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The Economywide Impact of Promoting Renewable Power Generation in the Philippines

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ABSTRACT

Meeting future demand for electricity is one big challenge that the Philippine government has to face amidst strong economic growth. Promoting renewable technology in the power sector has been part of the government plan in order to increase energy security and to benefit from environmental externalities. This study assesses the economywide impact of promoting renewable power generation by targeting a 50 percent share of renewables in energy production by 2040. Using a novel approach by linking a bottom-up energy model with a top-down economywide model, we found that increasing the share of renewables in the power sector could slightly slow down the industrialization process and reduce economic growth. Implementing this policy, however, would allow the country to reduce carbon emissions by 65 million tons in 2040 and improve energy security. The health co-benefit is estimated to reach up to 324 billion Philippine pesos (PHP), which levels the welfare loss. Receiving foreign financial inflow as a compensation for reducing carbon emissions could drive the economy into Dutch disease, shifting more economic activities into the nontradable sector. Increasing total investment demand in the future as a policy response could potentially mitigate this effect and improve economic welfare by 155 billion PHP.

Keywords: Renewable power generation, computable general equilibrium, energy model, Dutch disease

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1. Introduction

The Philippine economy has started to maintain strong economic growth in the past few years after slackening growth for decades. This exciting opportunity, however, is accompanied by the challenge of how the country will meet its future energy demand to support the growing economy. The power sector plays a central role in this regard. Not only does it provide essential input for the industrial and service activities that have become the engine of growth, but more important, electricity has become a basic public good for all Filipinos living today and, moreover, in the future.

Past experience has shown that the country needs to make strong investment in the power sector across the country to allow the supply to catch up with the soaring demand (Cham 2007; USAID 2013; TIME 2013). Given the country's aim of achieving energy security and its strong effort to fight climate change, moving toward more renewables in the power sector has been the government's target (Congress of the Philippines 2008, DOE 2011, Philippines Climate Change Commission 2016). A reduction in greenhouse gas (GHG) emissions is the long-term externality that the country would expect to have under this green growth strategy. Energy dependence on a foreign country will also decline, creating more stability in the growing economy. Furthermore, green job growth in the renewable power sector will also flourish as fossil fuel–based power plants are replaced. Finally, financial compensation from carbon emission reduction provided by developed nations is another potential benefit the country would gain from this climate mitigation policy (UN 1992; UNFCCC 2009).

All of these benefits, however, will come only at a cost that has to be paid in advance. The Philippines has to be ready to bear a higher cost of electricity production from renewable sources compared with fossil fuel–based sources such as coal. Allocating future investment into other sectors that might have been more profitable and contributed more to economic growth is another opportunity cost of promoting investments in the renewables. Industrialization processes could also slow down given the higher price of electricity that potentially deters production in manufacturing sectors. As a consequence, there will be less labor that can move into the manufacturing sectors, which reduces laborers' potential to earn higher income in the future. An increase in commodity prices is also expected, which eventually reduces household welfare. This effect could become more serious among vulnerable households who spend much of their income on basic necessities.

This study seeks to understand the optimal energy pathways to promote renewable power generation in the Philippines as the economy maintains strong economic growth. We approach this issue by understanding the energy mix of electricity generation based on the least cost approach that maximizes benefits to society. It first explores the optimal energy mix to target 50 percent renewable power generation based on the country's energy resource potential and the investment cost across different technologies. Then it conducts an economywide impact assessment to understand the implications of this green growth strategy as more capital investments are allocated to support renewable power plants, in accordance with the optimal energy mix.

The economywide cost of allocating resources to support the production of renewable energy in the power sector is estimated based on the reallocation of factors across sectors. Factor movement into manufacturing sectors, which reflects the industrialization process, is analyzed by observing labor reallocation as the more investment is allocated into renewable electricity to achieve the targeted renewable share. Green job opportunity is presented by showing the additional amount of labor needed to produce renewable energy in the power sector in contrast to the reduction of labor in fossil fuel–based power plants. The net impact on factor payment will translate into changes in household income that will steer income distribution and economic welfare. Based on this welfare indicator, compensation from the government to vulnerable households is expected, given the potential for income reduction coupled with higher commodity prices in the economy. Finally, the cost of carbon mitigation is estimated by calculating how much foreign transfer is needed to compensate for the welfare loss from this green growth strategy. The health co-benefit from the reduction of GHG emissions is also calculated to estimate the externalities benefit that society will gain in the future.

We employ a novel approach in assessing the opportunity cost of energy transition in the power sector by linking two complementary models: a bottom-up TIMES (The Integrated MARKAL-EFOM System) energy assessment model and a top-down Computable General Equilibrium (CGE) model. The two models are solved dynamically by running simulations from 2014 to 2040. To allow the two models to communicate with each other, we build a soft linkage approach by setting up the price trend following the TIMES model, while the electricity demand on the other hand is endogenously solved by the CGE model. In calibrating the two models, we set up the growth parameters of supply mix and electricity demand from two comprehensive studies that take into account detailed microeconomic factors (Ravago et al. 2016; Danao and Ducanes 2016). Iteration between the two models is conducted until both models reach similar parameter values of electricity supply and demand growth rate. In this way, we have set up a proper baseline for the two models to run under similar supply and demand growth trajectories. More detailed discussion on the calibration process is given in the next section.

The next section provides overviews of the CGE and TIMES models and describes how the two models are linked. Scenario design is discussed in Section 3 to explain how we approach the research questions through simulation analysis. Section 4 presents the baseline result to show the model calibration output by focusing on the electricity sector. Simulation results are presented in the Section 5, exploring the economywide effects of promoting renewable power generation through factor reallocation as well as the co-benefit gain. Finally, Section 6 provides a summary and some policy recommendations.

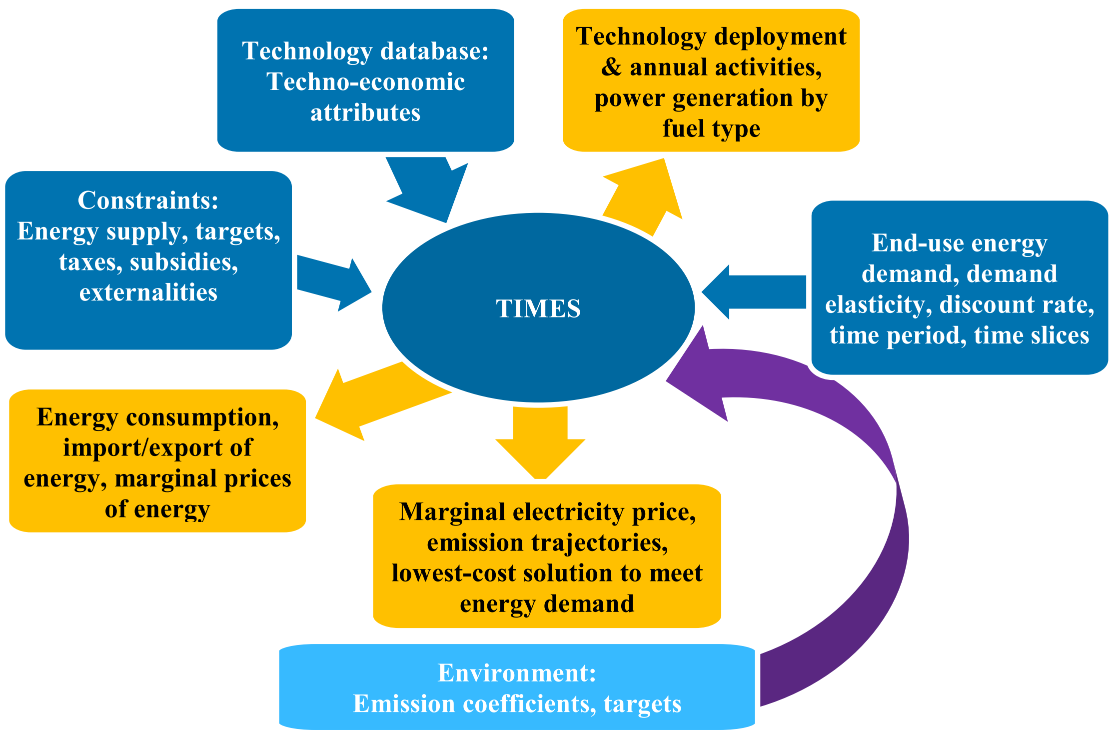
2. Overview of Models

Understanding the economywide impact of promoting renewable electricity generation requires deep understanding of both the economic structure and the detailed system cost of the power sector itself. An energy system model such as TIMES offers an ideal approach to identify the optimal pathway of promoting long-term renewable policy development in the power sector. The model provides the least cost solutions for alternative technology selection to supply the energy to meet future demand. This optimal energy mix is solved using a linear programming approach that computes an economic equilibrium for energy markets from the supply to the end-use energy services across time. The TIMES model also computes both the energy flow and energy prices in such a way that the suppliers of energy produce exactly the amount of energy demanded each year.

The main building blocks of the model are the processes (types of power plants or technologies) and commodities (energy carrier, cost, emission, and so on), which are connected by commodity flows in a network called the reference energy system (RES). The commodities flow through the process, and the process itself represents a technology in the RES. This approach facilitates graphical analysis of the whole energy system, from primary energy resources to the end use of energy services by each sector, through different conversion processes.

The TIMES model determines the energy and technology mix needed to meet the energy demands of a particular energy system, given specific limitations regarding available technologies and energy sources. It then determines an optimal energy supply mix based on technological and economic parameters, such as the minimum cost for the technologies selected. Figure 1 shows the schematic structure of the TIMES model. Key exogenous input parameters are a techno-economic database, energy demand, energy prices, emission coefficients, targets, subsidies, and taxes. Endogenous outputs are technology investments, annual activities of technologies, energy requirement, marginal energy prices, leveled cost of electricity, import/export of energy, emission trajectories, emissions permit, and total discounted system costs.[1] The TIMES model used in this study is the most widely used energy system optimization model, having been used in many country-level analyses (for example, Rout et al. 2011; IRG 2010; Amorim et al. 2014; De Laquil, Wenying, and Larson 2003; Nguyen 2005; Mondal, Kennedy, and Mezher 2014).

Figure 1. Schematic structure of the TIMES model



Source: Mondal et al. (2018).

Note: TIMES = The Integrated MARKAL-EFOM System.

The Philippine Dynamic Computable General Equilibrium (Phil-DCGE) model, on the other hand, is an economywide model that was built based on the standard International Food Policy Research Institute (IFPRI) model (Lofgren, Harris, and Robinson 2002) but extended by incorporating the interperiod solution to capture the effect of changes in investment and capital accumulation as documented in Diao and Thurlow (2012). The strength of this model is its ability to capture the interlinkages of economic activities across sectors and the interactions among agents

[1] Detailed parameter values assigned in the TIMES model can be found in Mondal et al. (2018).

