

Figure 1. Green Economy Efficiency Framework



GMM method is that it is free from serial correlation disturbances and is stronger against heteroscedasticity (Wang et al., 2022). Specifically, the GMM is particularly appropriate for examining the dynamic nature of greenhouse gas (GHG) emissions, where current emissions may be influenced by past emissions due to cumulitive environmental impacts such as those from burning oil, coal, and deforestation (Li et al., 2017; Rehman et al., 2021). In this context, GMM facilitates the incorporation of lagged variables into the regression model, thereby effectively capturing the temporal dependencies inherent in GHG emissions data. We also identify potential endogeneity between GHG emissions and renewable energy variables. Utilization of renewable energy can increase resource efficiency thereby mitigating environmental impacts including reducing carbon emissions (Li et al., 2024; Wang et al., 2022).On the other hand, the urgency to mitigate carbon emissions has accelerated market shifts, driving increased demand for renewable energy sources (Dilanchiev et al., 2024). This method was also used by prior studies to investigate green economic evaluation and carbon neutrality (Wang & Peng, 2021; Wang, Zhang, & Li, 2022).

The GMM Arellano-Bond model built in this study uses the following equation:

$$GHG_{i,t} = \alpha + \beta GHG_{i,t-1} + \delta_1 GP_{i,t} + \delta_2 RE_{i,t} + \delta_3 CONT_{i.t} + \mu_{i,t} + \varepsilon_{i,t} \quad ....(1)$$

where $GHG_{i,t}$ is province-*i*'s greenhouse gas emissions in year-*t*, which is a proxy for the green economy, and$GHG_{i,t-1}$is its lag value. GHG emission province generated from the database of the Ministry of Environment and Forestry of Indonesia. $GP_{i,t}$ is the green investment of pension funds in province-*i* in year-*t*, which is simulated in terms of the investment ratio in green security. This simulation was carried out because investment in pension institutions was not specifically allocated to the green market, so we took 0.26 portion of each pension fund investment allocation per province and calculated the ratio to the investment level in all provinces. The 26% value is Indonesia's commitment to reduce carbon emissions by 26% (following the Paris Climate Agreement) so we assume that pension companies will be willing to contribute at least 26 percent to the green sector. Assume that investment in a province as much as *i* at the level of carbon emissions *c*. Hence, in *ceteris paribus*, the investment in i_1 will produce emission c_1 ($i_1 = c_1$). With a 26% reduction in emissions, hence the emissions will be shifted to $c_2 = c_1 - 0.26c_1 = 0.74c_1$. At this point, the investment will be pushed up by $i_2 = 0.74c_1$. Since $i_1 = c_1$, then $i_2 = 0.74i_1$ with the assumption that all of the investments are non-green, resulting in all investments causing carbon emissions. In other words, reducing carbon emissions by 0.74 requires a decrease in the amount of investment of 0.74. Furthermore, if the investment is diversified in the green sector, then the investment portfolio is in$i_2 = i_1 - i_{green}$, subject to $0.74i_1 = i_1 - i_{green}$. Thus, the level of investment in the green sector will be $i_{green} = i_1 - 0.74i_1 = 0.26i_1$. Finally, to see the investment ratio per province in green securities, each i_{green} is expected to generate a return equal to the average market value. The market benchmark used the average return on the IDX Sri-Kehati (JKSRI), which is a green index that applies the principles of responsible and sustainable investment.

Furthermore, $RE_{i,t}$ is the renewable energy potential of province-*i* in year-*t* which is proxied by renewable electricity productivity (Chien et al., 2023). $CONT_{i.t}$ is the control variable for province-*i* in year-*t* namely Regional Gross Domestic Product (RGDP) and Labor cost. Labor cost is measured by the number of labor force multiplied by its minimum wage. $\mu_{i,t}$

represents the province-specific consequences and $\varepsilon_{i,t}$ is the error term. The variable measurements in this study are summarized in Table 1.

The second method uses Data Envelopment Analysis (DEA) to identify green economy efficiency as followed by several previous studies (Feng et al., 2022; Geng et al., 2017). Efficiency is observed using the DEA-CCR model in each province in Indonesia which is called Decision Making Units (DMU) with the following equation:

$$DMU_i = [x_i y_i] \quad i = 1,2,\ldots,n,$$

and $$E_i = \frac{y_i u}{x_i v} \qquad \ldots(2)$$

where x_i and y_i represent the input and output of DMU-i respectively. Then, u and v are the weight values on input and output. E_i is the efficiency of DMU_i. The DEA model in this study uses three inputs. First, the labor cost (X1) is as follows Ma et al. (2022) and Yang et al. (2015). Second, renewable energy (X2) is as follows Chen and Geng (2017) and Zhao et al. (2022). Third, capital investment (X3) as adopted from Ma et al. (2022), which in this study was specifically measured through green pension investment. The output used are; GHG emission (Y2) and RGDP (Y1) as recommended by several prior studies (Chen & Geng, 2017; Iftikhar et al., 2016; Ma et al., 2022). Green economy efficiency will be in the score interval (0, 1) for each DMU. The higher the value of θ, the more efficient the green economy is, where a score of 1 indicates super efficiency.

