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The Impact of Global Climate Change on the Indonesian Economy

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ABSTRACT

Global climate change influences the economic performance of all countries, and Indonesia is no exception. Under climate change, Indonesia is predicted to experience temperature increases of approximately 0.8°C by 2030. Moreover, rainfall patterns are predicted to change, with the rainy season ending earlier and the length of the rainy season becoming shorter. Climate change affects all economic sectors, but the agricultural sector is generally the hardest hit in terms of the number of poor affected. We assess climate change impacts for Indonesia using an Indonesian computable general equilibrium (CGE) model that focuses on the agricultural sector. Climate change input data were obtained from the International Food Policy Research Institute's International Model for Policy Analysis of Agricultural Commodities and Trade. Our results show that by 2030, global climate change will have a significant and negative effect on the Indonesian economy as a whole. In these projections, we see important impacts for particular sectors in the CGE model, especially for the agricultural sector (both producers and consumers) and in rural areas and for poorer households. Real gross domestic product (GDP) drops slightly and the consumer price index (CPI) increases by a small amount. Negative GDP growth is chiefly the result of adverse impacts on agriculture and agro-based industries, with the largest impact for soybeans, rice, and paddy (unmilled rice). Decreasing output of paddy and rice will adversely affect the country's food security. Domestic prices for paddy and rice increase significantly, pushing up the CPI. Taking international food price shocks into account would increase negative impacts. We find that addressing constraints to agricultural productivity growth through increased public agricultural research investments will be important to counteract adverse impacts of climate change. Enhanced awareness of both government agencies and farmers will be needed for the rural economy to adapt to the adverse impacts of climate change.

Keywords: climate change, IMPACT model, national CGE model, Indonesian economy

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1. INTRODUCTION

Ample evidence proves that the climate in Indonesia has changed. With increasing frequency in the past three decades, changes in precipitation and cycles of droughts and floods triggered by the Australasia monsoon and by the El Niño Southern Oscillation (ENSO) have damaged agricultural production in Indonesia, causing negative consequences for rural incomes, food prices, and food security (Naylor et al. 2007; Boer 2010). From 1970 to 2000, ENSO was the major factor influencing the year-to-year variation in rice production (Naylor et al. 2001, 2007). In Java, Indonesia, the strong El Niño event of 1997–1998 caused a reduction in rice-cultivated area of 700,000 hectare (ha) and a cumulative production loss of 3.2 million tons of milled rice, about one-fourth of the total rice traded annually in international markets between 1971 and 1998 (Naylor et al. 2001).

Boer, Buono, and Rakhman (2008) analyzed the rainfall data from 26 stations for East Java for 25–40 years and found a significantly declining trend in seasonal rainfall in East Java. At the same time, rainfall data in most other areas show increasing trends. Moreover, the rainy season has shortened, ending earlier, while the dry season has become longer. As a result, more rainfall is concentrated in fewer days, resulting in increased flooding.

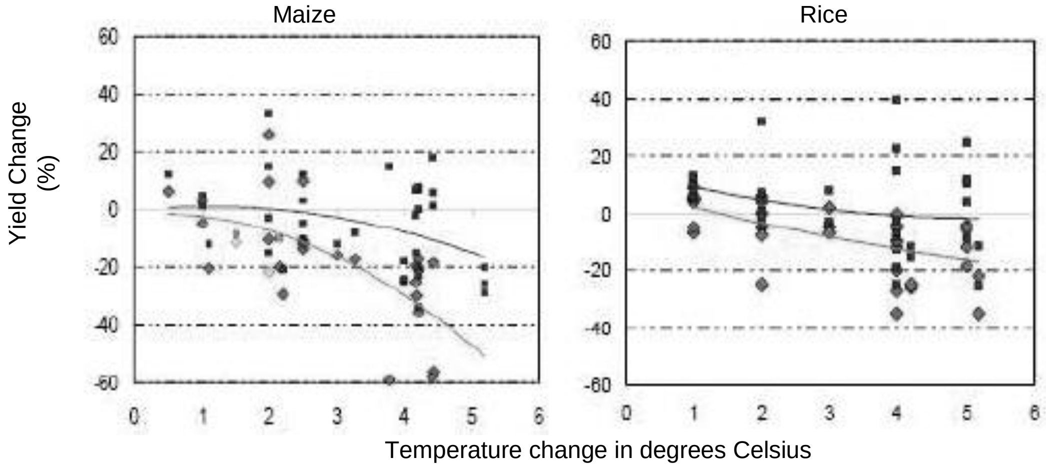
By 2050, total rainfall is expected to increase, on average, by nearly 10 percent from April through June but decrease by 10 to 25 percent in July through September, with peaks of –50 to –75 percent. When ENSO effects are superimposed on the projected annual cycle of precipitation to 2050, the likelihood of exceeding a 30-day delay in the onset of the monsoon, and therefore in the rice wet-season planting dates, increases significantly compared with the current period, particularly threatening rice production (Naylor et al. 2007; Cruz et al. 2007).

Thus, climate change is predicted to have a significant impact on agricultural production in Indonesia, especially food crops. The impact may be direct, for example, in the form of decreased agricultural productivity due to increased air temperature and changes in rainfall patterns. Indirect effects include changes in irrigation water availability as a result of changes in crop evaporative demands and runoff as well as shifts in the types of pests and diseases affecting food crops and livestock. Boer (2009) found that global warming and climate change in tropical regions can reduce corn yields by more than 40 percent and rice yields by 20 percent if temperature increases by 5°C (Figure 1.1). Rice yields are sensitive to the rising of minimum temperatures in the dry season; experiments conducted by the International Rice Research Institute in the Philippines have shown that yields could decrease 10 percent for every 1°C increase in minimum temperature (Peng et al. 2004).

Sea level rise (SLR) as a result of climate change is another important threat to the Indonesian economy. According to one estimate, the various economic activities that take place on the about 81,000 kilometers (km) of the Indonesian coastline contribute 25 percent of the national gross domestic product (GDP; Dahuri and Dutton 2002). Coastal areas contain vast agricultural land, many settlements, and about 400,000 fish ponds. A 1-meter SLR could flood 405,000 ha of coastal lands, particularly the northern coast of Java, the eastern coast of Sumatra, and the southern coast of Sulawesi. A rise in the sea level will impact agriculture through flooding, an increase of storm surges, and the increased salinization of coastal aquifers.

A 1992 study estimated that SLR may reduce the local rice supply in Karawang and Subang districts (West Java) by about 300,000 tons. Similarly, maize output could be reduced by 10,000 tons, about half of this due to inundation (Boer 2010). In addition, coastal aquaculture will suffer, and the coastal groundwater would have increased salinization, with potentially devastating results.

Figure 1.1—Estimation of rice and maize yield change in tropical areas as a result of changes in temperature



Source: Boer (2009).

The poor are the first to suffer from such changes. Delayed rainfall produces a longer lean season. Delays in the monsoon onset date, along with increases in extreme events, are projected to affect especially the more than 110 million Indonesians who live on less than US$2 per day. A longer *hunger season* and price increase would also push more people below the poverty line. Price instability hits poor farmers who spend more than 50 percent of their household income on food purchases particularly hard. Policy measures need to be set up to control increases in rice prices due to productivity shocks. For instance, better linkages to the global food market, with increased imports and larger stocks, would allow a buffer against the risk of falls in rice production (Naylor et al. 2007).

This paper examines the economic consequences of global climate change on Indonesia. Losses in primary production inputs, such as capital, infrastructure, land endowments, and productivity, because of climate change induce higher costs and prices with varying impacts on industries and regions. Because of the trade linkages, effects disseminate throughout the world economy causing systemic impacts and structural adjustments. Studies to assess the impact of climate change on the socioeconomic conditions in Indonesia are still limited. However, several global studies have hinted at potentially large adverse impacts from climate change. By 2050, global mortality due to climate hazards may reach 100,000 people per year and economic losses may reach US$300 billion per year (SEI, IUCN, and IISD 2001). Moreover, predicted yield declines are largest in Asia (Nelson et al. 2010). Adverse impacts from climate change will make it more difficult to reach the Millennium Development Goals. New investments and policy reform will therefore be urgently needed to increase the resilience of the Indonesian economy to climate change.

Specific Objective

Although the effects of climate change are already a reality in Indonesia, few studies have assessed the impacts of current and future climate change on the economy. This paper assesses the impact of global climate change on Indonesian macro and sectoral performance through linking an existing global partial equilibrium agriculture sector model, IMPACT (International Model for Policy Analysis of Agricultural Commodities and Trade), with a national computable general equilibrium (CGE) model called The Indonesian CGE Model for Climate Change.