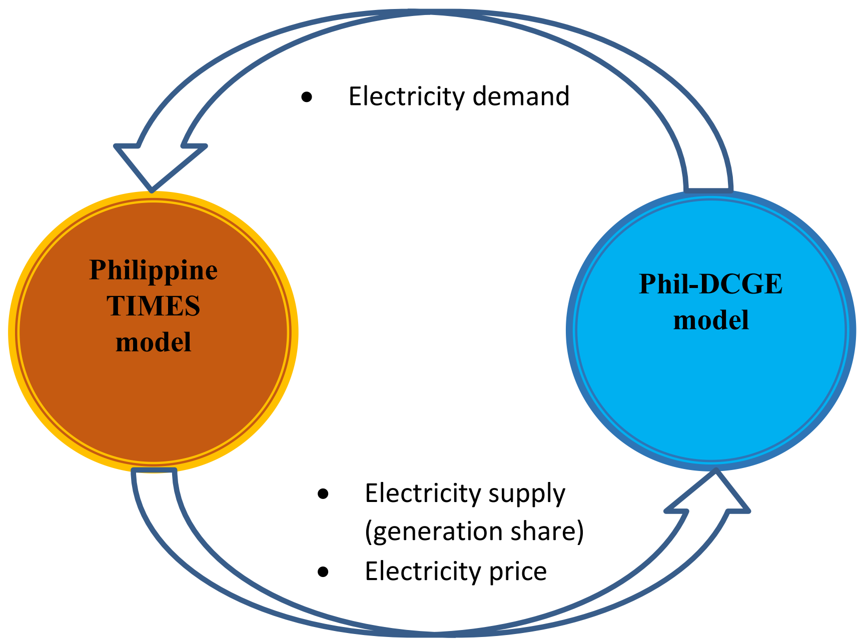
across the economy in a consistent manner based on microeconomic theory. This type of model has also been applied to analyze energy and environmental issues at a country level in a number of cases (for example, Arndt et al. 2016; Rosegrant et al. 2016; Pradesha and Robinson 2017; World Bank 2010; Wiebelt et al. 2013).

The model can be seen as a laboratory experiment that allows us to capture the impact of certain economic shocks on the whole economy. In this study, we introduce the optimal energy supply mix in the power sector to meet certain targets for renewable electricity generation. This sector-specific shock will consequently affect the rest of the economy through reallocation of input factors across sectors. The Phil-DCGE model will then give a new solution by finding the new equilibrium level that results in the maximum benefit to all agents, following the movement of prices and factor payments. The net impact of this shock can be traced from the micro to the macro level, given the model's ability to capture changes in both factor and commodity markets consistently. This feature is very appealing and informative to policy makers because it could help identify the potential direct and indirect effects of the shock, helping them anticipate any unintended spillover effects. Furthermore, the model also includes macroeconomic components that allow us to analyze some policy responses to mitigate the negative effects of the economic shocks.

In this study, the Philippine economy is portrayed in the model using social accounting matrix data based on the most recent input-output table and supported by various other macro- and microlevel datasets (PSA 2014). Given the energy focus of the study, the energy sector is disaggregated into 14 different sectors based on energy balance and the Global Trade Analysis Project (GTAP) database (DOE 2015; Aguiar, Narayanan, and McDougall 2016). The energy balance is used to calibrate the energy supply and demand structure, whereas the GTAP database provides a matrix of electricity production based on different technologies. Carbon emission data from each industry are also constructed following the International Energy Agency (IEA) database (IEA 2017). We choose 2014 as the base year, and the model solves recursively for each consecutive year to 2040. The model includes 14 agricultural subsectors, 3 mining subsectors, 14 food-industry subsectors, 7 other manufacturing subsectors, 14 energy subsectors that include fuel and power sectors, and 7 service subsectors. Detailed descriptions of these 59 subsectors are provided in Table 1A in the appendix. The more detailed disaggregation of the electricity/power sector is intended to facilitate model linkage with the TIMES model.

All production activities in the model combine intermediate and factor inputs used in generating sectoral outputs. For the electricity sector, we set up a single commodity with a multiple-output production system. We follow this approach to capture the features of the electricity market in the country, wherein electricity produced by all power plants has to be connected to a central grid before it is distributed to users. We assume that both capital and labor are mobile across sectors, given the long-term analysis of the study. Labor is categorized based on four levels of education to represent unskilled labor at one extreme and highly skilled labor at the other. The model categorizes households based on income levels and location, both based on the country's three major subregions and whether households are living in a rural or urban area.

Figure 2. Linkage of Philippine TIMES and Phil-DCGE models



Source: Authors.

Note: Phil-DCGE = Philippine Dynamic Computable General Equilibrium; TIMES = The Integrated MARKAL-EFOM System.

Based on the discussion above, it is clear that the two models have different features and strengths to capture the market dynamics of the electricity sector. The energy TIMES model is a partial equilibrium model that provides detailed analysis at a sector-specific level to inform the optimal energy supply mix in the power sector that meets total electricity demand. On the other hand, the Phil-DCGE model provides an economywide analysis encompassing all sectors in the economy and the interlinkages between commodity and factor markets, based on microeconomic theory. In this study, we use the TIMES model to complement the Phil-DCGE model by providing information on the electricity price and energy supply mix in the power sector based on lowest-cost solutions. On the other hand, the Phil-DCGE model provides the electricity demand trend to the TIMES model in order to capture market dynamics as a response to changes in electricity supply. The models are linked by adjusting these parameters until a new equilibrium is achieved (Figure 2).

In linking the two models, we first calibrate both models to reach a similar equilibrium level based on the most plausible future condition of the economy and electricity market situation in the country. We take advantage of earlier studies conducted by our collaborators that provide projections on economic growth, production mix, and electricity demand in the Philippines through the year 2040. Ravago and colleagues (2016) conducted a comprehensive study on the power sector in the Philippines that explored plausible scenarios of a power supply mix to fulfill future electricity demand. The study considers the country's installed capacity in both fossil and renewable power sources as well as the potential environmental cost of producing electricity. The authors suggest that under a high economic growth scenario of 7 percent per year, the country would potentially utilize lower-cost electricity production from coal power plants at the early stage, despite some environmental cost. They found that the generation supply mix in 2040 will be dominated by coal, at 56 percent, followed by conventional renewable energy and natural gas. Variable renewable energy sources such as solar, wind, and biomass will take minimal shares, whereas the contribution from natural gas power plants will be about 16 percent of total power generation. Table 1 provides the calibration results from both the TIMES and CGE models for 2040, following Ravago and others (2016), showing the plausible future condition of the energy supply mix in the power sector.

Table 1. Energy supply mix in the Philippine power sector in 2040

Generation share by fuel type in 2040 (%)	Plausible future	Phil-DCGE	TIMES
Coal	57	57.0	57.5
Natural gas	16	15.7	16.6
Conventional (hydro and geothermal) renewable	24	23.7	24.4
Variable renewable (biomass, wind, and solar)	1	1.6	1.3
Others (diesel and heavy fuel oil)	2	2.0	0.2
Total	100	100	100

Source: The "plausible future" share is based on the Policy 2 scenario in Ravago et al. (2016); the baseline value for the TIMES model follows Mondal et al. (2018).
Note: Phil-DCGE = Philippine Dynamic Computable General Equilibrium; TIMES = The Integrated MARKAL-EFOM System.

On the demand side, we follow Danao and Ducanes (2016), who forecast that electricity demand under strong economic growth would increase by 5.7 percent per year. This parameter is also used to calibrate both the TIMES and the Phil-DCGE models as another linkage point. Based on this common calibration process, we have indirectly set up two-way communication between the two models. The results will become the common base run for both models, to be compared with simulation scenarios that will be discussed in the next section.

3. Scenario Design

The main focus of the study is to understand the potential economywide impact of promoting renewable power generation in the Philippines by exploring alternative pathways of technology selection based on the lowest-cost approach to producing electricity. Among all other renewable technologies, solar has become the most promising technology that allows renewable electricity generation to compete with fossil-fuel power plants. The free fall of production cost has been followed by a sharp increase in installations worldwide (Martin 2018). Global investment in research and development, as well as economies of scale, are the key factors that help suppress the solar investment cost.

This trend is expected to continue, but the speed will depend on various factors. Mayer and colleagues (2015) did a comprehensive study to project the future long-term reduction in the cost of large-scale solar installations, based on combining a bottom-up and a top-down approach. They came up with four different scenarios reflecting, on the two extremes, conservative to optimistic market situations in the future. We follow the country-level result for Thailand as stated in the paper, which we believe closely reflects the solar market in the Philippines. Simulations 1 and 2

(SIM1 and SIM2, respectively) in Table 2 capture these market trends. SIM1 applies the optimal energy supply mix in the power sector provided by the TIMES model, aiming to achieve a 50 percent share for renewables in 2040 under a conservative reduction in solar investment cost. SIM2, on the other hand, provides for the possibility of a further reduction in solar investment cost by 30 percent, following the optimistic market situation described by Mayer and colleagues (2015). We represent this cost reduction by reducing the capital requirement to produce the same electricity from solar power plants as in SIM1, so as to reflect the cost-saving possibility of promoting renewable power generation. As a result, there will be less capital needed to support solar electricity production, which reduces capital constraints in the economy.

Table 2. Scenarios for promoting renewable power generation and for policy response

Scenario	Description
SIM1	Increasing share of renewables by 50 percent, following TIMES result based on conservative view of cost reduction for solar
SIM2	Increasing share of renewables by 50 percent, following TIMES result based on optimistic view of cost reduction for solar
SIM3	SIM1 + foreign transfer to government to cover welfare loss (carbon income from abroad)
SIM4	SIM2 + foreign transfer to government to cover welfare loss (carbon income from abroad)
SIM5	SIM4 + higher domestic investment share

Source: Authors.
Note: TIMES = The Integrated MARKAL-EFOM System.

The remaining simulations explore another opportunity—that of earning significant foreign transfer money into Philippine government accounts from developed countries who agree to cover the full incremental costs of mitigation measures (UNFCCC 2009). We set up the scenarios by introducing foreign transfers to government accounts in order to cover the welfare loss from promoting renewable power generation as captured in SIM1 and SIM2. Therefore, SIM3 corresponds to SIM1, and SIM4 corresponds to SIM2. Comparing these scenarios could show us the cost of a carbon mitigation policy under two different market situations by measuring how much foreign transfer is needed to cover the welfare loss resulting from reducing carbon emissions by promoting renewable electricity generation.