RESULT AND DISCUSSION

Preliminary research results show descriptive statistics as presented in Table 2. Average GHG emissions in Indonesia from 2016 to 2022 were 129,722.5 Gg CO2e with a decreasing trend to a minimum GHG of -36,148.84 Gg CO2e in 2019 in Papua Province (we do not display annual trend data but can be provided upon request). Negative emissions mean that greenhouse gas emissions from activities are smaller than the amount of carbon dioxide absorbed by nature.

Table 1. The Measurement Variables

Variables	Proxy	Measurement	Source
Green Economy	GHG emissions per province	$\text{Log}(\text{GHG}_{\text{province}})$	Ministry of Environment and Forestry of Indonesia
Green Pension Investment	Pension fund investment simulation in green securities	$\frac{0.26\ pension\ fund \text{x annual return JKSRI}}{\text{Total Investment of all provinces}}$	Financial Services Authority (OJK) and Indonesia Stock Exchange
Renewable Energy	Renewable electricity productivity	% of electricity from renewables multiplied by electricity distribution for the province	World Bank and Central Bureau of Statistics of Indonesia (BPS)
Province specific factor	Regional Gross Domestic Product	Log(RGDP)	Central Bureau of Statistics of Indonesia (BPS)
Labor	Labor cost	Size of labor force per province multiplied by the minimum wage per hour per province	Central Bureau of Statistics of Indonesia (BPS)
Green Economy Efficiency	DEA score of green economy	• Input: labor cost, renewable energy, green pension investment • Output: GHG emission, RGDP	Processed by the author from MaxDEA

Table 2. Descriptive Statistic

Variable	Obs	Mean	Std. dev.	Min	Max
GHG	238	129,722.5	424,493	-36,148.84	3,646,243
GP	238	0.00005	0.00038	-0.00065	0.00424
RE	238	956.59	1,638.45	22.71	8,885.74
RGDP	238	18.86	1.14	16.89	21.39
Labor	238	59,599.36	80,456.2	4,797.75	44,649

Note: Greenhouse gas emission data were withdrawn in March 2023 at signmart.menlhk.go.id where the GHG value for 2022 is still experiencing changes in line with data updates made on the website, notation in Gg CO2e. GP is a return from the green pension fund. RE is a percentage of electricity distribution from renewable energy. RGDP in natural logarithm. Labor in hundreds of millions IDR.

Green pension is a return ratio obtained from a simulation of pension fund investment per province in the green stock index or IDX SRI-KEHATI (JKSRI). This means that if a pension institution invests 0.26 portion of its pension funds into the green index, it will get an average return of 0.00005 or a 1% investment would be equivalent to a return of 0.00019%. This average return is relatively low due to the poor performance of the green stock market from 2018 to 2020 which cannot be separated from several negative domestic catalysts such as Indonesia's economic growth which is still stagnant at 5%, rupiah depreciation and negative market sentiment in 2020 due to the COVID-19 pandemic. However, returns from green pension investments will begin to increase from 2021 to 2022.

1. GMM Arellano-Bond Analysis

1.1. Panel Unit Root Test

Panel unit root tests were performed before the GMM Arellano-Bond estimation to ensure that the results of the model are reliable, hence avoiding spurious regression (Maddala & Wu, 1999). We used two inspection methods of Augmented Dickey–Fuller (ADF) test, and Phillips–Perron (PP) test to identify the unit root test in our panel data. Table 3 shows that all variables are stationary at the first-order difference at a significance level of 1%. This confirms that each indicator sequence is stable.

Table 3. Unit Root Test Result

Variables	Value	ADF		PP	
		I(0)	I(1)	I(0)	I(1)
GHG	t-stat	183.713*	98.704*	61.105	108.652*
	prob	0.000	0.000	0.508	0.000
GP	t-stat	252.414*	205.856*	67.235	196.027*
	prob	0.000	0.000	0.503	0.000
RE	t-stat	9.766	151.286*	16.983	244.192*
	prob	1.000	0.000	1.000	0.000
RGDP	t-stat	34.703	207.422*	42.449	98.188*
	prob	0.997	0.000	0.994	0.009
Labor Cost	t-stat	606.806	286.323*	76.658	118.710*
	prob	0.724	0.000	0.221	0.000

*Note: ***, **, * represent significant at 1%, 5%, and 10% inspection, respectively*

1.2. Density Distribution

Kernel density estimation is used to estimate the probability density function of a random variable which is a fundamental step in the GMM estimation procedure (Kuersteiner, 2012). Figure 2 shows the kernel density estimation result of the sample distribution of parameters. All parameters are symmetrical with their normal density indicating that the posterior distribution estimations are highly dependable, and their mean values can be considered as the conclusive parameter estimates.