2. BACKGROUND: VARIOUS APPLICATIONS OF NATIONAL COMPUTABLE GENERAL EQUILIBRIUM MODELS

Computable general equilibrium (CGE) models have been widely used in many countries since the beginning of the 1980s to analyze the consequences of macroeconomic policy choices and the allocation of resources. In terms of scope, CGE models can be developed for different purposes: to analyze multiple countries jointly, such as the GTAP (Global Trade Analysis Project) and LINKAGE models; to analyze one specific country, such as the INDORANI, WAYANG, and INDOF (Indonesian Forecasting) models; and to analyze at the subnational (province/district) or interregional level. Here we will only focus on national-level CGE models. Several CGE models have been developed for the Indonesian economy, including WAYANG by Warr (1998), INDOF by Oktaviani (2001, 2009), Indonesian CGE Model by Oktaviani et al. (2005), the Indonesian Energy CGE Model by Hartono and Resosudarmo (2006), and the Indonesian Energy and Environmental CGE Model by Yusuf (2008). However, none of these CGE models has linked with other economic models and been used to assess the impact of climate change on the Indonesian economy.

The application of CGE to assess the impact of global climate change on a national economy has been conducted through several research projects. Zhai, Lin, and Byambadorj (2009) examined the potential impacts of global climate change on China's agricultural production and trade as well as its macroeconomy through changes in agricultural productivity. The results suggest that with the anticipated decline in the agricultural share of GDP, the impact of climate change on China's macroeconomy will be moderate. The baseline results show that climate change will result in a 1.3 percent decline in GDP and a welfare loss equivalent of 1.1 percent in 2080 for China. However, if future growth in China's agricultural productivity is slower, dependence on world agricultural markets will be higher, leading to more welfare and output losses through worsening terms of trade.

This research is conducted with a global economy CGE model based on the World Bank's LINKAGE model (van der Mensbrugghe 2011). It is part of a family of multicountry, applied general equilibrium models used frequently to look at trade and environmental issues. The model is recursive dynamic, beginning with the base year of 2004, and can be solved annually through 2080, though in this analysis we project only to 2030.

Recently, environmental aspects have become one of the major concerns for policymakers. Therefore, it is interesting to construct a linkage between economic and environmental indicators. Two example studies are Schafer and Jacoby (2003) and Nilsson and Huhtala (2000). Schafer and Jacoby (2003) linked the Emission Prediction and Policy Analysis (EPPA) model that splits passenger and freight transport and the International Energy Agency's MARKet ALlocation (MARKAL) model that shows least-cost technology alternatives for meeting future energy demands. The EPPA model is a recursive dynamic and multiregional CGE model of the world economy. The environmental indicator that is used in this model is carbon dioxide (CO_2) emissions. Nilsson and Huhtala (2000) analyze the cost-efficiency of trading CO_2 emissions by focusing on the overall environmental impacts of active climate policy measures. The model uses the Swedish general equilibrium model Environmental Medium Term Economic Model–EMEC, developed to analyze environmental policy measures and their economic impacts.

Pauw, Thurlow, and Van Seventer (2010) use stochastic hydrometeorological crop-loss models with a regionalized CGE model to estimate losses for the full distribution of possible weather events (drought and floods) in Malawi. Results for Malawi indicate that, on average, droughts and floods together reduce total GDP by about 1.7 percent per year. However, damages vary considerably across weather events, with total GDP declining by at least 9 percent during a severe 1-in-20-year drought. Smaller-scale farmers in the southern regions of the country are especially vulnerable to declining agricultural revenues and increasing poverty during drought and flood years.

CGE models have been linked with other models to add details on the regional or sectoral economy, depending on the research question assessed. One example is the global–national linkage approach to model trade liberalization by Huff et al. (1995), Adams et al. (1997), Oktaviani (2001), and Oktaviani, Puspitawati, and Haryadi, (2008). Trade liberalization applied in the global model entails all participating countries other than the country of interest (in this study, Indonesia), reducing their tariffs. The result of the global simulation is essentially a hypothetical new global equilibrium in which world prices have changed and tariffs have been reduced in participating countries and altered in the country of interest. The price changes can then be treated as exogenous in the national country model. This paper uses climate change impacts on agriculture from the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT; Rosegrant et al. 2008; Nelson et al. 2010) in the Indonesia CGE model to capture the impact of global climate change on the Indonesian economy. The results from IMPACT—changes in yield growth and international food prices—are treated as exogenous shocks to the Indonesian CGE model.

3. METHODOLOGY

To measure the impact of climate change on the Indonesian economy, a combination of the partial equilibrium model and the CGE model was used as the main analytical tool. To analyze in detail the impact on the agricultural sector and macroeconomic conditions in Indonesia, IMPACT was linked with the national Indonesian general equilibrium model (Indonesian CGE Model for Climate Change), which is has different agricultural product aggregations and also includes labor aggregations. The key endogenous variables, such as yield levels and price changes, from IMPACT's base and climate change scenarios are employed as exogenous changes (augmenting output technical change) in the Indonesian CGE model. CGE models have several advantages over partial models. First, a CGE model is able to produce a factual and accurate economic interpretation compared with a partial model (Robinson 1990). Second, it allows us to see an economic interaction with consistent behavior (Rae and Sjakur 1999). Third, the impacts on various aspects, such as welfare economics, terms of trade, and the distribution of income and poverty, can be explored.

Brief Description of the IMPACT Model

IMPACT is a partial equilibrium model of the agricultural sector, representing a competitive agricultural market for crops and livestock. Demand is a function of prices, income, and population growth. Growth in crop production in each country is determined by crop and input prices and the rate of productivity growth. World agricultural commodity prices are determined annually at levels that clear international markets. IMPACT generates projections for crop area, yield, and production; demand for food, feed, and other uses; prices; and trade. For livestock, IMPACT projects numbers, yield, production, demand, prices, and trade. IMPACT includes 30 agricultural commodities and 115 economic regions, representing most developing countries; 126 global (aggregated) hydrological basins; and 281 global food production units, defined by intersections of economic regions and hydrological basins. IMPACT incorporates a water simulation model to assess water supply and demand and respective impacts on food supply and demand (Rosegrant et al. 2008). Moreover, IMPACT receives climate-adjusted water data through its linkage with a global hydrologic model that derives climate-adjusted crop yield impact data through its linkage with a process-based crop simulation model, Decision Support System for Agrotechnology Transfer (DSSAT).

Indonesian CGE Model for Climate Change

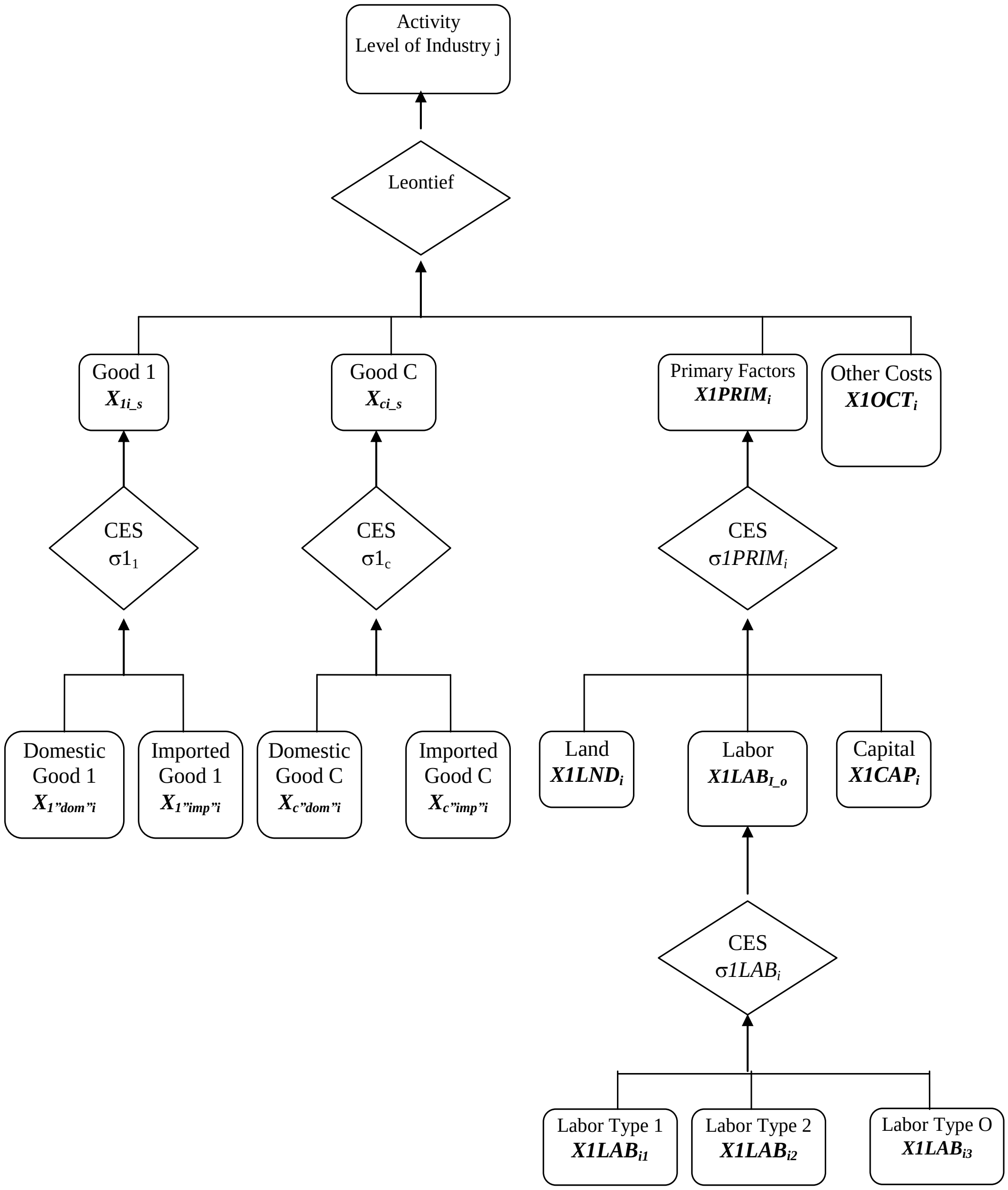
The structure of the Indonesian CGE Model for Climate Change is conventional and belongs to the class of general equilibrium models that are linear in proportional changes, sometimes referred to as Johansen models. The Indonesian CGE Model for Climate Change uses structural equations from the WAYANG model for the Indonesian Economy (Warr 1998), the ORANI general equilibrium model of the Australian economy (Dixon et al. 1982), and the Indonesian Forecasting Model (INDOF; Oktaviani 2001, 2009). The equation system of the model is organized into 18 blocks as follows:

1. Demands for labor
2. Demands for primary factor
3. Demands for intermediate inputs
4. Demands for composite primary factor and intermediate input
5. Commodity composite of industry output
6. Demands for investment goods
7. Household demands
8. Export and other final demands

9. Demands for margin
10. Purchaser prices
11. Market clearing condition
12. Indirect taxes
13. GDP from the income and expenditure sides
14. Trade balance and other aggregates
15. Rates of return, indexation
16. Investment-capital accumulation equation
17. Debt accumulation equations
18. Regional extension

The structure of production in a given industry is depicted in Figure 3.1; other structural details can be found in Oktaviani (2001, 2009). In the production process, each industry can produce several commodities. Industries use both intermediate and factor inputs. Each intermediate input can be sourced domestically or imported. Factor inputs for each industry are labor, capital, and land. Key simplifying assumptions made in this production model include input–output separability and the multistage, hierarchal structure based always on constant elasticity of substitution (transformation) production functions except for the combining of intermediate goods and aggregate primary factors, a stage that uses the Leontief or fixed proportions technology.

Figure 3.1—Structure of production in the Indonesian CGE Model for Climate Change



Source: Horridge, Parmenter, and Pearson (1999).

This structure, together with further assumptions about firm behavior and market structure, determines the demands for labor, other primary factors, and intermediate inputs and supply of commodities by the industry. These market and behavioral assumptions are as follows:

1. Producers and consumers are price takers in both input and output markets.
2. Producers seek to maximize profit by choosing input levels subject to the depicted production technology and therefore choose the least-cost combination of inputs for any given level of output.

The production function can be defined as

F(input, output) = 0

and can be written as

G(input)=**X1TOT**=H(outputs),

where **X1TOT** is an index or the level of industry activity. The assumption of input–output separability or separability in the transformation function means that the production of a combination of products by an industry is not directly linked to the particular combination of inputs used, but only through the intermediary of the index of activity in that industry (Blackorbyet, Primont, and Russell 1978).
At the highest level of the input side of the production process, the commodity composite, the primary-factor composite, and the *other costs* factor are combined in a Leontief production function to determine the level of output activity for the industry (see Figure 3.1). This function is

$$\boldsymbol{X1TOT_i} = \frac{1}{A1TOT_i} MIN\left\{ \underset{c \in COM}{MIN}\left(\frac{\boldsymbol{X1_{ci\_s}}}{A1_{ci\_s}} \right), \frac{\boldsymbol{X1PRIM_i}}{A1PRIM_i}, \frac{\boldsymbol{X1OCT_i}}{A1OCT_i} \right\} i \in IND \quad , \qquad (1)$$

where

$X1tot_i$	:	Activity level of value added by industry *i*
$A1tot_i$	:	All input augmenting technical change by industry i
$X1_{ci\_s}$	:	Demand for import and domestic commodity composite *c* for current production in industry *i*
$A1_{ci\_s}$	:	Technical change for import and domestic composite commodity *c* for current production *i*
$X1prim_i$	:	Aggregate output: value-added weights
$A1prim_i$	:	All factors augmenting technical change
X1octi	:	Demand for other cost tickets for industry *i*
A1octi	:	Other cost tickets augmenting technical change for industry *i*

The demand equations for the composite primary factor, for intermediate inputs, and for *other costs* are, under profit-maximizing behavior, directly proportional to the level of activity in the industry.

The ratios in which the various inputs must be combined are parameters of the Leontief production function. These ratios, together with the prices of the inputs, will determine the cost or expenditure shares in the industry. Vice versa, information on these shares and prices effectively defines the production function. Because the industry under competition must operate with zero profit, revenue equals costs.

A indicates the parameter of the input augmentation technology. With constant returns to scale and homogeneous of degree 1 production, multiplying the input factor with a constant *A* will result in the additional increase of the output by *A* as well. Therefore, the assumed total factor productivity growth rates replace the parameter of input augmentation technology, which can be the exogenous shock representing the percentage yield change due to global climate change. Other blocks of equations can be seen in Oktaviani (2001, 2009).

The model utilizes the 2005 Indonesian Input–Output (I–O) Table as the basic source of information for the database and is complemented by the 2005 Indonesian Social Accounting Matrix

(SAM) and other sources. Other data required for the general equilibrium model include various elasticity parameters and other indexing parameters.

Industries

The Indonesian CGE Model for Climate Change contains 74 producer goods and services produced by 74 corresponding industries: 21 agricultural industries, 9 mining industries, 14 food processing industries, 25 manufacturing and utility industries, and 5 service industries.

Commodities

The database for the Indonesian CGE Model for Climate Change contains two types of commodities—producer goods and consumer goods. Producer goods come from two sources: domestically produced and imported. All 74 producer goods are in principle capable of being imported, although some, such as services and utilities, have zero levels of imports. The 20 consumer goods identified in the model are each transformed from the producer goods, where the proportions of domestically produced and imported goods of each kind used in this transformation are sensitive to their (Armington) elasticities of substitution and to changes in their relative prices.

Households

The model contains 10 major household categories—7 rural and 3 urban—differentiated by socioeconomic group, as identified in the 2005 SAM. The sources of income of each of these household types depend on their ownership of factors of production and are estimated from the household income and expenditure survey (*Survey Sosial Ekonomi Nasional* - SUSENAS, Central Bureau of Statistics 2008). Following are the household categories:

1. Agricultural employees—agricultural workers who do not own land
2. Small farmers—agricultural workers with land < 0.5 ha
3. Medium farmers—agricultural workers with land 0.5 ~ 1 ha
4. Large farmers—agricultural workers with land >1 ha
5. Rural low-income—nonagricultural households, consisting of small retail store owners, small entrepreneurs, small personal service providers, and clerical and manual workers in rural areas
6. Rural nonlabor—force and unclassified households in rural areas
7. Rural high-income—nonagricultural households consisting of managers, technicians, professionals, military officers, teachers, large entrepreneurs, large retail store owners, large personal service providers, and skilled clerical workers in rural areas
8. Urban low-income—small retail store owners, small entrepreneurs, small personal service providers, and clerical and manual workers in urban areas
9. Urban nonlabor force and unclassified households in urban areas
10. Urban high-income—managers, technicians, professionals, military officers, teachers, large entrepreneurs, large personal service providers, and skilled clerical workers in urban areas

The Closure of the Model

The impact of global climate change on the Indonesian economy is projected in *long-run mode*, where the model allows both international and intersectoral mobility of capital. It endogenizes the total stocks of mobile agricultural and nonagricultural capital and the total stock of fixed capital in the nonagricultural sectors. These forms of capital are fully mobile among industries and are mobile internationally. Their rate of return is exogenously determined by an international rate of return. The total stock of agricultural land remains fixed exogenously, but land is mobile among agricultural industries.

Macroeconomic closure refers to the specification of endogenous and exogenous variables to satisfy the balancing of the capital and current accounts (that is, the difference between national savings and investment must equal exports plus international transfers less imports). In this application, the standard closure is modified by fixing the trade balance at its baseline level and endogenizing the real devaluation. It also assumes much greater flexibility in Indonesia's adjustment to the global climate change scenarios.

Policy Scenarios

In this study we analyze the impact of global climate change on Indonesian economic performance through five technical simulations. We first develop a scenario without climate change for the period 2005–2030 (Table 3.1), which serves as the baseline scenario.