Furthermore, SIM3 and SIM4 provide analysis of the impact of receiving foreign transfers while the economy is undergoing an industrialization process as well as promoting renewable energy technology under SIM1 and SIM2 scenarios respectively. A high flow of foreign transfers could potentially deteriorate economic growth if the traded sectors lose competitiveness due to appreciation in the exchange rate. This will cause more input to move into nontraded sectors, which could further slow down the industrialization process. Thus, the two simulations analyze the potential Dutch disease effect from receiving foreign transfers.

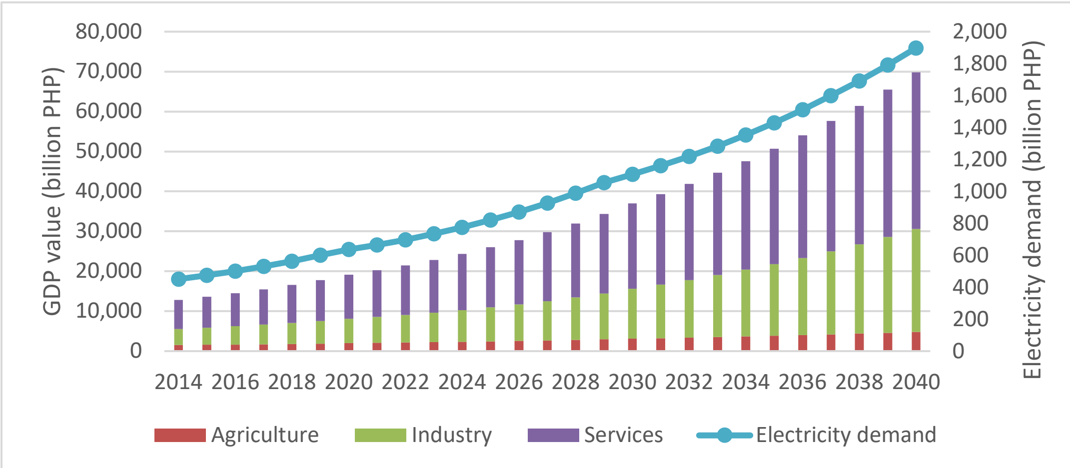
Finally, SIM5 is designed to capture the policy impact of promoting domestic investment to anticipate the Dutch disease effect of having a high flow of foreign transfers, as reflected in SIM4. In this scenario, we assume an investment share increase of up to 1 percent to let the new capital inflow from foreign transfers be absorbed by domestic investment activities. This simulation can be seen as a policy response of stimulating more factors to move into the traded sectors, in order to mitigate the potential negative effects of foreign transfers that could slow down the industrialization process in the country.

3.1 The Baseline Scenario

This study assumes that the Philippines could maintain strong economic growth in coming decades and anticipate high demand for electricity by committing to investment in the power sector. We set the economy to grow at 7 percent annually, following the optimistic view suggested in Ravago and colleagues (2016), in which the country will reach high-income status in 2040. Under this strong growth scenario, the demand for electricity is forecast to increase by 5.7 percent annually, according to the recent study by Danao and Ducanes (2016).

Figure 3 shows results from the Phil-DCGE model for gross domestic product (GDP) and electricity demand trend, showing how strong economic growth is followed by a growing demand for electricity. The 2040 GDP is expected to be more than four times its base-year level, with the industry and service sectors dominating economic activities. A structural transformation process is also observed, whereby a lower share of agriculture in the economy is followed by an increasing share of industry. Given the high demand for electricity as an input factor in both industry and services, the electricity demand has to grow in pace, pushing up the electricity market to reach about 2 trillion Philippine pesos (PHP) in 2040. This huge market potential indicates that future investment in the electricity sector is needed to meet the growing demand, and renewable electricity generation should take a bigger share if the government chooses to promote a green growth strategy.

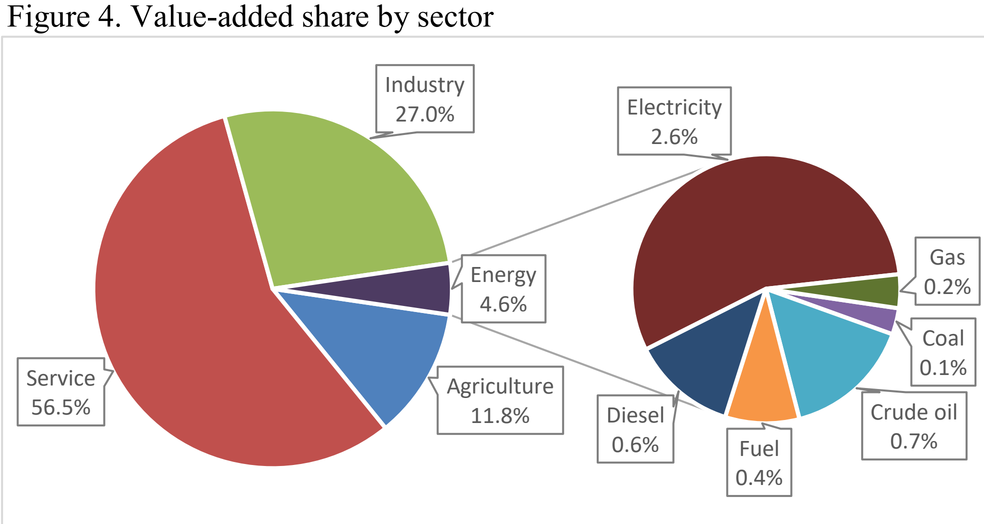
Figure 3. Gross domestic product trend by sector and electricity demand



Source: Constructed by authors from computable general equilibrium model simulation results.
Note: GDP = gross domestic product; PHP = Philippine pesos.

One of the main concerns in promoting renewable energy is the potential disruption in the economy caused by the energy transition process. The industry and service sectors are the ones that would be much affected by this transition process. However, these sectors are affected mainly by indirect effects such as from changes in electricity price. On the other hand, the more important direct impact of the energy transition will hit mainly the energy sector itself and the bigger the energy sector in the economy, the stronger the disruption that might take place. In the case of the Philippines, the share of the energy sector in total GDP is only about 4.6 percent, with around half of this contribution from the electricity sector (Figure 4). This economic structure shows that the potential negative effect from the energy transition in the power sector should be minimal.

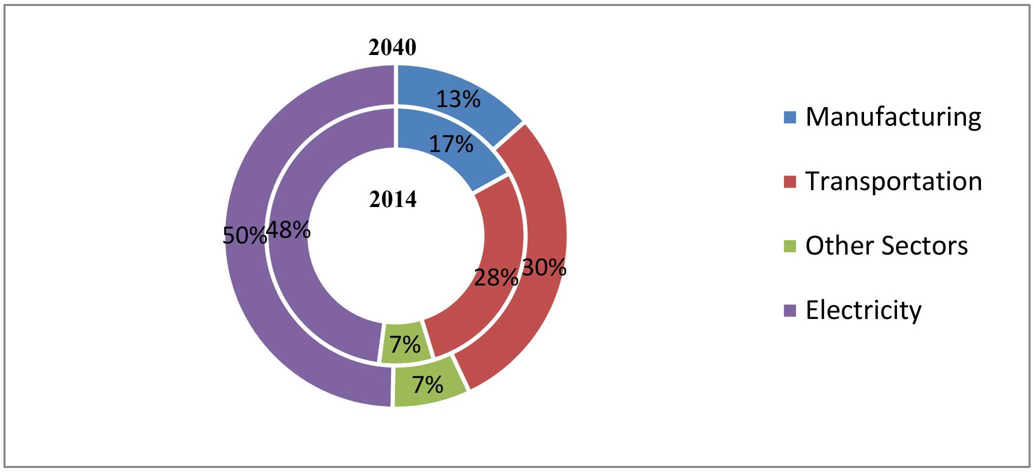
Figure 4. Value-added share by sector



Source: Constructed by authors from computable general equilibrium model simulation results.

Other energy sectors in the economy that also supply energy input to electricity have even smaller value-added. As shown in Figure 4, the oil industry, comprising crude oil, diesel, and fuel, in total accounts for only about 1.7 percent of GDP, while the coal and gas industries combined make up about 0.3 percent of total GDP. These figures indicate that it will be less likely that the energy transition into renewables in the power sector would significantly disrupt economic activities and halt the dream of the country to become an advanced nation in the coming decades.

Figure 5. Emissions contribution by sector

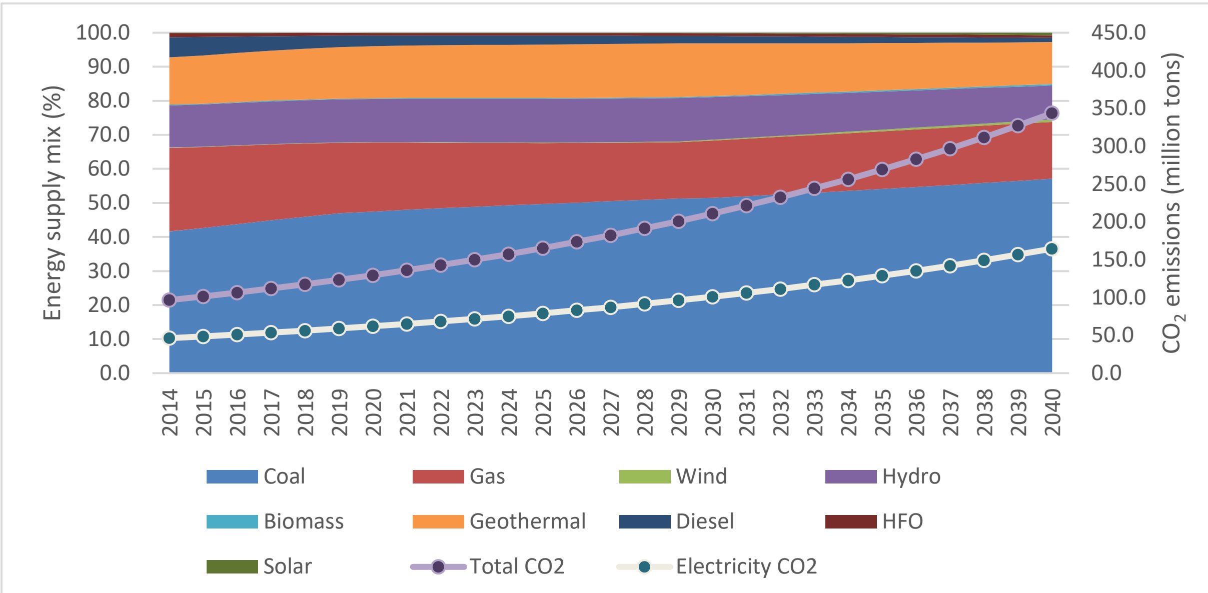


Source: IEA (2017).