1.3. GMM Estimator

Table 4 shows the result of the GMM Arellano Bond Estimator in one step difference. The lagged dependent variables (Lag_GHG) were statistically significant and positive in all model estimations, demonstrating that the previous GHG emission in panel data of provinces in Indonesia affects the current level of GHG emission. This result confirms the increasing trend of GHG emissions during 2016-2022. Furthermore, the AR(1) for all model estimations shows a significant value below 1% indicating that there is no first-order serial correlation. While the AR(2) is expected to be not significant at 5% to confirm the absence of serial autocorrelation in the errors (Labra & Torrecillas, 2018). Hansen's test above 5% shows overidentifying and the selection of instrumental variables is valid.

Figure 2. Kernel density estimation results of each variable

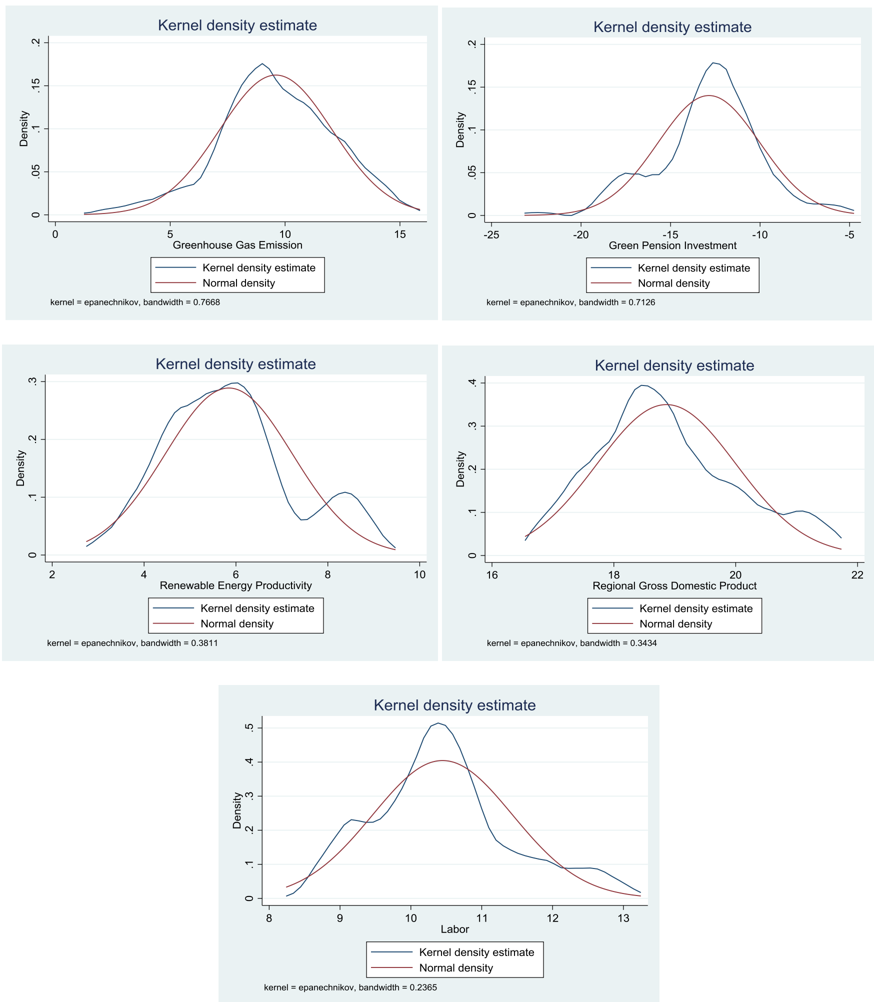


Table 4. GMM One-Step Model Estimates

	(1) GHG	(2) GHG	(3) GHG	(4) GHG
Lag_GHG	0.730***	0.725***	0.623***	0.357***
	(0.000)	(0.000)	(0.000)	(0.000)
GP	-81.75***	-32468.22*	-4281.75*	-1917.16
	(0.009)	(0.068)	(0.077)	(0.380)
RE	-0.0014**	-0.0015**	-0.0016*	-0.00011
	(0.016)	(0.014)	(0.053)	(0.913)
GPxRE		0.613*	0.997*	0.446
		(0.075)	(0.088)	(0.391)
RGDP			-7.400**	5.888
			(0.003)	(0.120)
Labor cost			0.00002	0.000015
			(0.123)	(0.205)
Year FE	NO	NO	NO	YES
AR(1) test	-3.06***	-3.00***	-2.92***	-2.81**
	(0.002)	(0.003)	(0.004)	(0.005)
AR(2) test	-0.87	-0.82	-0.80	-0.96
	(0.382)	(0.413)	(0.426)	(0.339)
Hansen Test	23.75	29.13	27.35	24.44
	(0.163)	(0.215)	(0.850)	(0.928)
Obs.	135	135	135	135
No of group	31	31	31	31
No of Instrument	21	28	30	27

Note: *GMM is run with robust standard error using the xtabond2 command in Stata. The number of instruments does not exceed the number of groups (< 31). The p-value is based on a two-tailed test; * p < 0.10, ** p < 0.05, *** p < 0.01.*

Table 4 also shows that green pension investment has a significant negative effect on GHG emissions. The results remained constant when the control variables RGDP and labor costs were included, also when the GPxRE interaction variables were added. We also add up the year control effect and find a similar negative correlation between green pension investment on GHG emissions, although not significant. This finding indicates that increasing green pension investment has a significant contribution to reducing greenhouse gas emissions. Specifically, for every 1% increase in green pensions, on average, GHG emissions will decrease between 81.75% to 4281.75%. By considering the green sector investment (such as through green securities or green obligation), companies or institutions have channeled fresh capital to green industry players, such as organic farmers, and waste processors, including small and medium-scale suppliers of renewable energy. This initiative will repeatedly and continuously improve environmental quality and reduce CO2 emissions (Hordova et al., 2023; Priyan, 2023)

On the same side, renewable energy is also negatively correlated with GHG emissions in almost all model estimates, except when controlled by years which obtain insignificant results. However, it provides statistical evidence that the increase in renewable energy has led to a reduction in GHG emissions. The reduction in GHG emissions by 0.0014% to 0.0016% was driven by a 1% increase in renewable energy productivity. Our results are similar to the findings of Szetela et al. (2022) for a sample of 43 countries over the period 2000–2015.