Table 3.1—Yield productivity and international price change for baseline and climate change scenarios (percent), 2005–2030

	Baseline Scenario	Climate Change Scenarios		
Sector	Productivity change	Productivity change MIROC A1B	Productivity change CSIRO A1B	International price impact in 2030, MIROC A1B compared with baseline
Paddy/Rice	13.19	10.13	13.43	11.80
Maize	23.29	20.80	19.48	30.70
Soybean	19.17	20.39	15.78	28.90
Cassava	31.43	34.20	33.88	30.00
Fruits and Vegetables	41.80	43.40	43.65	43.80
Sugarcane	31.18	28.19	27.90	15.90

Source: IMPACT model.
Notes: CSIRO = Commonwealth Scientific and Industrial Research Organization; MIROC = Model for Interdisciplinary Research on Climate.

Among the global circulation model (GCM) datasets that are available in the public domain for a range of scenarios, including the three Special Report on Emissions Scenarios (SRES) used in the Intergovernmental Panel on Climate Change's Fourth Assessment Report (Parry et al. 2007), only four GCMs make sufficient data publicly available (precipitation, maximum daily temperature, and minimum air temperature) to run DSSAT crop models, including CNRM-CM3 (Météo-France/Centre National de Recherches Météorologiques, France), CSIRO-Mk3.0 (Commonwealth Scientific and Industrial Research Organization (CSIRO) Atmospheric Research, Australia), ECHam5 (Max Planck Institute for Meteorology, Germany), and MIROC 3.2 (medium resolution; Model for Interdisciplinary Research on Climate; Center for Climate System Research, University of Tokyo; National Institute for Environmental Studies, and Frontier Research Center for Global Change, or JAMSTEC, Japan).

Among these four GCMs, the MIROC 3.2 A1B and B1 scenarios represent, globally, the relatively wettest and warmest future, while the CSIRO A1B and B1 scenarios represent the relatively coolest and driest future. Among these four, the MIROC2 A1B simulation (Sim 2a) and the CSIRO A1B simulation (Sim 2b) were chosen. Data were downscaled using the procedure described in Jones et al. (2009) and incorporated into a DSSAT crop growth model to assess impact on both rainfed and irrigated crops. For irrigation, we also assessed the impact of climate change on runoff, which was modeled directly in IMPACT, through its coupling with a global hydrologic model. For details, see Nelson et al. (2010).

The yield impacts from the IMPACT model are directly passed to the Indonesian general equilibrium model through productivity shocks. In this instance the feedback is mixed with both increases and decreases in yield levels depending on the crop and GCM source. Productivity shocks were modeled separately for three food-producing units in Indonesia and were limited to six key agricultural commodities: maize, soybean, cassava, sugarcane, fruits and vegetables, and rice. Instead of rice, the Indonesia CGE model includes paddy (premilled). Thus a conversion ratio of 3/2 was included to convert rice to paddy. Detailed changes in yield growth over 25 years are presented in Table 3.1.

In a third simulation (Sim 3), we assess the impact of global climate change on Indonesia assuming an increase in agricultural productivity by 10 percent—triggered in response to growing food price trends as a result of adverse climate change impacts, among others. A fourth simulation (Sim 4) combines climate change impacts with the 10-percent productivity increase in crops with a 10-percent productivity increase in beef, given that the country is currently increasing investments in beef to achieve self-sufficiency. Lastly, we assess the impacts of changes in international food prices as a result of climate change on Indonesia (Sim 5) (see Tables 3.1 and 3.2).

Table 3.2—Summary of simulations implemented

Number	Description
Sim 1	No climate change baseline simulation
Sim 2a	MIROC A1B climate change scenario
Sim 2b	CSIRO A1B climate change scenario
Sim 3	MIROC A1B climate change scenario, increase in crop productivity by 10 percent
Sim 4	MIROC A1B climate change scenario, increase in both crop and livestock productivity by 10 percent
Sim 5	Sim 4 plus impact of international food prices as a result of climate change, run for 10 years

Source: Authors' simulations.
Notes: CSIRO = Commonwealth Scientific and Industrial Research Organization; MIROC = Model for Interdisciplinary Research on Climate.

4. RESULTS AND DISCUSSION

In this section we present the impact of global climate change on macroeconomic indicators, sectoral output, domestic commodity prices, labor, exports, and imports. Generally, global climate change under the MIROC A1B simulation (Sim 2a) projected to 2030 (simulating the 2010–2040 climate) is expected to worsen Indonesian economic performance. Growth in real GDP will decrease to 1.85 percent relative to the baseline conditions in Sim 1 (2.07 percent).In the globally driest and coolest future, as reflected in the CSIRO scenario (Sim 2b), the negative impacts on GDP growth are slightly less (1.92 percent; see Table 4.1).

Table 4.1—Indonesian macroeconomic performance (percent change) under scenarios of climate change and agricultural research and development investment compared with baseline change, 2005–2030

Description	Sim 1	Sim 2a	Sim 2b	Sim 3	Sim 4	Sim 5
Terms of trade	0.91	0.81	0.84	1.18	1.22	0.78
Consumer price index	–2.37	–2.08	–2.17	–3.07	–3.15	–2.07
Average real wage of administrator labor	9.02	7.95	8.30	11.66	12.02	10.14
Average real wage of farmer labor	–5.45	–5.55	–5.53	–6.98	–6.54	–0.77
Average real wage of operator labor	3.64	3.36	3.42	4.72	4.91	3.38
Average real wage of professional labor	14.59	12.84	13.41	18.87	19.45	16.90
Import volume index, CIF weights	0.51	0.25	0.36	0.65	0.32	–0.93
Real GDP from expenditure side	2.07	1.85	1.92	2.68	2.86	2.80
Real household consumption	5.36	4.70	4.92	6.94	7.15	6.52
Export volume index	–4.24	–3.75	–3.91	–5.48	–5.65	–5.53
Aggregate real government demands	5.36	4.70	4.92	6.94	7.15	6.52
Aggregate real inventories	–4.52	–3.77	–4.03	–5.83	–6.00	–5.78

Source: Authors' simulations.
Notes: CIF =Cost Insurance and Freight, GDP = gross domestic product.

This reflects the long-run stagnation in the contribution of the Indonesian agricultural sector to overall GDP. On the other hand, if the government of Indonesia significantly accelerates investments in crop research and development (R&D; paddy and rice, maize, soybean, cassava, and fruits and vegetables) to counteract adverse climate change impacts (Sim 3), overall GDP is projected to grow by2.68 percent. The macroeconomic impact on GDP is even higher under Sim 4 (2.86 percent), where the government of Indonesia supports accelerated R&D in both the crop sector and beef. Beef is of strategic importance for the government and the Ministry of Agriculture. Higher R&D investments for beef translate into higher productivity and will, in the long run, support Indonesia's import-substitution strategy (Table 4.1).

Increased investment in agricultural R&D strengthens not only food security in the country, which has come to the forefront as a result of a series of recent food price spikes, but also the economy as a whole. Indonesia also has yet to fulfill the promising potential of adding value to its agricultural exports. Although Indonesia is one of the largest commodity exporters in the world, the country received less revenue from its natural resource endowments than its competitors because of the low value-added content of its exports (World Bank 2009).

The impact on domestic prices, measured by the consumer price index (CPI), is expected to increase from –2.37 percent change in the baseline to –2.08 and –2.17 percent change in Sims 2a and 2b, respectively, worsening the deflation of the baseline scenario. Real household consumption is expected to slightly decrease because of climate change due to the decrease in average real wage in most labor classifications. Furthermore, operator and professional labor will suffer from the highest negative impact under the climate change scenario. There is also a reduction in capital rental. Net export performance worsens because Indonesia has to focus on allocating resources to provide adequate supply in response to domestic demand of strategic food commodities (rice and maize).

Accelerated investment in R&D for food (Sim 3) and beef (Sim 4) will increase average real wage for most labor classifications (farmers excluded) and will increase real household consumption by 6.94 and 7.15 percent, respectively, compared with a baseline change of 5.36 percent. Increased supply of domestic food production will also lower inflation. An increase in agricultural R&D of 10 percent will thus be more than sufficient to counteract adverse impacts from climate change on the Indonesian economy, at least as projected to 2030. In Sim 5, where international food price impacts of climate change are taken into account for 10 years, real household consumption increases but real GDP growth changes significantly compared with Sim 1. The increasing real GDP is mainly because the improvement in the terms of trade means that higher levels of domestic consumption are now possible. Real household consumption is a much better welfare indicator than real GDP when external terms of trade are the source of the shock (Warr et al. 2009).

To get a detailed overview of global climate change impacts on the economic performance of Indonesia, we also analyzed sectoral impacts. Table 4.2 shows that the negative growth on GDP as a result of climate change is chiefly contributed by the negative growth of agriculture and agro-based industry.

Negative impacts are strongest for paddy under the CSIRO scenario. Decreasing output of paddy will directly affect food security in Indonesia, given the strategic importance of rice. Rice production involves 15 million farmers and 220 million Indonesian consumers (TREDA 2008). Rice supply is the major focus of Indonesia's food security policy and keeps attracting debates on how to support both farmers and consumers (Simatupang and Timmer 2008). The rest of the manufacturing and service sectors experience higher output. This is because the model assumes perfect labor mobility. Thus, labor (particularly farmers) will move away from those sectors that experience negative productivity shocks toward those with positive outcomes.