The CGE model also produced carbon emission indicators for energy-intensive sectors such as electricity, manufacturing, and transportation. Total emissions are calibrated to follow carbon emission data from IEA (2017), in which total carbon emissions in 2014 for the Philippines are about 96 million tons of CO_2. Among the energy-intensive sectors, electricity has become the biggest emission contributor. In Figure 5, the inner part of the pie shows that almost half of total carbon emissions actually originate from the electricity sector. The transportation sector, on the other hand, accounts for only about 28 percent of total emissions. Manufacturing and other sectors take the rest, together accounting for about a quarter of total emissions in the country.

The carbon emission structure also does not change much in 2040, as shown by the outer part of the pie (Figure 5). The growing emissions share from the transportation sector is mainly caused by the stronger demand for service activities to move more commodities produced in the future. On the other hand, the increasing emissions contribution from electricity, from 48 to 50 percent, is caused by a higher share of coal in the energy supply mix to meet the future electricity demand. This emissions trend suggests that there is large potential for the country to reduce carbon emissions by promoting an energy transition into renewables in the power sector.

Figure 6. Energy supply mix in the power sector



Source: Constructed by authors from computable general equilibrium model simulation results.

Note: HFO = heavy fuel oil.

Under the baseline scenario, the Philippine government is assumed to follow the status quo, whereby fossil-fuel energy will dominate the power sector. Figure 6 provides a more detailed projection of the Philippine energy supply mix across time. The power sector has been depending on coal power plants to produce electricity, and this trend could potentially become stronger in the future. It is projected that the coal share in the energy supply mix will increase from about 40 percent in 2014 to 57 percent in 2040. On the other hand, the share of conventional renewable generation will decrease to 24 percent. This means that investment allocation in the power sector will mainly go to promote development of coal power plants instead of allocating more resources into renewables. Consequently, total emissions in the country are expected to grow strongly, as shown by the upward lines, with the carbon contribution from electricity going up, on average, by 4.5 million tons of CO_2 per year.

4. The Impact of Promoting Renewable Electricity Generation

This section explores some economic challenges that the country would face as the government commits to promoting a higher share of renewable generation in the power sector. The analysis will be focusing on macro-level changes such as economic growth, input factors movement, and welfare impact at both the national and the household level. The cost of carbon mitigation is estimated by calculating how much foreign transfer is needed to maintain the welfare level as in the baseline scenario. Furthermore, the macroeconomic impact from this foreign transfer is also assessed by anticipating the potential Dutch disease effect as the country receives a high flow of foreign capital.

Table 3. Optimal energy supply mix for targeting 50 percent renewable generation in 2040

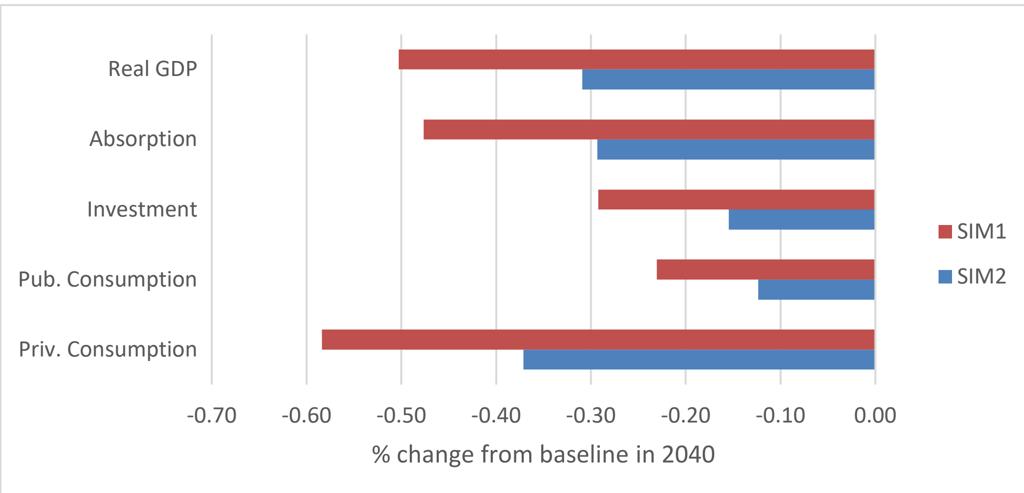
Generation share by fuel type (%)	Baseline	TIMES result (50 percent renewable share)	Phil-DCGE result (50 percent renewable share)
Fossil fuel–based	74.5	50.0	49.6
Coal	57.4	34.7	35.0
Gas	15.2	15.2	13.6
Diesel	0.8	0.0	0.5
Heavy fuel oil	1.1	0.0	0.5
Renewable	25.5	50.0	50.4
Hydro	11.0	11.3	11.5
Geothermal	13.5	16.2	17.1
Solar	0.2	19.1	18.6
Wind	0.4	3.0	2.7
Biomass	0.4	0.4	0.5
Total	100	100	100

Source: Constructed by authors from simulation results using the respective models.
Note: Phil-DCGE = Philippine dynamic computable general equilibrium model; TIMES = The Integrated MARKAL-EFOM System.

The result from the TIMES model on the optimal energy mix for targeting 50 percent renewable generation in 2040 is used as the starting point of the analysis. This energy supply mix is adopted in the Phil-DCGE model under all scenarios by adjusting the working capital in the power sectors to closely match the supply mix result provided by the TIMES model (Table 3). In comparison with the baseline, the share of fossil fuel–based generation decreases by 25 percent, with the biggest reduction observed in coal-based generation. The coal share falls from 57 to 35 percent, while generation based on other fuels decreases from 17 percent to 15 percent. For diesel and heavy fuel oil generation, the TIMES model suggests that there will be a complete shutdown of these technologies, given their 0 percent share. However, in the Phil-DCGE we cannot have 0 production, so instead we set the two technologies to produce minimally.

On the other hand, the share of renewables peak up to match the fossil fuel–based generation share, supported mainly by variable renewables. Solar technology takes the lead, with the share increasing significantly, reaching almost 19 percent in 2040. The contribution from wind also increases by around 2 percent, while the generation share from biomass is maintained. There is not much increase in conservative renewables, with the geothermal share going up from 13.5 to 17.1 percent. The model selection mainly promotes solar technology, which is mainly due to the potential of cost reduction that solar technology offers in the future. Furthermore, the Philippines also has a strong endowment in terms of solar radiation level, which opens more opportunity to exploit this technology option.

Figure 7. Projected impact of promoting renewable energy on value-added growth by sector in 2040

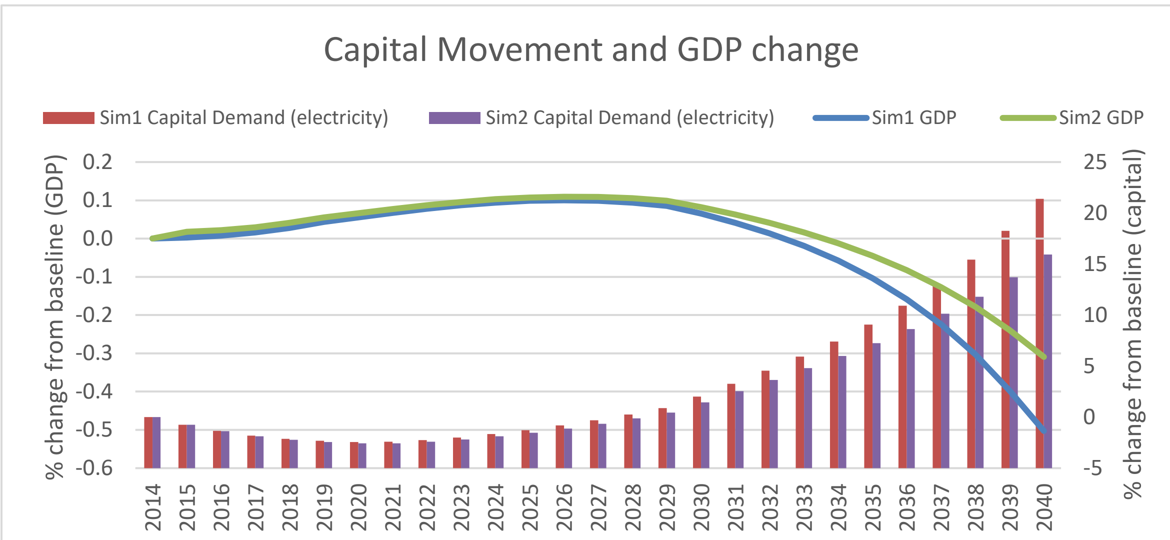


Source: Constructed by authors from computable general equilibrium model simulation results.

As mentioned earlier, the optimal energy mix is applied in all scenarios. The first two scenarios, however, look specifically at how the impact of promoting renewable generation would be different under two different market situations that drive solar investment cost. The first scenario (SIM1) adopts a conservative reduction in solar investment cost, whereas the second scenario (SIM2) reflects an optimistic view, in which the solar investment cost could be reduced by a further 30 percent. Lower investment cost means that less capital is needed to build a solar power plant. As a result, SIM2 should provide less negative impact compared with SIM1 because less capital is absorbed by the power sector, which reduces capital constraints under the renewable energy transition process.

The macroeconomic impact of promoting renewable power plants shows that real GDP could be reduced by 0.5 percent under SIM1 (Figure 7). The negative impact becomes less under SIM2, in which GDP decreases by only 0.3 percent. Again, this is the result of different investment costs in solar production. Private consumption, which is the main component of GDP, decreases by 0.6 percent, whereas the growth rate in public consumption and investment go down by 0.23 and 0.29, respectively. The growth reduction also becomes less under SIM2 for all GDP components. The difference is mainly caused by how input factors are reallocated across sectors as more capital is needed to support renewable power plants, when the solar investment cost is higher.