To seek the integrated connection between green pensions as potential funding for renewable energy, we examine the interaction term between GP and RE on GHG emissions. The results of this interaction test indices are a significant and positive correlation with GHG emission at a 10% significant level. This implies that renewable energy productivity can be increased from green pension funding, but at some point, exclusive funding from green pension investment may not be able to effectively reduce GHG emissions. GHG emissions can still increase due to contributions from other sectors, such as forestry, waste management, and agriculture. In addition, an excessive increase in the production of renewable energy without being matched by optimal consumption can increase the stock of reserves of the renewable energy itself, which in turn may lead to an increase in the remaining waste from the production of renewable energy. Renewable sources offer strategic value but the investment may be prohibitively costly (Chen et al., 2021), hence requiring funds from various alternative sources.

The result in Table 4 also shows that RGDP has a negative influence on GHG emissions. This result is in line with the findings of Arslan et al. (2023)that GDP has a negative impact on low-income countries which is possible because of the great efforts of the state to control the efficient use of natural resources. Also, Niyonzima et al. (2022) said that the short-term correlation between GDP and CO2 emissions can become negative due to a dramatic increase in economic output which is sought to be achieved through more efficient use of energy through several government policies that may increase welfare while reducing CO2 emissions. Meanwhile, labor costs were found to be insignificant in all estimation models, indicating that labor in Indonesia does not yet have green labor behavior, such as using bicycles instead of motorized vehicles to go to the office, recycling household waste, or even not smoking in public places. In addition, the labor costs that are charged at each company may not be proportional to the overall green project costs, so the effect is not significant in reducing GHG emissions. Lastly, the result shows that no exogenous variables have a significant correlation to GHG emissions when controlled by the Year dummies.One-step GMM models are very sensitive to sample sizes (Kripfganz, 2020), hence, in this case, the small sample size resulting in insignificant estimates is possible because the data only covers a few years, so the relatively small comparison between the number of observations and the number of parameters in the model makes the results insignificant. Considering that the linear combination of time dummies and the constant term is equivalent to their respective first differences or orthogonal deviations, it is not particularly significant whether these variables collectively enter the model in their original form or in a transformed state (Roodman, 2006).