The impact of enhanced investments on food crops and beef under climate change result in positive outcomes for maize, fruits and vegetables, sugarcane, and beef. The highest positive response is achieved for soybeans, with approximately 44.76 percent increase compared with the long-run baseline scenario. Because domestic production levels are insufficient to meet total demand, higher productivity levels as a result of enhanced investment levels results in a strong sectoral response. The impact of higher international prices (over 10 years) as a result of climate change varies by commodity group. Output of soybeans, paddy and rice, fruits and vegetables, and livestock increases faster than that of other agricultural commodities because of higher demand growth and more limited production capacity and thus higher prices elsewhere.

Table 4.2—Impact of global climate change on Indonesian sectoral output (percent change for baseline, climate change, agricultural research and development investment scenarios), 2005–2030

Sector	Sim 1	Sim 2a	Sim 2b	Sim 3	Sim 4	Sim 5
Paddy	–2.03	0.31	–0.50	–2.49	–2.47	–2.93
Maize	15.17	13.67	13.28	19.96	19.98	20.39
Cassava	17.87	18.27	18.29	24.48	24.52	22.76
Soybeans	29.60	30.63	25.34	44.85	44.76	56.50
Other Food Crops	5.60	5.13	5.27	7.26	7.28	5.23
Fruits and Vegetables	34.72	35.64	35.68	44.74	44.72	50.49
Cereal Food Crops	7.23	6.64	6.73	9.47	9.47	7.22

Table 4.2—Continued

Sector	Sim 1	Sim 2a	Sim 2b	Sim 3	Sim 4	Sim 5
Rubber	1.17	1.22	1.21	1.50	1.41	–0.80
Sugarcane	23.88	21.75	21.61	29.52	29.48	27.28
Coconut	4.28	3.93	4.03	5.54	5.53	3.95
Oil Palm	0.76	0.74	0.73	1.00	0.91	0.05
Other Estate Crops	4.96	4.74	4.78	6.43	6.28	2.90
Tobacco	3.18	2.79	2.92	4.11	4.18	3.73
Coffee and Tea	4.59	4.36	4.39	5.96	5.84	2.90
Clove	3.10	2.78	2.89	4.01	4.04	3.16
Cacao	5.06	4.87	4.91	6.56	6.40	2.72
Other Agriculture	5.44	5.07	5.15	7.07	6.99	4.28
Livestock	7.49	6.81	6.95	9.74	9.94	8.32
Wood and Forest Products	2.60	2.50	2.53	3.37	3.27	1.29
Seafood and Fish Products	2.97	2.76	2.82	3.85	3.82	2.41
Land and Water Fish	3.88	3.54	3.64	5.03	5.05	3.71
Coal	–1.83	–1.68	–1.72	–2.37	–2.45	–2.18
Crude Oil	–0.30	–0.27	–0.28	–0.39	–0.40	–0.35
Natural Gas	–0.37	–0.34	–0.35	–0.48	–0.50	–0.43
Tin Ore	–1.97	–1.82	–1.86	–2.55	–2.65	–2.37
Nickel Bauxite Ore	–1.82	–1.67	–1.71	–2.36	–2.45	–2.17
Copper Ore	–1.18	–1.09	–1.11	–1.52	–1.58	–1.41
Gold Ore	–2.06	–1.90	–1.94	–2.67	–2.77	–2.46
Other Mining Metals	–1.99	–1.83	–1.87	–2.57	–2.66	–2.37
Other Mining	–0.48	–0.46	–0.46	–0.62	–0.65	–0.55
Livestock Products	4.61	4.21	4.26	5.99	16.74	17.95
Fisheries Products	0.22	0.28	0.25	0.29	0.19	–0.71
Animal and Vegetable Oils	0.55	0.54	0.52	0.73	0.64	–0.09
Rice	11.12	7.05	8.43	14.22	14.25	13.79
Wheat Flour	2.62	2.30	2.40	3.39	3.46	3.18
Other Flours	18.36	16.67	16.66	24.57	24.43	21.81
Bakery and Pasta	4.04	3.57	3.71	5.22	5.35	4.94
Sugar	27.22	24.78	24.60	33.62	33.57	31.32
Peeled Grain	3.14	2.99	2.98	3.99	3.97	3.08
Chocolate, Coffee and Tea	3.59	3.22	3.18	4.67	4.70	4.09
Soybean Products	3.61	3.23	3.28	4.73	4.81	3.07
Other Food Industries	5.80	5.34	5.48	7.54	7.52	5.94
Animal Feed	6.50	5.91	5.94	8.50	8.60	7.18
Beverages	5.85	5.55	5.64	7.49	7.56	6.74

Table 4.2—Continued

Sector	Sim 1	Sim 2a	Sim 2b	Sim 3	Sim 4	Sim 5
Tobacco and Cigarettes	2.74	2.39	2.51	3.54	3.61	3.32
Yard and Kapok	–2.24	–2.09	–2.12	–2.90	–3.01	–2.67
Textiles	–1.55	–1.48	–1.49	–2.01	–2.09	–1.77
Leather Shoes	–1.65	–1.51	–1.55	–2.14	–0.45	–1.00
Sawmill and Plywood	–0.31	–0.27	–0.28	–0.40	–0.46	–0.68
Wood Industries	–0.54	–0.50	–0.50	–0.70	–0.77	–0.90
Pulp and Paper	–0.72	–0.68	–0.68	–0.93	–0.97	–0.88
Basic Chemical	–2.00	–1.85	–1.89	–2.60	–2.70	–2.42
Fertilizer	–4.07	–3.52	–3.64	–5.27	–5.29	–3.71
Pesticide	–1.29	–1.23	–1.27	–1.63	–1.72	–1.25
Resins and Paints	–2.06	–1.90	–1.94	–2.66	–2.77	–2.55
Chemical Products	0.48	0.40	0.44	0.61	0.55	0.22
Other Chemical Products	–1.03	–0.96	–0.97	–1.33	–1.37	–1.35
Petroleum	–1.44	–1.34	–1.36	–1.87	–1.94	–1.58
Liquid Natural Gas	–0.14	–0.15	–0.15	–0.18	–0.20	–0.26
Rubber Products	1.37	1.42	1.41	1.76	1.50	–0.84
Plastic Products	–0.19	–0.22	–0.20	–0.25	–0.26	–0.17
Glass Products	–1.55	–1.45	–1.47	–2.01	–2.09	–1.80
Cement	–0.48	–0.45	–0.45	–0.62	–0.64	–0.56
Metal Products	–2.06	–1.90	–1.94	–2.67	–2.77	–2.46
Machine	–2.59	–2.38	–2.43	–3.36	–3.48	–3.12
Electrical Appliances	–2.84	–2.61	–2.67	–3.68	–3.81	–3.39
Machine Tool	–1.97	–1.83	–1.86	–2.55	–2.64	–2.34
Vehicle Industries	–0.89	–0.86	–0.86	–1.15	–1.21	–0.98
Other Industries	–1.74	–1.63	–1.65	–2.26	–2.34	–2.08
Electricity and Gas	0.68	0.57	0.61	0.88	0.90	0.89
Water	1.45	1.26	1.32	1.87	1.91	1.84
Private Service	0.09	0.07	0.08	0.11	0.12	0.11
Transportation Service	–0.59	–0.57	–0.57	–0.77	–0.81	–0.64
Public Service	4.12	3.61	3.78	5.33	5.50	5.00

Source: Authors’simulations.

Table 4.3presents the impact of global climate change (Sims 2a and 2b) on domestic commodity prices. Prices increase particularly for paddy and rice under the MIROC A1B scenario, which shows higher impacts for Indonesia. In general, prices are expected to rise, as reflected by the CPI increase. The rise of the CPI is mostly due to the increase in prices of agricultural commodities and agro-based industries. Even though the higher prices in those commodities are compensated by the lower prices for nonagricultural commodities, the CPI will increase because the changes in food and other agricultural processing prices, such as animal and vegetable oil prices, affect the Indonesian CPI. Sims 3, 4, and 5, however, decrease the price of most food sectors because of the increased productivity of outputs by 10 percent.