Figure 8. Capital demand in the electricity sector and changes in gross domestic product



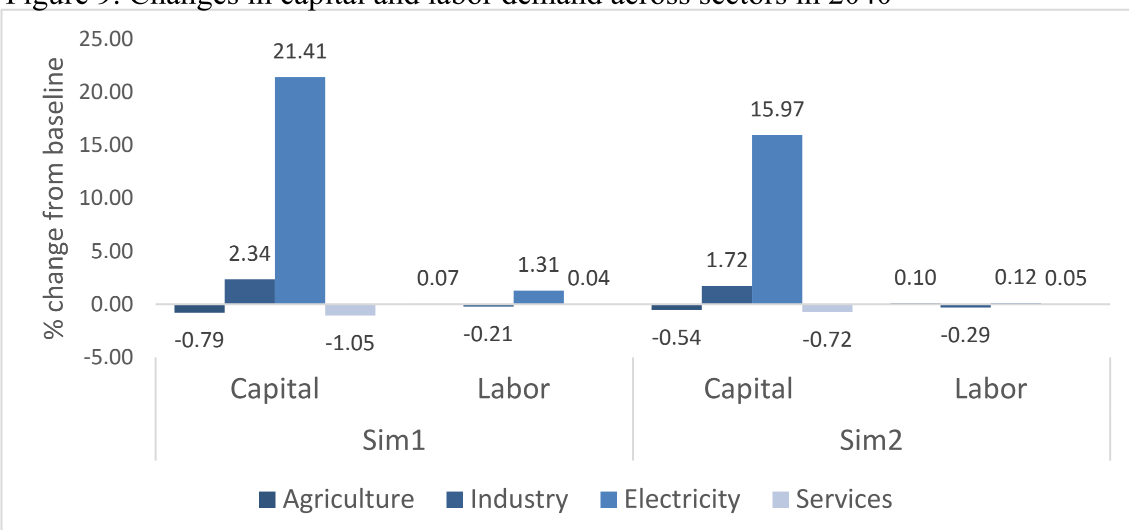
Source: Constructed by authors from computable general equilibrium model simulation results.

Note: GDP = gross domestic product.

Figure 8 illustrates the relationship between capital movement and GDP change as the economy puts more investment into renewable power generation. Given the limited supply of capital, allocating more investment into the power sector means that there will be less capital available to support production in other sectors. As a result, GDP starts going down in 2030 as more capital is absorbed by the power sector to promote production of renewable electricity, especially to build new solar power plants. In total, the capital demand of the electricity sector needs to go up by 21 percent under SIM1 at a cost of capital reduction in other sectors. However, given the lower capital requirement to invest in renewables under SIM2, the negative impact on GDP is smaller. Lower capital demand from renewables under SIM2 also allows the other sectors to produce more goods in comparison with SIM1 because of fewer capital constraints in the economy.

Capital movement into the power sector is followed by reallocation of labor across sectors. This condition will affect the structural transformation process as the country starts producing more advanced commodities and moving more labor into the manufacturing sectors. Promoting renewable power plants may disturb this process because more capital has to be allocated to the electricity sector, reducing production in other manufacturing industries. In both scenarios (SIM1 and SIM2), more capital is absorbed by the industrial sector. However, this capital mainly goes into the electricity sector to promote production of renewable generation, especially solar power plants (Figure 9). Given the capital-intensiveness of the electricity sector, there is only a slight increase in labor demand in the electricity sector, about 1.3 percent under SIM1 and only 0.1 percent under SIM2. On the other hand, labor demand decreases by around 0.2 percent in other industrial sectors under both scenarios. Furthermore, there is a slight increase in labor demand from the agriculture sector, which further slows down the structural transformation process.

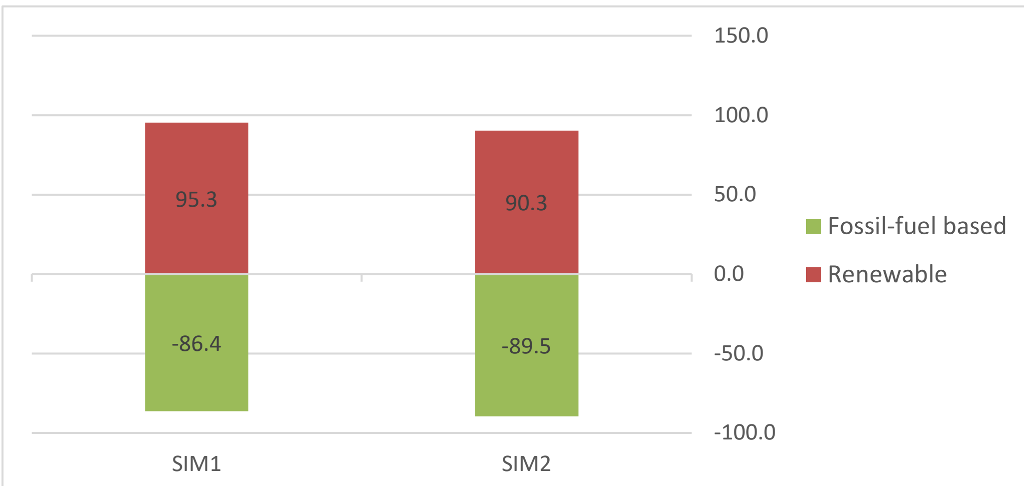
Figure 9. Changes in capital and labor demand across sectors in 2040



Source: Constructed by authors from computable general equilibrium model simulation results.

Within the electricity sector, we observe growing demand for green job opportunities as more labor is released from fossil fuel–based power plants. Under SIM1, renewable power generation could potentially hire more workers by 95,000 in 2040 compared with the baseline scenario (Figure 10). On the other hand, about 86,000 workers have to be released from fossil fuel–based power plants due to lower production of electricity from these plants. The same trend is also observed under SIM2, where 90,000 additional workers are expected to move into renewable power plants, followed by reduction of labor in fossil fuel–based power plants at the same rate. This labor movement suggests that there is only a slight increase in labor demand in the power sector. Indeed, under SIM1, about 8,000 additional laborers are needed in the power sector. This demand becomes less than 1,000 under SIM2. This labor movement also suggests that there is potentially less disruption than one might expect in the labor market for the power sector, given that all labor from fossil fuel–based power plants could be absorbed by the renewable sector. However, there is a need to support this process by providing training and education as well as more information about job opportunities in the renewable sector. This incentive will help future workers to be well prepared and help them get into the growing renewable energy industries.

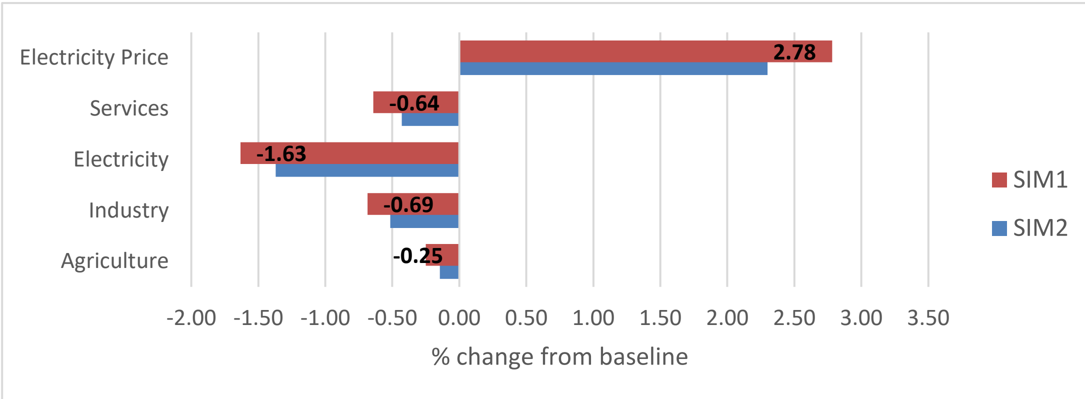
Figure 10. Labor movement within the electricity sector in 2040 (in thousands of workers)



Source: Constructed by authors from computable general equilibrium model simulation results.

As mentioned earlier, production across sectors, including electricity, has to go down due to reallocation of factors to promote renewable power generation. Despite getting more capital, the power sector will produce less output when the share generated renewably increases. This is mainly due to the high cost of producing electricity using renewable technology, compared with fossil fuel–based technologies such as coal power plants. As a result, electricity production is projected to decrease by 1.63 percent in 2040 and its price is expected to go up by 2.8 percent. Given the important role of electricity as an input commodity in other sectors, the higher price of electricity has added more burden on the lower capital usage by other sectors. This means that the economy has to face two challenges as it promotes production of renewable electricity—a lower supply of capital in the economy coupled with a higher price of electricity—that cause output production across sectors to be reduced further. Figure 11 shows that output from the industry and service sectors is projected to go down by 0.69 and 0.64 percent, respectively. On the other hand, agricultural output decreases by only 0.25 percent. This difference shows how strongly the electricity sector affects production activities in industry and services, compared with the agriculture sector. This also shows how disruption in the power sector could slightly affect the industrialization process that the country is undergoing.

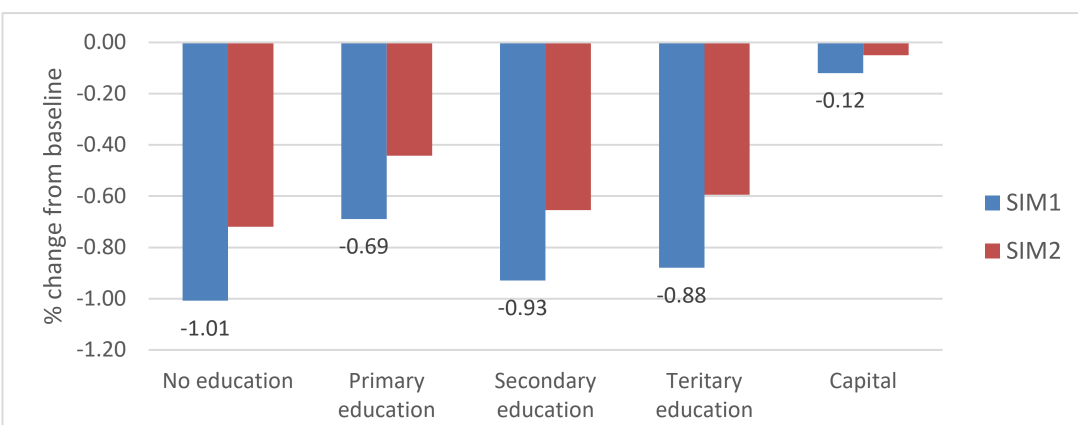
Figure 11. Total production by sector and electricity price in 2040



Source: Constructed by authors from computable general equilibrium model simulation results.

Lower production across sectors means that there will be less demand for input factors, which translates into lower factor payment. As expected, both capital and labor payment decreases as the economy promotes renewable energy production (Figure 12). Less negative impact is observed under SIM2, given the smaller distortion in the factor market when the solar investment cost is cheaper. Under SIM1, capital rent is projected to decrease by 0.1 percent, while wages decrease further, up to 1 percent, in 2040. Workers with no education who mainly work in low-value-added sectors such as agriculture experience the highest wage reduction. However, higher-skilled workers who have earned at least a secondary education are also getting paid less, by 0.9 percent.