1.4. Robustness Check

The robustness of GMM estimation can be evaluated through OLS, Fixed Effect, and Two-step Difference GMM as done by Mulusew and Mingyong (2023). According to Bond et al. (2001), it slopes downward when the lag of the dependent variable estimate is below or approaches the FE estimate. The GMM system estimate is therefore valid, accurate, and robust. Table 5 shows consistent results for the lagging GHG coefficient values among four model estimations of OLS, FE, two-step GMM, and one-step GMM. We use a full sample model without control by years to confirm the robustness in all years. The result shows that the stability of the dynamic panel model of GMM estimates was robust.

Table 5. Full sample estimation for Robustness Check

	OLS	FE	2-Step GMM	GMM
	GHG	GHG	GHG	GHG
Lag_GHG	0.864***	0.669***	0.663***	0.632***
	(0.000)	(0.000)	(0.000)	(0.000)
GP	1224.2	-4651.6*	-4839.4*	-4739.5*
	(0.363)	(0.077)	(0.062)	(0.066)
RE	-0.0000605	-0.00169*	-0.00169*	-0.00173**
	(0.792)	(0.056)	(0.052)	(0.048)
GPxRE	-0.272	1.087*	1.132*	1.108*
	(0.404)	(0.086)	(0.070)	(0.074)
Log_RGDP	0.0727	-6.391**	-6.332***	-6.608**
	(0.689)	(0.024)	(0.009)	(0.016)
Labor	0.00000205	0.0000178	0.0000178	0.0000190
	(0.597)	(0.209)	(0.188)	(0.169)
_cons	-0.553	125.4**		
	(0.861)	(0.020)		
Obs.	166	166	135	135
Adj.R2	0.664	0.413		

p-values in parentheses *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

2. DEA Analysis

Basic DEA models are unable to resolve an analysis with negative numbers, hence all numbers are required to be positive and preferably no zero values. For our dataset, the values of greenhouse gas emission (as output parameter) and green pension investment (as input parameter) have negative and zero values. To deal with this, we employ Bowlin's (1998) technique, which involves adding a sufficiently big positive constant to the values of the input or output that contains the non-positive integer and making a negative number or zero value smaller than any other number in the data set. We then selected numbers that were greater than the minimum variable and added this value for each variable. This method was also used by many prior studies (Keskin et al., 2018; Sarkis, 2007).

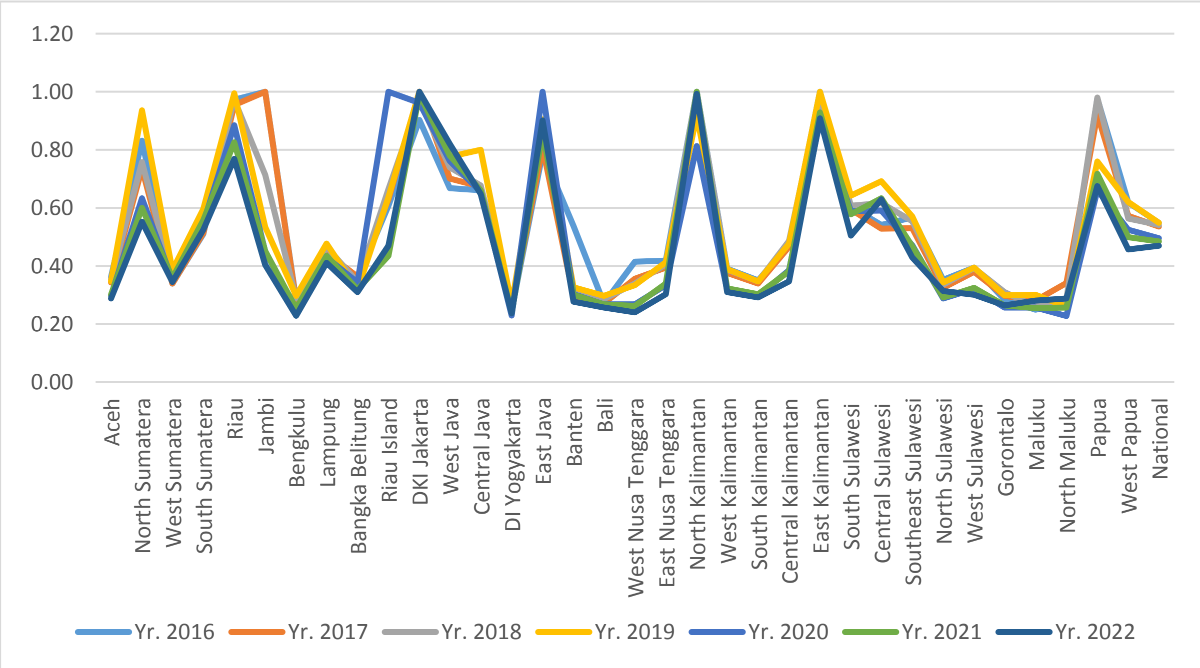
Our outcome dataset of green economy efficiency score is shown in Table 6. The national average green economy efficiency score has decreased from 0.550 in 2016 to 0.470 in 2022, indicating that Indonesia is not yet efficient in green economic growth. However, impressively, DKI Jakarta is the most efficient region in green economic growth, especially in 2017, 2019, and 2022, with an average score of 0.975. Followed by East Kalimantan with a score of 0.955 and North Kalimantan with a score of 0.949. Meanwhile, DI Yogyakarta is ranked lowest on green economy efficiency with a score of only 0.247. Our argument against this specific finding is largely due to the labor cost, with Yogyakarta having the lowest minimum wage. Furthermore, we also note that several provinces show an optimal level of efficiency with a score of 1, namely Jambi in 2016 and 2017, Riau Island in 2020, and East Java in 2020. Figure 3 shows a dynamic trend of green economy efficiency over seven years in Indonesia, where almost 60% of provinces (n=20) have a trend below the national trend and the remaining 40% (n=14) are above the national trend.