Table 4.3—Impact of global climate change on Indonesian domestic prices (percent change for baseline, climate change, agricultural research and development investment scenarios), 2005–2030

Sector	Sim 1	Sim 2a	Sim 2b	Sim 3	Sim 4	Sim 5
Paddy	–13.31	–7.54	–9.49	–16.94	–16.60	–11.37
Maize	–41.91	–37.91	–35.65	–55.32	–55.01	–48.03
Cassava	–60.46	–65.92	–65.25	–84.72	–84.37	–79.12
Soybeans	–19.87	–21.03	–16.78	–30.85	–30.65	–12.44
Other Food Crops	–4.04	–4.19	–4.12	–5.26	–4.91	0.32
Fruits and Vegetables	–60.93	–63.74	–63.48	–78.48	–78.19	–64.60
Cereal Food Crops	–1.64	–1.90	–1.90	–2.04	–1.76	2.55
Rubber	–6.11	–5.89	–5.95	–7.90	–7.66	–3.26
Sugarcane	–46.69	–42.54	–42.16	–57.44	–57.20	–53.41
Coconut	–3.12	–3.25	–3.20	–4.06	–3.79	0.55
Oil Palm	–4.80	–4.68	–4.72	–6.21	–6.03	–2.07
Other Estate Crops	–1.59	–1.58	–1.59	–2.07	–1.99	–0.39
Tobacco	–2.53	–2.58	–2.54	–3.27	–3.05	0.13
Coffee and Tea	–2.58	–2.57	–2.60	–3.35	–3.19	–0.54
Clove	–4.84	–4.90	–4.86	–6.30	–5.98	–0.73
Cacao	–2.20	–2.13	–2.15	–2.85	–2.77	–1.00
Other Agriculture	–2.60	–2.65	–2.58	–3.40	–3.19	–0.24
Livestock	–4.95	–4.88	–4.75	–6.50	–6.14	–1.73
Wood and Forest Products	–5.37	–5.22	–5.25	–6.97	–6.78	–2.64
Seafood and Fish Products	0.17	–0.19	–0.06	0.20	0.44	2.84
Land and Water Fish	0.95	0.43	0.65	1.21	1.56	4.51
Coal	0.46	0.42	0.43	0.60	0.62	0.55
Crude Oil	–0.03	–0.03	–0.03	–0.04	–0.04	–0.03
Natural Gas	–2.55	–2.39	–2.41	–3.30	–3.39	–2.76
Tin Ore	–0.14	–0.13	–0.13	–0.18	–0.19	–0.20
Nickel Bauxite Ore	1.09	1.00	1.02	1.41	1.47	1.30
Copper Ore	0.67	0.62	0.63	0.87	0.90	0.80
Gold Ore	–0.51	–0.47	–0.48	–0.66	–0.69	–0.61
Other Mining Metals	0.17	0.15	0.16	0.22	0.23	0.20
Other Mining	1.88	1.75	1.78	2.43	2.52	2.20
Livestock Products	0.32	0.11	0.25	0.38	–9.53	–7.29
Fisheries Products	1.52	1.26	1.34	1.96	2.10	2.74
Animal and Vegetable Oils	0.29	0.23	0.26	0.38	0.42	0.58
Rice	–23.18	–11.59	–15.54	–29.43	–29.15	–25.71

Table 4.3—Continued

Sector	Sim 1	Sim 2a	Sim 2b	Sim 3	Sim 4	Sim 5
Wheat Flour	2.12	1.91	1.97	2.75	2.82	2.58
Other Flours	–10.58	–9.65	–9.57	–14.28	–14.12	–12.58
Bakery and Pasta	–0.37	–0.39	–0.34	–0.45	–0.47	–0.15
Sugar	–18.93	–17.25	–17.05	–23.21	–23.04	–21.54
Peeled Grain	0.16	0.02	0.07	0.28	0.37	0.37
Chocolate Coffee and Tea	–0.28	–0.32	–0.11	–0.39	–0.29	0.19
Soybean Products	1.19	0.81	1.22	1.30	1.47	6.85
Other Food Industries	–1.91	–1.86	–1.87	–2.50	–2.39	–1.41
Animal Feed	–3.32	–3.11	–2.56	–4.65	–4.36	–3.91
Beverages	–4.34	–4.60	–4.50	–5.49	–5.39	–4.30
Tobacco and Cigarettes	2.50	2.21	2.30	3.24	3.37	3.42
Yard and Kapok	0.46	0.42	0.43	0.59	0.62	0.55
Textiles	0.86	0.79	0.81	1.12	1.16	1.05
Leather Shoes	0.83	0.74	0.77	1.08	0.71	0.81
Sawmill and Plywood	0.06	0.05	0.05	0.08	0.10	0.20
Wood Industries	0.31	0.28	0.29	0.40	0.42	0.44
Pulp and paper	0.77	0.69	0.72	1.00	1.04	0.95
Basic Chemical	0.47	0.43	0.44	0.61	0.63	0.55
Fertilizer	–0.71	–0.56	–0.58	–0.92	–0.86	–0.37
Pesticide	0.78	0.71	0.72	1.02	1.06	1.03
Resins and Paints	0.63	0.58	0.59	0.82	0.85	0.74
Chemical Products	1.01	0.90	0.93	1.31	1.38	1.44
Other Chemical Products	0.77	0.70	0.72	1.00	1.04	0.98
Petroleum	1.37	1.26	1.29	1.78	1.84	1.48
Liquid natural gas	0.01	0.01	0.01	0.01	0.01	0.01
Rubber Products	–0.29	–0.31	–0.31	–0.38	–0.31	0.26
Plastic Products	1.07	0.97	1.00	1.38	1.43	1.30
Glass Products	1.27	1.16	1.19	1.65	1.71	1.53
Cement	1.34	1.22	1.25	1.73	1.80	1.60
Metal Products	0.59	0.54	0.55	0.76	0.79	0.70
Machine	0.74	0.67	0.69	0.96	0.99	0.88
Electrical Appliances	0.75	0.69	0.71	0.98	1.01	0.90
Machine Tool	0.72	0.65	0.67	0.93	0.96	0.88
Vehicle Industries	1.18	1.06	1.10	1.52	1.57	1.43
Other Industries	0.99	0.90	0.92	1.28	1.32	1.21
Electricity and Gas	2.55	2.29	2.37	3.30	3.41	2.99
Water	3.33	2.99	3.10	4.31	4.45	4.03

Table 4.3—Continued

Sector	Sim 1	Sim 2a	Sim 2b	Sim 3	Sim 4	Sim 5
Private Service	3.16	2.80	2.91	4.09	4.19	3.97
Transportation Service	2.24	2.00	2.07	2.90	2.98	2.73
Public Service	5.97	5.22	5.46	7.72	7.98	7.36

Source: Authors' simulations.

In line with the impact of global climate change on sectoral output, sectoral employment of farmers in agriculture and laborers in agro-based industries will drop as well (Table 4.4a and 4b). Cassava, sugar, and the other flour sectors will experience the largest drop relative to other sectors. Labor in nonagricultural sectors is expected to rise because these sectors experience less impact from global climate change. Increase in sectoral output of nonagricultural sectors will drive higher demand for administrators, operators, and professional labor as inputs for these industries.

On the other hand, paddy and maize have a positive impact on employment under climate change, as a result of their inelastic demand. That is, consumers continue to consume these products despite higher prices under climate change. Therefore, these sectors need more employment despite lower productivity. However, an increase of food crop productivity (Sim 3) and beef productivity (Sim 4), as well as higher international prices for agricultural commodities as a result of climate change will reduce the employment for food crops.

Table 4.4a—Impact of global climate change on Indonesian sectoral employment (percent change for baseline and climate change scenarios), 2005–2030

	Sim 1				Sim 2a				Sim 2b			
Sector	F	O	A	P	F	O	A	P	F	O	A	P
Paddy	–3.36	–5.62	–7.31	–6.53	0.27	–1.94	–3.40	–2.70	–0.98	–3.20	–4.73	–4.02
Maize	–13.65	–15.91	–17.59	–16.82	–12.00	–14.20	–15.66	–14.96	–10.53	–12.76	–14.29	–13.57
Cassava	–24.03	–26.29	–27.97	–27.20	–27.90	–30.10	–31.57	–30.86	–27.33	–29.56	–31.09	–30.38
Soybeans	15.26	13.00	11.31	12.09	15.05	12.84	11.38	12.08	13.99	11.76	10.23	10.94
Other Food Crops	7.90	5.64	3.96	4.73	7.22	5.02	3.55	4.25	7.44	5.22	3.69	4.40
Fruits and Vegetables	–12.14	–14.40	–16.08	–15.31	–13.74	–15.94	–17.41	–16.71	–13.46	–15.69	–17.22	–16.50
Cereal Food Crops	10.78	8.52	6.84	7.61	9.93	7.72	6.26	6.96	10.06	7.83	6.30	7.01
Rubber	1.24	–2.40	–5.16	–4.38	1.36	–2.24	–4.61	–3.82	1.34	–2.26	–4.78	–3.99
Sugarcane	–11.52	–15.16	–17.92	–17.14	–10.17	–13.77	–16.14	–15.35	–9.95	–13.56	–16.07	–15.29
Coconut	5.99	2.34	–0.42	0.37	5.51	1.91	–0.47	0.33	5.66	2.05	–0.46	0.33
Oil Palm	0.57	–3.08	–5.83	–5.05	0.61	–2.99	–5.37	–4.57	0.58	–3.03	–5.54	–4.75
Other Estate Crops	7.45	3.80	1.05	1.83	7.19	3.59	1.22	2.01	7.25	3.64	1.13	1.92
Tobacco	4.88	1.23	–1.53	–0.74	4.42	0.82	–1.56	–0.76	4.58	0.98	–1.54	–0.75
Coffee and Tea	6.50	2.85	0.10	0.88	6.23	2.63	0.25	1.05	6.26	2.65	0.14	0.92
Clove	4.17	0.52	–2.23	–1.45	3.74	0.14	–2.23	–1.44	3.90	0.29	–2.22	–1.43
Cacao	7.41	3.76	1.01	1.79	7.19	3.59	1.22	2.02	7.25	3.65	1.13	1.92
Other Agriculture	7.57	3.92	1.17	1.95	7.09	3.49	1.11	1.91	7.19	3.58	1.07	1.85
Livestock	7.81	4.08	1.48	–1.90	7.06	3.36	1.15	–1.83	7.23	3.53	1.17	–1.94
Wood and Forest Products	2.53	–0.35	–3.68	–2.11	2.49	–0.37	–3.31	–1.79	2.52	–0.35	–3.43	–1.89
Seafood and Fish Products	6.40	2.82	0.72	1.31	5.93	2.39	0.64	1.24	6.09	2.54	0.66	1.25
Land and Water Fish	7.99	4.42	2.32	2.90	7.26	3.71	1.96	2.56	7.48	3.93	2.06	2.65
Coal	–3.90	–3.94	–4.17	–4.43	–3.54	–3.58	–3.77	–4.01	–3.64	–3.68	–3.89	–4.13
Crude Oil	–2.48	–2.52	–2.74	–3.01	–2.23	–2.27	–2.46	–2.70	–2.30	–2.34	–2.55	–2.79