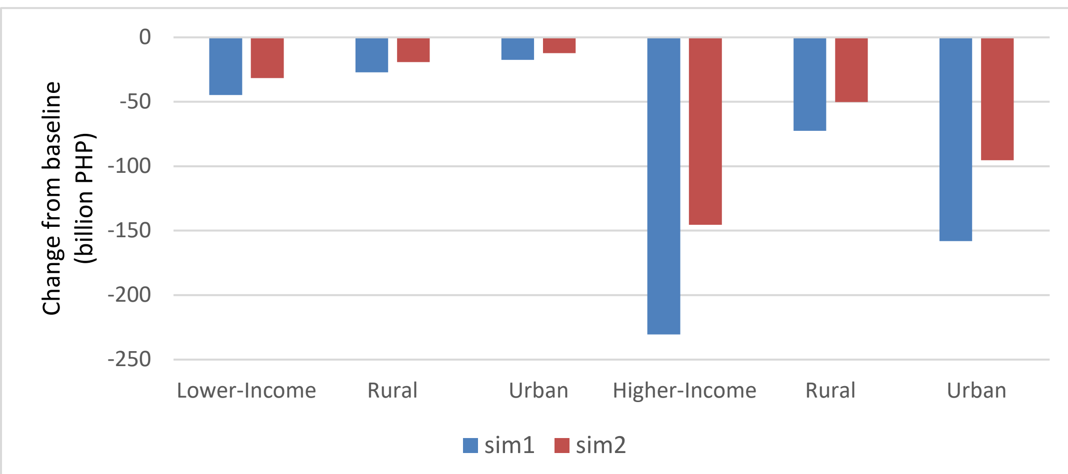
Figure 12. Changes on wages and capital rent in 2040



Source: Constructed by authors from computable general equilibrium model simulation results.

Household income is also expected to decrease, given the reduction in factor payments. The lower-income group, who mainly earn their income from low-skilled labor, should suffer more than the rich, given that less impact is observed on factor payments for high-skilled wages and for capital rent. However, the impact on net welfare shows that the lower-income group suffers less than the higher-income group (Figure 13). Price changes and consumption patterns drive the results. Higher prices for manufactured goods that are mainly consumed by the higher-income group cause their purchasing power to go down despite less impact on the income they receive. On the other hand, the lower-income group, who spend much of their income on food, gets a benefit, given the reduction in food prices, such as that of rice, despite a higher reduction in their income.

Figure 13. Household welfare across income groups in 2040

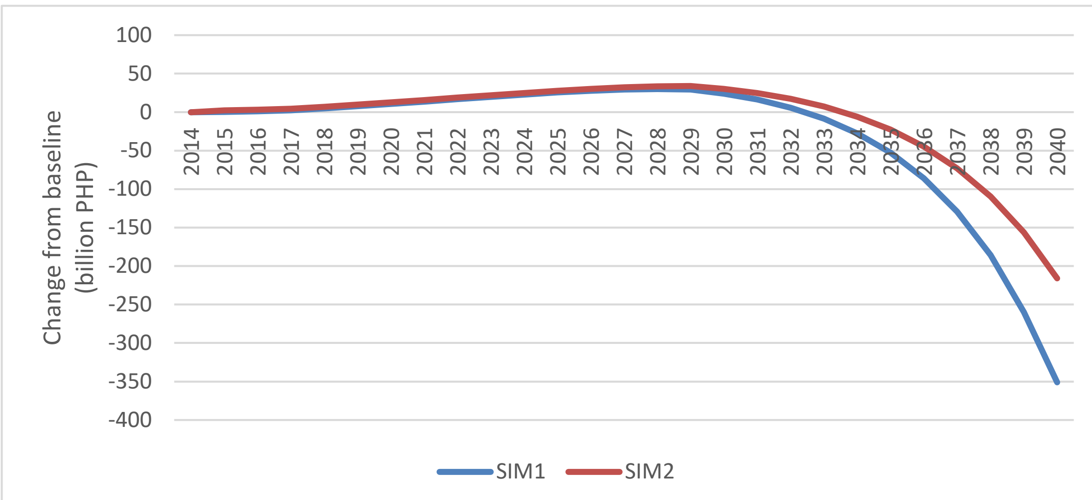


Source: Constructed by authors from computable general equilibrium model simulation results.

Overall, we observe that welfare reduction among the lower-income group is far less than in the higher-income group. Within the higher-income group itself, urban households actually suffer the most, accounting for about 70 percent of total welfare loss. Under SIM1 the welfare loss from the higher-income group accounts for about 230 billion PHP, which is much higher than that of the lower-income group, who lose only 45 billion PHP (Figure 13). Under SIM2, the welfare impact is less severe, with the higher-income group losing only about 145 billion PHP. Similarly, welfare loss among the lower-income group is far less, at about 30 billion PHP. In total, promotion of renewable power generation is projected to reduce household welfare in 2040 by 275 billion PHP under SIM1. But this loss could be reduced by 100 billion PHP if the future investment cost of solar energy can be suppressed further. This result also shows that promoting renewable power plants is less damaging and can be seen as a pro-poor energy policy given its less negative impact on the more vulnerable group.

At the national level, welfare loss is indicated by changes in total absorption, comprising public and private consumption as well as investment demand. In total, promotion of renewable electricity generation would cost the economy 351 billion PHP under SIM1, but this loss becomes less under SIM2, where the total absorption is reduced by only 216 billion PHP (Figure 14). This result again suggests that the welfare loss from the energy transition into renewables can be suppressed if the future investment cost of renewable technology, such as solar, becomes cheaper.

Figure 14. Welfare change at national level in 2040



Source: Constructed by authors from computable general equilibrium model simulation results.
Note: PHP = Philippine pesos.

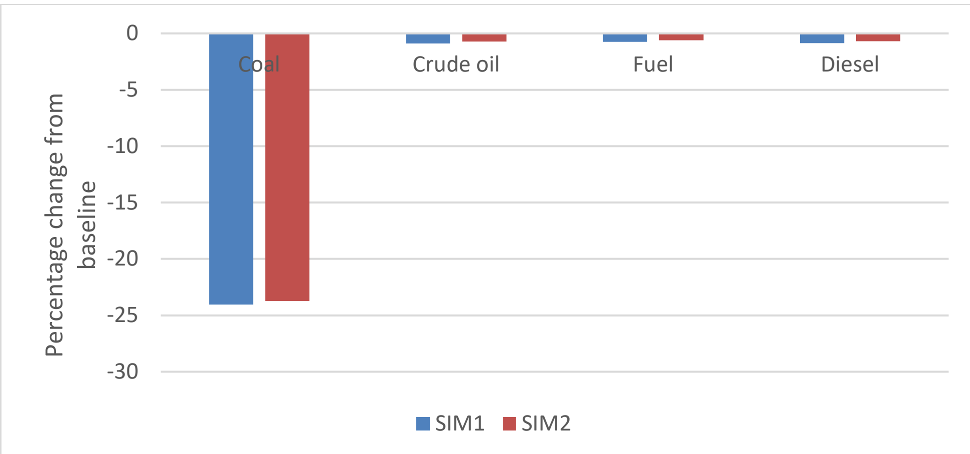
Table 4. Emissions reduction in 2040 compared with baseline (million tons of CO_2)

Emissions source	SIM1		SIM2	
	Electricity	Others	Electricity	Others
Coal	-62.9	-0.3	-62.1	-0.2
Oil	-0.4	-1.6	-0.5	-1.1
Gas	0.6	-0.2	0.5	-0.1
Total	-62.7	-2.0	-62.0	-1.5

Source: Constructed by authors from computable general equilibrium model simulation results.

On the other hand, by promoting production of electricity from renewable technology, the country could potentially reduce carbon emissions by more than 60 million tons in 2040 (Table 4). There is not much difference in emissions reduction under the two scenarios. The main reduction is obviously caused by less use of coal to produce electricity. Emissions reductions from other sectors are also observed, but the total is small, less than 2 million tons. This emission reduction, however, is mainly contributed by less use of oil in the economy. Overall, by aiming for a 50 percent share of renewables in electricity generation, the country could potentially reduce CO_2 emissions from coal by 62 million ton, which is equal to 27 percentage point reduction from the baseline.

Figure 15. Demand for imported energy commodities in 2040



Source: Constructed by authors from computable general equilibrium model simulation results.

Another benefit that the country could gain from transitioning into renewable technology is improvement in energy security through less dependency on energy imports. Coal is the main fossil fuel used to produce electricity in the country, and more than 60 percent of coal is imported. While the country is transitioning into renewable energy, less coal is needed to produce electricity, which consequently reduces the demand for imported coal. It is observed that imported coal could be reduced by 24 percent in 2040, compared with the baseline scenario, if the country aims to reach a 50 percent renewable energy generation share (Figure 15). Imports of other energy, such as oil, could also be reduced, but the magnitude would be small compared with the reduction in coal. This is mainly because oil has a small share in electricity generation, which makes the impact on it from the energy transition smaller.

Less imported energy will not only increase the energy security of the country, but it could also improve the current account balance. Given the fixed foreign savings assumption imposed on the model, the real exchange rate has to adjust, which makes the country's currency appreciate. The model shows that when renewable electricity generation is promoted, the real exchange rate appreciates by 0.1 percent in 2040. As a result, imported goods become cheaper than before, which makes the price for some commodities, such as food, decrease. This is one reason why we observe a reduction in the price of foods such as rice, as discussed earlier, which eventually improves the welfare of vulnerable households who spend much of their income on food. On the other hand, appreciation in the real exchange rate slightly hurts the exporting sectors such as manufacturing, given that the country becomes less competitive in the world market. This is another factor, in addition to the higher price of electricity, that pushes down production in the manufacturing sector.

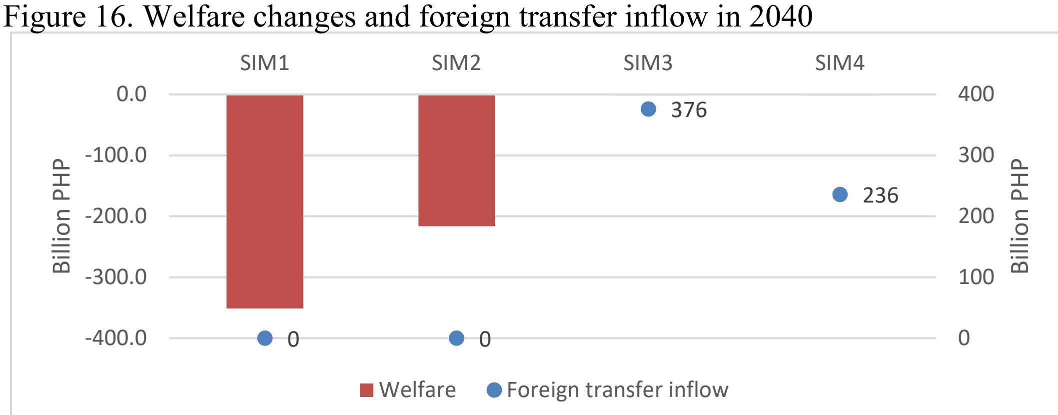
Finally, the potential health co-benefit of promoting renewable energy production can be estimated by calculating how much power generation from coal power plants is reduced, which implies less air pollution emitted from the power plants. The main air pollutants from coal power plants are sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and particulate matter (PM_{10}). We adopt the parameter of the externality cost from air pollution emitted by coal power plants proposed by Gunatilake, Ganesan, and Bacani (2014). These authors evaluate the potential cost of air pollution from coal power plants in India by monetizing the value of avoided premature mortality using the value of statistical life (VSL) approach. We follow their study because we could not find any such study that focuses on the Philippines or even other Asian countries. Given the higher population density and concentration of coal power plants in Luzon that has similar characteristics to the city in India studied by Gunatilake, Ganesan, and Bacani (2014), we believe the cost estimation is applicable for our study.