Table 6. Green Economy Efficiency Scores

No	Province (DMU)	DEA Score							Mean Score
		Yr. 2016	Yr. 2017	Yr. 2018	Yr. 2019	Yr. 2020	Yr. 2021	Yr. 2022	
1	Aceh	0.362	0.343	0.354	0.347	0.298	0.301	0.288	0.328
2	North Sumatera	0.831	0.736	0.758	0.936	0.634	0.601	0.553	0.721
3	West Sumatera	0.340	0.339	0.359	0.385	0.353	0.358	0.346	0.354
4	South Sumatera	0.510	0.513	0.551	0.597	0.550	0.558	0.524	0.543
5	Riau	0.973	0.954	0.974	0.995	0.884	0.826	0.768	0.911
6	Jambi	1	1	0.715	0.534	0.449	0.451	0.404	0.650
7	Bengkulu	0.283	0.278	0.288	0.297	0.251	0.253	0.229	0.268
8	Lampung	0.443	0.444	0.466	0.477	0.430	0.435	0.412	0.444
9	Bangka Belitung	0.355	0.363	0.344	0.318	0.344	0.320	0.310	0.336
10	Riau Island	0.608	0.630	0.664	0.638	1	0.434	0.469	0.635
11	DKI Jakarta	0.903	1	0.969	1	0.962	0.992	1	0.975
12	West Java	0.668	0.701	0.739	0.776	0.762	0.780	0.820	0.749
13	Central Java	0.660	0.674	0.677	0.800	0.655	0.662	0.648	0.682
14	DI Yogyakarta	0.247	0.254	0.250	0.269	0.229	0.240	0.237	0.247
15	East Java	0.789	0.810	0.863	0.905	1	0.859	0.901	0.875
16	Banten	0.538	0.294	0.312	0.326	0.302	0.302	0.277	0.336
17	Bali	0.271	0.272	0.287	0.297	0.267	0.268	0.257	0.274
18	West Nusa Tenggara	0.414	0.355	0.339	0.334	0.269	0.263	0.241	0.317
19	East Nusa Tenggara	0.419	0.395	0.406	0.414	0.334	0.339	0.303	0.373
20	North Kalimantan	1	0.924	1	0.917	0.813	1	0.992	0.949
21	West Kalimantan	0.392	0.377	0.388	0.390	0.318	0.322	0.309	0.357
22	South Kalimantan	0.351	0.340	0.347	0.346	0.297	0.303	0.292	0.325
23	Central Kalimantan	0.471	0.466	0.487	0.478	0.385	0.382	0.348	0.431
24	East Kalimantan	1	0.967	0.983	1	0.900	0.928	0.908	0.955
25	South Sulawesi	0.603	0.594	0.608	0.642	0.589	0.578	0.505	0.589
26	Central Sulawesi	0.541	0.528	0.616	0.693	0.591	0.632	0.629	0.604
27	Southeast Sulawesi	0.568	0.530	0.555	0.572	0.473	0.468	0.429	0.513
28	North Sulawesi	0.353	0.325	0.335	0.343	0.288	0.293	0.313	0.321
29	West Sulawesi	0.394	0.379	0.392	0.395	0.322	0.325	0.300	0.358
30	Gorontalo	0.284	0.298	0.311	0.300	0.256	0.265	0.264	0.283
31	Maluku	0.250	0.280	0.261	0.301	0.256	0.255	0.282	0.269
32	North Maluku	0.273	0.341	0.287	0.260	0.228	0.257	0.287	0.276
33	Papua	0.977	0.922	0.981	0.760	0.661	0.717	0.675	0.813
34	West Papua	0.618	0.573	0.563	0.620	0.525	0.500	0.457	0.551
National (Mean)		0.550	0.535	0.542	0.549	0.496	0.484	0.470	0.518

Note: The results in the table were prepared by the author based on MaxDEA Lite calculation results.