Table 4.4a—Continued

Sector	Sim 1 F	Sim 1 O	Sim 1 A	Sim 1 P	Sim 2a F	Sim 2a O	Sim 2a A	Sim 2a P	Sim 2b F	Sim 2b O	Sim 2b A	Sim 2b P
Natural Gas	–4.03	–4.06	–4.29	–4.56	–3.68	–3.72	–3.91	–4.15	–3.77	–3.80	–4.01	–4.25
Tin Ore	–4.27	–4.31	–4.54	–4.80	–3.89	–3.93	–4.13	–4.36	–4.00	–4.03	–4.24	–4.48
Nickel Bauxite Ore	–3.48	–3.52	–3.75	–4.01	–3.15	–3.19	–3.38	–3.62	–3.25	–3.28	–3.49	–3.73
Copper Ore	–3.19	–3.23	–3.45	–3.72	–2.88	–2.92	–3.11	–3.35	–2.97	–3.01	–3.21	–3.46
Gold Ore	–4.63	–4.67	–4.89	–5.16	–4.21	–4.25	–4.44	–4.68	–4.32	–4.36	–4.57	–4.81
Other Mining Metals	–4.27	–4.31	–4.53	–4.80	–3.88	–3.91	–4.11	–4.34	–3.99	–4.02	–4.23	–4.47
Other Mining	–0.71	–0.77	–0.99	–1.09	–0.67	–0.73	–0.92	–1.01	–0.67	–0.73	–0.93	–1.02
Livestock Products	8.12	7.56	5.19	2.56	7.45	6.88	4.86	2.55	7.54	6.99	4.84	2.42
Fisheries Products	1.24	0.67	–1.70	–4.33	1.29	0.71	–1.31	–3.62	1.26	0.70	–1.45	–3.86
Animal and Vegetable Oils	2.41	1.84	–0.53	–3.16	2.32	1.74	–0.28	–2.58	2.28	1.72	–0.43	–2.84
Rice	–2.88	–3.44	–5.81	–8.44	1.42	0.85	–1.17	–3.48	–0.07	–0.62	–2.78	–5.19
Wheat Flour	5.46	4.89	2.52	–0.11	4.86	4.28	2.26	–0.04	5.03	4.47	2.32	–0.09
Other Flours	33.44	32.88	30.50	27.88	30.42	29.84	27.82	25.51	30.40	29.85	27.70	25.29
Bakery and Pasta	6.76	6.20	3.82	1.20	6.03	5.46	3.44	1.13	6.23	5.68	3.52	1.11
Sugar	40.57	40.01	37.64	35.01	36.96	36.39	34.37	32.06	36.72	36.16	34.01	31.60
Peeled Grain	9.58	9.01	6.64	4.01	9.12	8.55	6.53	4.22	9.09	8.53	6.38	3.97
Chocolate, Coffee and Tea	8.99	8.42	6.05	3.42	8.10	7.53	5.51	3.20	8.03	7.48	5.33	2.91
Soybean Products	8.59	8.03	5.66	3.03	7.74	7.17	5.14	2.84	7.85	7.30	5.14	2.73
Other Food Industries	13.16	12.59	10.22	7.59	12.14	11.57	9.55	7.24	12.44	11.88	9.73	7.32
Animal Feed	19.94	19.37	17.00	14.37	18.17	17.60	15.58	13.27	18.26	17.70	15.55	13.14
Beverages	9.20	8.64	6.27	3.64	8.72	8.14	6.12	3.82	8.86	8.30	6.15	3.74
Tobacco and Cigarettes	5.08	4.52	2.15	–0.48	4.50	3.93	1.91	–0.40	4.69	4.13	1.98	–0.43
Yard and Kapok	–2.53	–3.05	–5.44	–8.09	–2.33	–2.86	–4.91	–7.23	–2.39	–2.90	–5.07	–7.50

Table 4.4a—Continued

Sector	Sim 1				Sim 2a				Sim 2b			
	F	O	A	P	F	O	A	P	F	O	A	P
Textiles	–1.37	–1.89	–4.28	–6.92	–1.31	–1.84	–3.88	–6.20	–1.31	–1.83	–4.00	–6.43
Leather Shoes	–1.21	–1.73	–4.12	–6.77	–1.07	–1.61	–3.65	–5.97	–1.11	–1.63	–3.80	–6.23
Sawmill and Plywood	0.01	–0.61	–2.90	–4.72	0.08	–0.54	–2.49	–4.08	0.06	–0.55	–2.62	–4.29
Wood Industries	–0.44	–1.06	–3.35	–5.17	–0.36	–0.98	–2.93	–4.52	–0.38	–0.98	–3.06	–4.73
Pulp and paper	–0.64	–1.18	–3.55	–5.44	–0.61	–1.16	–3.18	–4.84	–0.62	–1.15	–3.30	–5.03
Basic Chemical	–1.53	–2.06	–4.44	–6.89	–1.40	–1.95	–3.97	–6.12	–1.43	–1.96	–4.11	–6.37
Fertilizer	–4.98	–5.52	–7.89	–10.35	–4.23	–4.78	–6.80	–8.95	–4.39	–4.92	–7.07	–9.33
Pesticide	–1.00	–1.53	–3.91	–6.36	–0.97	–1.51	–3.54	–5.69	–1.02	–1.54	–3.70	–5.95
Resins and Paints	–1.81	–2.35	–4.72	–7.18	–1.66	–2.21	–4.23	–6.38	–1.70	–2.22	–4.38	–6.63
Chemical Products	1.72	1.18	–1.19	–3.64	1.55	1.00	–1.02	–3.18	1.61	1.08	–1.08	–3.33
Other Chemical Products	–0.67	–1.21	–3.58	–6.04	–0.62	–1.17	–3.19	–5.34	–0.63	–1.16	–3.31	–5.56
Petroleum	–1.36	–1.90	–4.27	–6.16	–1.25	–1.80	–3.82	–5.47	–1.28	–1.81	–3.96	–5.69
Liquid natural gas	0.52	–0.02	–2.39	–4.28	0.48	–0.07	–2.09	–3.74	0.48	–0.05	–2.20	–3.93
Rubber Products	2.95	2.42	0.05	–1.84	2.96	2.42	0.39	–1.26	2.96	2.43	0.28	–1.45
Plastic Products	0.73	0.20	–2.18	–4.06	0.63	0.08	–1.94	–3.60	0.66	0.14	–2.02	–3.75
Glass Products	–1.21	–1.75	–4.12	–6.58	–1.13	–1.67	–3.70	–5.85	–1.14	–1.67	–3.83	–6.08
Cement	0.32	–0.21	–2.59	–5.04	0.30	–0.24	–2.27	–4.42	0.31	–0.22	–2.37	–4.63
Metal Products	–2.02	–2.55	–4.92	–6.81	–1.84	–2.39	–4.41	–6.06	–1.89	–2.42	–4.57	–6.30
Machine	–2.36	–2.89	–5.26	–7.15	–2.15	–2.69	–4.71	–6.37	–2.20	–2.73	–4.88	–6.61
Electrical Appliances	–3.02	–3.56	–5.93	–7.82	–2.76	–3.31	–5.33	–6.98	–2.83	–3.36	–5.51	–7.24
Machine Tool	–2.14	–2.68	–5.05	–6.94	–1.97	–2.52	–4.54	–6.19	–2.01	–2.54	–4.69	–6.42
Vehicle Industries	–0.33	–0.86	–3.24	–5.12	–0.35	–0.90	–2.92	–4.57	–0.33	–0.86	–3.01	–4.74
Other Industries	–1.44	–1.97	–4.34	–6.23	–1.34	–1.89	–3.91	–5.56	–1.36	–1.89	–4.04	–5.77
Electricity and Gas	2.61	2.14	–0.68	–3.93	2.31	1.81	–0.59	–3.45	2.41	1.93	–0.62	–3.61

Table 4.4a—Continued

	Sim 1				Sim 2a				Sim 2b			
Sector	F	O	A	P	F	O	A	P	F	O	A	P
Water	3.82	3.34	0.53	–2.72	3.40	2.90	0.49	–2.36	3.53	3.05	0.50	–2.48
Private Service	3.02	2.36	–0.29	–2.64	2.67	2.00	–0.25	–2.32	2.79	2.14	–0.26	–2.42
Transportation Service	–1.09	–1.19	–1.56	–1.92	–1.03	–1.13	–1.44	–1.76	–1.03	–1.14	–1.47	–1.80
Public Service	9.31	8.63	5.98	2.89	8.19	7.50	5.25	2.54	8.56	7.89	5.49	2.65

Source: Authors'simulations.
Note: F=farmer, O=operator, A=administrative, P=professional.