Gunatilake, Ganesan, and Bacani (2014) estimated that the cost of air pollution ranges from 1.05 cents to 12.58 cents (in US dollars) per kilowatt hour of electricity produced from a coal power plant. The lower cost estimation comes from the assumption that the coal power plant has installed a pollution control that can significantly reduce air pollution. On the other hand, the higher cost estimation assumes no pollution control installed in the power plant. Based on the TIMES model, promoting a 50 percent share of renewable electricity generation could reduce electricity production from coal power plants by 70 terawatt hours. This means that the health externality cost from air pollution borne by society could be reduced by at least US$0.73 billion (32 billion PHP), and potentially up to US$13.68 billion (616 billion PHP). If we take the average of these values, the amount is approximately US$7.2 billion (324 billion PHP). If we compare this average value with the total welfare reduction from promoting renewable power generation, as discussed above (351 billion PHP), the net negative impact from this renewable energy policy is minimal. Furthermore, there is still economic gain that the country could receive by having foreign capital inflow from abroad as compensation for reducing carbon emissions, as discussed in the next section.

5. The Impact of Foreign Transfers and Policy Response

This study assumed that the negative results from promoting renewable power generation will be compensated for by developed nations through foreign transfers as the Philippines reduces its carbon emissions. The magnitude of this foreign transfer could be significant to the economy, with the International Monetary Fund calculating that the future financial inflow from this mitigation effort could easily reach up to 10 percent of GDP for Africa south of the Sahara and up to 5 percent for India from the year 2020 onward (IMF 2008). One concern of having a large financial inflow is the potential of Dutch disease, which slows down the industrialization process as the economic activities move into nontraded sectors due to appreciation of the real exchange rate. In this study, SIM3 and SIM4 introduce the foreign transfer inflow to compensate for the welfare loss caused by renewable energy promotion, as analyzed under SIM1 and SIM2. Therefore, the analysis will compare results between SIM1 and SIM3, and between SIM2 and SIM4.

Figure 16. Welfare changes and foreign transfer inflow in 2040



Source: Constructed by authors from computable general equilibrium model simulation results.

Note: PHP = Philippine pesos.

The simulation results show that the country needs to receive financial inflows from abroad of between 236 billion and 376 billion PHP in 2040 to compensate for the welfare loss due to promoting renewable electricity generation. This amount is about 0.2 to 0.3 percent of GDP. Figure 16 shows how the foreign transfers offset the welfare loss under SIM3 and SIM4. The macroeconomic impacts of this financial inflow are presented in Table 5, where the real exchange rate appreciates by 0.9 percent under SIM3 and 0.6 percent under SIM4. This currency appreciation is much higher than in SIM1 and SIM2, in which the country could save foreign currency by reducing imported energy from coal, as discussed earlier. As a result, the real exchange rate appreciates, causing the exports sector performance to be sluggish, whereby total exports decrease from 1.4 to 3.2 percent as we compare SIM1 with SIM3. A similar impact is observed in SIM4, but the magnitude is smaller. On the other hand, foreign transfer inflow does not improve growth performance; instead, it makes the growth rate slightly worse off.

Table 5. Impact of foreign transfers on macroeconomic variables in 2040 (percentage change from baseline)

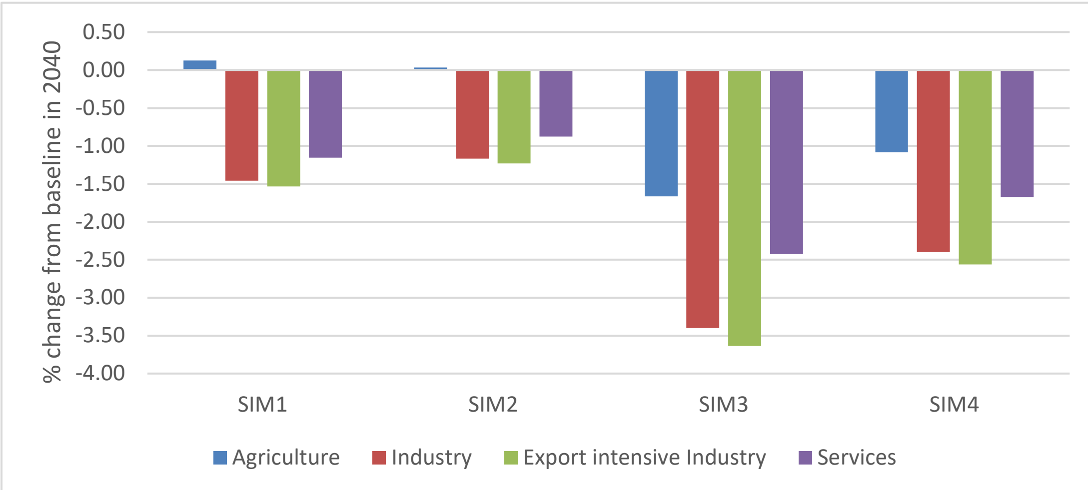
Variable	SIM1	SIM2	SIM3	SIM4
Real exchange rate	-0.13	-0.14	-0.9	-0.6
Exports	-1.41	-1.12	-3.2	-2.3
Imports	-1.12	-0.89	-0.6	-0.6
GDP	-0.50	-0.31	-0.53	-0.33

Source: Constructed by authors from computable general equilibrium model simulation results.

Note: GDP = gross domestic product.

The Dutch disease effect can also be observed by understanding how real exchange rate appreciation affects economic activities in the country. The direct effect would be a reduction in trade activities, as shown by the declining export of manufactured goods. Figure 17 shows how export demand in all sectors decreases when the country receives financial inflows from abroad. The worst impact is observed in the industrial sector, especially in export-intensive industries, which account for about 70 percent of the country's total manufacturing exports. Under SIM3, exports from the export-intensive industry sector decrease by around 3.6 percent, whereas it is about 2.6 percent for SIM4. Exports from the service sector also decline by 2.4 and 1.7 percent, respectively, under SIM3 and SIM4, while agriculture exports are less affected, decreasing by only around 1.1 percent.

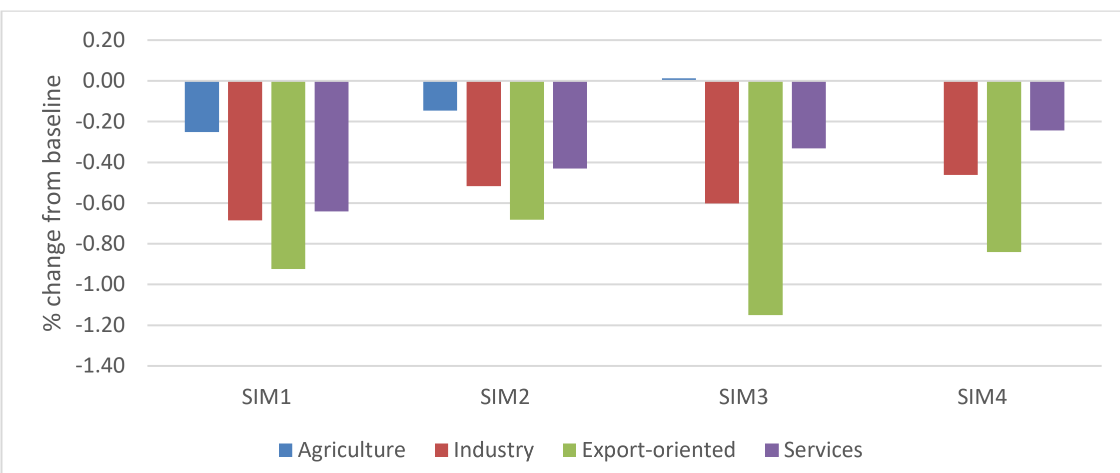
Figure 17. Export demand by aggregated sector in 2040



Source: Constructed by authors from computable general equilibrium model simulation results.

The economy is also expected to move toward nontraded goods, with output in agriculture and services improving but production from traded sectors, such as manufacturing, declining. Figure 18 shows how output in agriculture and services perform better (see the blue and purple bars under SIM3 and SIM4), in comparison with SIM1 and SIM2. On the other hand, output in the industry sector goes down, with a significant reduction observed in export-oriented industries, as shown by the green bar. These changes consequently affect the industrialization process, eventually slowing down labor movement into the industrial sector.

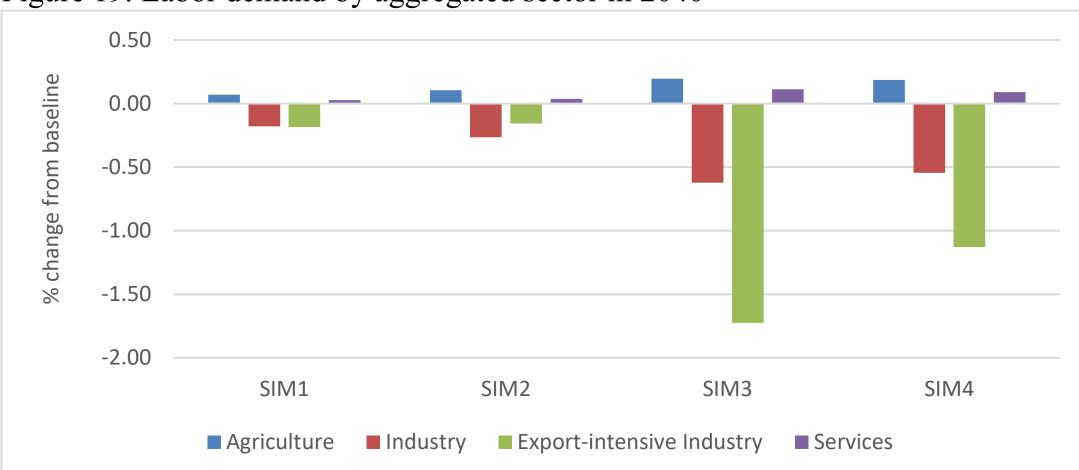
Figure 18. Output by aggregated sector in 2040



Source: Constructed by authors from computable general equilibrium model simulation results.