Figure 3. Green Economy efficiency of 34 provinces over seven years



The diverse efficiency of the green economy at the regional level indicates the presence of disparities in the inputs from labor costs, renewable energy, and green investment proportions between less developed provinces and more advanced provinces. As the population density in a province increases, the energy demand to produce one unit of GDP also increases(Azaliah et al., 2023). Consequently, carbon emissions generated from households may be significantly larger than each province's capacity to control these emissions at the ideal investment level. Yogyakarta province, holding the lowest efficiency score, serves as evidence in this study showing the province's low capacity in terms of labor capital. Therefore, pension investment inputs may need to be increased to cover this gap.

As a final step, we also examine the significant effect of green pension investment and renewable energy on green economy efficiency. We used fixed effect panel regression along with year-fixed effect, as result shown in Table 7. The result shows that green pension investment has a positive significant effect on green economy efficiency, although not significant with a year-fixed effect. But still, it indicates that the higher levels of green investment from pension funds can effectively increase the efficiency of green economy performance. Thus, provinces that are still less efficient can be supported by green pension investment on a large scale.

On the other hand, renewable energy has a significant negative impact on green economy efficiency. An increase in the intensity of renewable energy at some point can disrupt energy efficiency, especially due to an increase in the cost of producing renewable energy. The high cost of renewable energy production in turn causes the overall performance of the green economy to be less efficient. In the stock market, the high cost of renewable energy can reduce green economy stock prices (Avazkhodjaev et al., 2022) as evidence of cost inefficiencies for green economy projects.

Table 7. Fixed Effect Panel Regression of Green Economy Efficiency (GEE)

	(1) GEE	(2) GEE	(3) GEE
GP	14.50^{***}	-90.71	-88.78
	(0.000)	(0.136)	(0.192)
RE	-0.000101^{***}	-0.000115^{***}	-0.000107^{***}
	(0.002)	(0.002)	(0.005)
RGDP	-0.175	-0.174	0.373^{***}
	(0.115)	(0.118)	(0.003)
Labor	0.00000207^{***}	0.00000225^{***}	0.00000335^{***}
	(0.000)	(0.000)	(0.000)
GPxRE		0.0234^{*}	0.0224
		(0.095)	(0.152)
Year FE	NO	NO	YES
_cons	3.799^{*}	3.768^{*}	-6.526^{***}
	(0.070)	(0.072)	(0.005)
Obs.	238	238	238
Adj.R2	0.0981	0.0994	0.320

p-values in parentheses $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

However surprising results were found on the interaction of GP and RE, which showed a significant positive effect on green economy efficiency. When the cost of producing renewable energy is covered by green pension investment funds, the rates for renewable energy consumption can be lowered, and renewable energy productivity will increase because much more renewable energy output can be absorbed by society. Thus, the greater the pension fund investment that is dispensed, the higher the productivity of renewable energy, which in turn encourages an even higher level of green economy efficiency. Year fixed effect shows a negative influence of green economy efficiency in all years, indicating a downward trend throughout the year of observation.

RECOMMENDATIONS

This study confirms that green pension investment should be considered as alternative funding in many green initiatives. Pension fund managers may form a highly diversified investment portfolio in the green sector, such as through green security or green bonds. To encourage this, governments may establish clear and consistent environmental policies that prevent market failures and give institutional investors confidence to engage in green initiatives. The policy also applies to carbon pricing, including the elimination of fossil fuel subsidies. When the government incentivizes pension funds to transfer a certain percentage of assets to a green economy, it needs extraordinary long-term incentives, whether in the form of guarantees, tax incentives, or with the help of innovative institutions such as green infrastructure.

In developing countries like Indonesia, issuing green bonds can help increase liquidity in the market. However, a large scale of funds is needed, so an appropriate investment vehicle is needed for pension funds. This includes smaller funds that do not have the in-house expertise to invest directly in green projects. In addition, international financial institutions and the government can also help mitigate the risk of green pension fund projects, because market conditions make it difficult to carry out risk assessments. Mitigation mechanisms can take the form of financial instruments for country risk protection, low carbon policy risk protection, and currency risk protection.

The government should also support the establishment of a rating agency or standard setter for green projects. This move has been taken by OECD member countries in support of investor-driven rating initiatives such as the Climate Bonds Standards Scheme. The government can use the eligibility criteria of the scheme as a basic reference for preferential policies on green investment.