Figure 19 presents labor movement across sector, showing that demand for labor in agriculture and services further increases. On the other hand, the reduction of labor demand in the industry sector, as observed in SIM1 and SIM2, is strengthened under SIM3 and SIM4, which suggests that there will be potentially less labor moving into the industrial sector as the economy receives high capital inflows from abroad. The most significant impact is observed in export-intensive industries, where demand for labor could decrease by up to 1.6 percent in 2040. This result shows that the Philippine government needs to anticipate the negative side effect of Dutch disease if the country receives foreign transfers in the future as compensation for reducing carbon emissions.

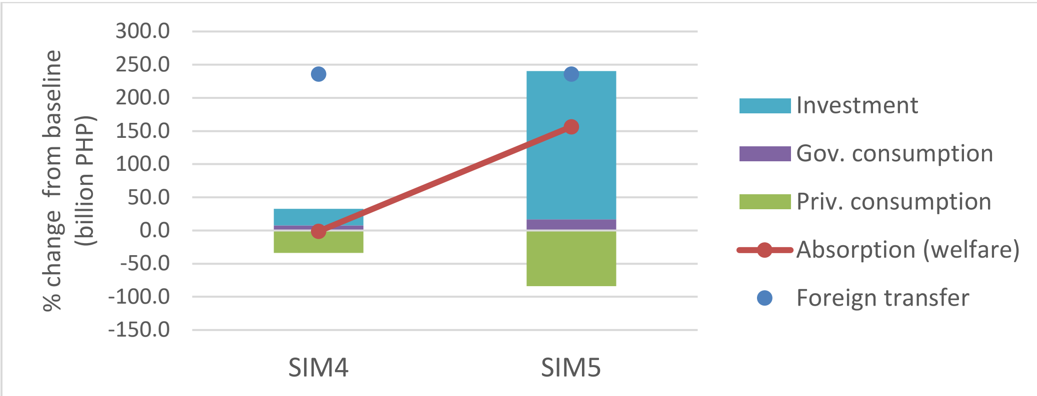
Figure 19. Labor demand by aggregated sector in 2040



Source: Constructed by authors from computable general equilibrium model simulation results.

In this study we look at the impact of increasing investment activity as a way to mitigate the Dutch disease effect. As explained earlier, we increase the share of total investment in the economy under SIM5 by 1 percent in order to allocate most of the foreign financial inflow into the traded sector. To analyze the net impact of this policy response in reducing the Dutch disease effect, we compare results from SIM5 with those of SIM4. Figure 20 shows that the country receives foreign transfers amounting to 236 billion PHP in 2040 under both scenarios, as indicated by the blue dots. However, under SIM5, this new capital inflow is mainly absorbed by investment demand, given the assumption of higher investment activity in the future. Government consumption also increases slightly under SIM5, while we observe a reduction in private consumption of around 50 billion PHP. In total, we observe a welfare gain of 155 billion PHP.

Figure 20. Impact of policy response through increase in investment activity in 2040



Source: Constructed by authors from computable general equilibrium model simulation results.

Note: PHP = Philippine pesos.

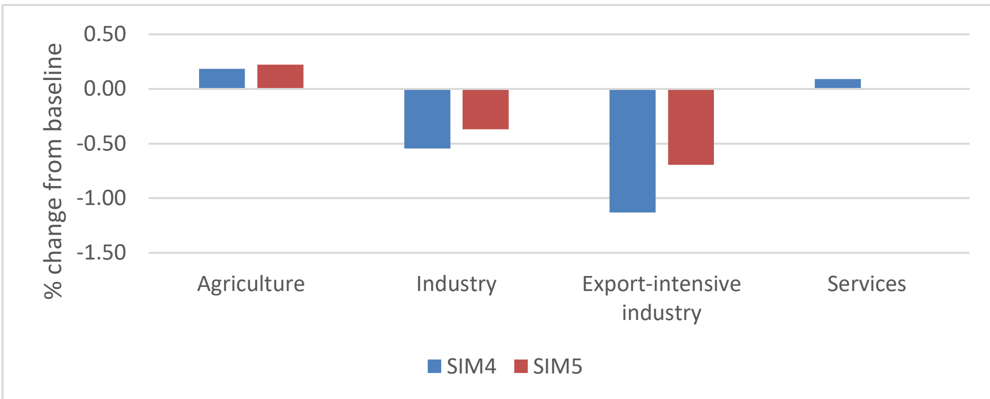
Figure 21. Impact of policy response on trade and gross domestic product in 2040

Source: Constructed by authors from computable general equilibrium model simulation results.

Note: GDP = gross domestic product.

The impact of the policy response on macroeconomic variables is encouraging. We found that export-sector performance improved given the lower export reduction observed in SIM5 compared with SIM4 under the similar exchange rate environment. Import demand also decreases because more goods can be supplied by domestic activities. In total, the GDP only decreases by 0.1 percent under SIM5 compare to 0.3 percent under SIM4, which suggests improvement in GDP by around 0.2 percent (Figure 21). This positive impact also has an effect at the sectoral level, where more labor moves into the industry sector, promoting the industrialization process in the country. The increase in labor demand is even higher for export-intensive industries, given the higher investment share allocated to these sectors (Figure 22). These results show that by promoting investment activities, the country can avoid the potential Dutch disease effect of receiving large capital inflows in the future. Increasing investment activity to absorb foreign transfer inflows could not only slightly improve economic growth but also increase economic welfare and promote the industrialization process.

Figure 22. Labor demand by aggregated sector in 2040



Source: Constructed by authors from computable general equilibrium model simulation results.

6. Conclusion

Meeting future electricity demand is one big challenge that the Philippine economy has to face in the next decades as the economy grows stronger. Promoting renewable technology in the power sector has become part of the government plan in order to increase energy security and to benefit from environmental externalities. Financial inflow from abroad is another opportunity to expect, given that the country has adopted a green growth strategy to reduce future carbon emissions. On the other hand, the country has to be ready to pay for the cost in advance. A high price of electricity and the reallocation of scarce capital input are expected to slow down the industrialization process and decrease economic growth.

Linking the bottom-up TIMES energy model with the top-down Phil-DCGE model has allowed us to scrutinize the potential economywide impact of promoting renewable electricity generation in the country. Simulation results show that solar technology would become the forefront of renewable electricity generation, taking almost one-fifth of the total generation share, given the stronger reduction of solar investment cost in the future, compared with the other renewable technologies. The contribution share from geothermal and hydro is also expected to increase, from approximately 24 to 29 percent. In total, renewable electricity generation is expected to be half of the country's total generation in 2040. On the other hand, the generation share from fossil fuel–based power plants is expected to decrease, with coal, as the biggest contributor, decreasing its share from 57 percent to only 35 percent. Generation from gas and oil power plants is also expected to decrease, from approximately 17 percent to 15 percent.

The model simulation indicates that the impact of allocating more investment into the renewable power sector could slightly reduce economic growth by 0.5 percent in 2040. Given the large share of solar electricity generation, this negative impact could be reduced if the investment cost in solar generation could be suppressed. However, the price of electricity is expected to rise as more electricity is produced using renewable technologies. Given the reliance of manufacturing sector on electricity as intermediate inputs in the production process, higher electricity price could potentially reduce manufacturing production. Scarce input factor of capital absorbed by the renewable power sector also forces all other sectors to reduce their production capacity. This capital reallocation eventually pushes down labor demand in the manufacturing sector, which slows down the industrialization process.

Lower economic growth, coupled with a deindustrialization process, also drives household income down. We found that the lower-income group, who are considered to be vulnerable households, are worse off than the high-income group in terms of reduction in total income. However, the welfare reduction from commodity price changes is much less in the lower-income group than in the higher-income group. In total, promotion of renewable power plants could potentially decrease economic welfare by up to 350 billion PHP in 2040.

On the other hand, carbon emissions could be reduced by 65 million tons in 2040.Lower production of electricity from coal power plants could also generate health co-benefit by reducing cost of air pollution approximately by 324 billion PHP. Furthermore, energy security could be improved as the renewable-generation share increases. The simulation result shows that reduction in coal generation causes the demand for imported coal to decrease by 24 percent. This import reduction means that the country could save foreign currency, which in the model is translated as an appreciation of the real exchange rate. As a result, the country enjoys a lower price of imported goods, which makes imported food such as rice become cheaper. On the other hand, the exports sector's performance becomes sluggish, especially manufacturing exports, which eventually increases the prices of other manufactured goods.

The Dutch disease effect could potentially hit the country through real exchange rate appreciation given the large financial inflow from abroad as the country receives compensation for its carbon emissions reduction. Simulation results show that export demand decreases as commodities from the Philippines become more expensive in the world market. Economic activities also start moving into the nontraded sector, which further slows down the industrialization process and slightly decreases economic growth.

Increasing investment activity in the future could help the economy absorb most of the financial inflow from abroad to finance productive activities in the traded sector. Simulation results show that manufactured exports increase, whereas import demand declines because more goods can be supplied by domestic activities. As a result, more labor could move into the manufacturing sector, which speeds up the industrialization process and improves economic growth. In total, the net welfare reflected by total absorption increases by 155 billion PHP.

APPENDIX

Table 1A. Subsectors of each aggregated sector

Aggregated sector	Individual sector
Agriculture	Palay (rice)
	Corn (maize)
	Coconuts, including copra
	Sugarcane
	Bananas
	Fruit
	Coffee
	Cassava
	Other crops
	Livestock
	Poultry
	Agricultural activities and services
	Forestry
	Fishing
Mining	Coal
	Crude oil, natural gas, and condensate
	Other mining
Manufacturing	Slaughtering, meat processing
	Dairy products
	Fruit and vegetable canning
	Fish canning and processing
	Coconut/vegetable oil
	Rice and corn milling
	Flour, grain milling, and starch products
	Bakery and noodle manufacturing
	Sugar milling and refining
	Cocoa manufacturing and coffee processing
	Manufacturing of animal feed
	Other food products
	Beverage industries
	Tobacco manufacturing
	Final goods manufacturing
	Electronic components
	Intermediate goods manufacturing
	Chemicals and chemical products
	Fertilizer

Aggregated sector	Individual sector
	Heavy industrial manufacturing
	Construction
Fuel	Gasoline
	Diesel
	Ethanol
	Biodiesel
Power	Electric—transmission & dist.
	Electric—coal based
	Electric—gas based
	Electric—wind based
	Electric—hydro based
	Electric—biomass based
	Electric—geothermal based
	Electric—diesel based
	Electric—heavy fuel oil based
	Electric—solar based
Services	Gas distribution
	Water distribution
	Land transportation
	Water transportation
	Air transportation
	Other private services
	Government services

Source: Authors.

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