Involving pension funds in green investments, it is necessary to first consider several things in the investment strategy, for example, adjusting the participant's pension benefit obligation profile, a combination of money market, capital market, and other instruments according to the liability profile and risk appetite of pension fund founders and participants; selection of instruments according to the risk profile; maintain the clarity of the exposure taken concerning the underlying instrument; paying close attention to the investment achievement targets set by the founders and the supervisory board of the pension fund, as well as the technical interest rate for the PPMP pension fund.

Capturing the results of the investigation consideration, the role that pension funds can play based on their funding character is stable in terms of receiving contributions and long-term in terms of accumulation and use; this is consistent with the concept of green financing. Green financing requires long-term stability and consistency to achieve sustainable development goals. Several things that can be done by pension funds to support green financing include: First, placing investments in state securities for sustainable development. Most recently, the government issued retail sukuk ST009, which carries the theme of green sukuk or sukuk, oriented towards developing environmentally friendly projects in anticipating climate change and reducing carbon emissions.

Second, placement in corporate bonds that support sustainable development. In the future, more and more economic actors will be aware of better resource management. The banking industry (conventional banks and sharia banks) which continues to develop green financing, it was revealed that it had reached 162 trillion (around 25% of the total credit disbursed) at the CNBC Indonesia Green Economic Forum, July 1, 2022; Third, company capacity development (direct placement) in implementing sustainable principles. Things that can be done at these companies include using and or producing environmentally friendly products and services. Having attention to the sustainable use of marine, forest, and biological resources. Thus, the overall objective of pension funds in maintaining the continuity of post-retirement participants' income can be combined with green financing to maintain the sustainability of future generations (regeneration). Both can go hand in hand for a better future.

Furthermore, the green pension investment disbursement can be increased in provinces that are less efficient in terms of their green economic performance, such as DI Yogyakarta. This investment can facilitate the real need to increase the productivity capabilities of renewable energy. Especially for Indonesia as an emerging market country, which needs to continue to pave the way for the production of renewable energy sources. Reducing the use of fossil fuels, for example by establishing policies on the use of biodiesel or biofuels for public transportation, would be an efficient way to reduce greenhouse gas emissions and promote a green economy. Governments can also limit the growth of fossil fuels and leave a lot of room for low-carbon resources. For example, by increasing capital for MSMEs or the household sector that provides raw materials for the production of renewable energy, such as organic materials, animal manure, vegetable oil, and wood-burning waste. In addition, this investment allocation can also be provided for farmers in promoting the reform of traditional agricultural production modes to petrochemical agriculture. Thus, the costs of increasing renewable energy production can be covered by high purchasing power at the consumption level, which in turn promotes renewable energy efficiency.

CONCLUSION

Indonesia has affirmed its commitment to achieving net zero emissions which can be seen from the trend of significant reductions in GHG emissions from 2016 to 2022. Investment from pension funds in green projects is a promising alternative to encourage green economic growth by reducing GHG emissions. Green pension investment simulations on the green index are statistically proven to drastically reduce GHG emissions. Increasing renewable energy as an environmentally friendly alternative energy source is also proven to reduce GHG emissions. However, the exclusivity of pension fund investments in renewable energy is allegedly increasing GHG emissions due to the accumulation of reserves of renewable energy production which have also increased and may not be fully absorbed by household consumption.

Green economy efficiency showed a downward trend nationally from 2016 to 2022, but the efficiency score was still above the median value of 0.5 so it can be concluded that the efficiency of Indonesia's green economy nationally is at a moderate level. Several provinces even recorded optimal efficiency levels, such as DKI Jakarta, North Kalimantan, and East Kalimantan. Efforts to increase efficiency in other provinces can be encouraged through increased green pension investment which statistically has a significant positive effect on green economic efficiency. In addition, our results study reveals unique findings that integration between green pension investment and renewable energy can increase green economic efficiency positively and significantly.

However, we realize that our identification of green economy performance and efficiency is still limited and has not fully taken into account the specific circumstances of each province such as poverty levels, population, human development index, and other specific factors. Therefore, this could provide a direction for future research. Other empirical methodologies may be considered in future studies to account for non-monotonic asymmetries, long- and short-term correlations, or regional convergence in greenhouse gas emission rates and renewable energy uptake.Furthermore, while our study results are based on robust estimations, it is important to acknowledge the limitations stemming from data availability. Some data points were unavailable for certain years, necessitating the use of data from the previous year (but this also refers to the original data source, such as BPS data, etc.). This limitation can be addressed in future research by extending the study period.

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