Table 4.4b—Impact of global climate change on Indonesian sectoral employment, continued (percent change for climate change and agricultural research and development investment scenarios), 2005–2030

	Sim 3				Sim 4				Sim 5			
Sector	F	O	A	P	F	O	A	P	F	O	A	P
Paddy	–4.16	–7.08	–9.25	–8.25	–4.13	–6.96	–9.21	–8.18	–4.88	–5.75	–7.95	–6.99
Maize	–18.26	–21.18	–23.35	–22.35	–18.24	–21.08	–23.32	–22.29	–17.60	–18.47	–20.66	–19.71
Cassava	–34.81	–37.72	–39.90	–38.90	–34.76	–37.59	–39.83	–38.80	–37.39	–38.26	–40.46	–39.50
Soybeans	21.19	18.27	16.09	17.10	21.04	18.20	15.96	16.99	39.45	38.59	36.39	37.34
Other Food Crops	10.18	7.27	5.09	6.09	10.21	7.38	5.13	6.16	7.22	6.36	4.16	5.11
Fruits and Vegetables	–15.60	–18.51	–20.69	–19.69	–15.64	–18.48	–20.72	–19.69	–6.37	–7.24	–9.44	–8.48
Cereal Food Crops	14.08	11.16	8.98	9.99	14.04	11.21	8.97	10.00	10.41	9.54	7.35	8.30
Rubber	1.57	–3.12	–6.67	–5.67	1.44	–3.13	–6.77	–5.82	–1.57	–3.00	–6.38	–6.21
Sugarcane	–13.78	–18.47	–22.02	–21.02	–13.87	–18.44	–22.08	–21.12	–17.11	–18.54	–21.92	–21.75
Coconut	7.71	3.02	–0.54	0.46	7.67	3.10	–0.54	0.41	5.29	3.86	0.48	0.65
Oil Palm	0.71	–3.98	–7.53	–6.53	0.56	–4.02	–7.65	–6.70	–0.81	–2.24	–5.62	–5.45
Other Estate Crops	9.62	4.93	1.37	2.37	9.33	4.76	1.12	2.07	3.60	2.17	–1.21	–1.04
Tobacco	6.27	1.58	–1.98	–0.98	6.29	1.72	–1.92	–0.96	4.64	3.21	–0.17	0.00

Table 4.4b—Continued

Sector	Sim 3				Sim 4				Sim 5			
	F	O	A	P	F	O	A	P	F	O	A	P
Coffee and Tea	8.39	3.70	0.14	1.14	8.17	3.60	–0.04	0.91	3.51	2.08	–1.30	–1.13
Clove	5.34	0.65	–2.90	–1.90	5.35	0.78	–2.86	–1.90	3.95	2.52	–0.86	–0.69
Cacao	9.56	4.87	1.32	2.32	9.26	4.69	1.05	2.01	3.24	1.81	–1.58	–1.41
Other Agriculture	9.79	5.10	1.55	2.55	9.65	5.08	1.44	2.39	5.53	4.10	0.72	0.89
Livestock	10.10	5.31	1.95	–2.42	10.36	5.68	2.24	–2.25	8.86	7.46	4.12	0.14
Wood and Forest Products	3.23	–0.46	–4.77	–2.75	3.06	–0.52	–4.90	–2.92	0.41	–0.48	–4.22	–3.33
Seafood and Fish Products	8.24	3.65	0.94	1.68	8.17	3.70	0.90	1.60	4.95	3.65	0.71	0.78
Land and Water Fish	10.31	5.72	3.01	3.75	10.34	5.87	3.07	3.78	7.61	6.31	3.36	3.43
Coal	–5.05	–5.10	–5.39	–5.74	–5.24	–5.29	–5.59	–5.94	–4.66	–4.69	–4.98	–5.30
Crude Oil	–3.21	–3.26	–3.55	–3.89	–3.33	–3.38	–3.68	–4.03	–2.95	–2.98	–3.27	–3.59
Natural gas	–5.21	–5.26	–5.55	–5.90	–5.39	–5.44	–5.74	–6.09	–4.62	–4.65	–4.94	–5.26
Tin Ore	–5.53	–5.58	–5.87	–6.22	–5.74	–5.80	–6.09	–6.45	–5.14	–5.17	–5.45	–5.78
Nickel Bauxite Ore	–4.51	–4.56	–4.85	–5.19	–4.67	–4.73	–5.02	–5.38	–4.15	–4.19	–4.47	–4.79
Copper Ore	–4.13	–4.17	–4.47	–4.81	–4.27	–4.33	–4.62	–4.98	–3.81	–3.85	–4.13	–4.46
Gold Ore	–5.99	–6.04	–6.33	–6.68	–6.21	–6.26	–6.56	–6.92	–5.52	–5.56	–5.84	–6.16
Other Mining Metals	–5.52	–5.57	–5.86	–6.21	–5.73	–5.78	–6.08	–6.43	–5.09	–5.13	–5.41	–5.74
Other Mining	–0.92	–1.00	–1.28	–1.41	–0.96	–1.04	–1.34	–1.47	–0.78	–0.84	–1.12	–1.24
Livestock Products	10.56	9.82	6.76	3.36	11.76	10.98	7.84	4.34	13.44	12.88	9.89	6.71
Fisheries Products	1.61	0.88	–2.18	–5.58	1.50	0.72	–2.41	–5.92	–0.03	–0.59	–3.58	–6.76
Animal and Vegetable Oils	3.16	2.42	–0.64	–4.04	3.02	2.24	–0.90	–4.40	1.09	0.52	–2.46	–5.65
Rice	–3.47	–4.21	–7.26	–10.66	–3.37	–4.15	–7.29	–10.79	–4.40	–4.96	–7.95	–11.13
Wheat Flour	7.06	6.32	3.26	–0.14	7.22	6.44	3.31	–0.20	6.57	6.01	3.02	–0.16
Other Flours	44.73	43.99	40.93	37.53	44.53	43.75	40.61	37.11	39.70	39.14	36.15	32.97

Table 4.4b—Continued

Sector	Sim 3				Sim 4				Sim 5			
	F	O	A	P	F	O	A	P	F	O	A	P
Bakery and Pasta	8.73	7.99	4.93	1.53	8.97	8.20	5.06	1.55	8.18	7.62	4.63	1.45
Sugar	50.17	49.43	46.38	42.98	50.15	49.37	46.23	42.73	46.68	46.11	43.13	39.94
Peeled Grain	12.21	11.48	8.42	5.02	12.21	11.43	8.29	4.79	9.57	9.01	6.02	2.84
Chocolate, Coffee and Tea	11.67	10.94	7.88	4.48	11.81	11.03	7.90	4.39	10.22	9.66	6.68	3.49
Soybean Products	11.25	10.51	7.45	4.05	11.46	10.68	7.54	4.04	7.64	7.07	4.09	0.90
Other Food Industries	17.11	16.37	13.31	9.91	17.12	16.34	13.20	9.69	13.61	13.04	10.06	6.87
Animal Feed	26.06	25.32	22.26	18.86	26.41	25.63	22.49	18.99	22.07	21.51	18.52	15.34
Beverages	11.80	11.07	8.01	4.61	11.95	11.17	8.03	4.53	10.59	10.03	7.05	3.86
Tobacco and Cigarettes	6.58	5.84	2.78	–0.62	6.72	5.94	2.80	–0.70	6.09	5.53	2.54	–0.64
Yard and Kapok	–3.27	–3.95	–7.03	–10.46	–3.39	–4.11	–7.28	–10.80	–3.05	–3.56	–6.57	–9.78
Textiles	–1.77	–2.44	–5.53	–8.95	–1.84	–2.56	–5.73	–9.25	–1.56	–2.07	–5.08	–8.28
Leather Shoes	–1.57	–2.24	–5.33	–8.75	0.64	–0.07	–3.24	–6.76	–0.26	–0.77	–3.78	–6.98
Sawmill and Plywood	0.02	–0.78	–3.73	–6.09	–0.08	–0.93	–3.96	–6.38	–0.88	–1.51	–4.40	–6.59
Wood Industries	–0.57	–1.37	–4.32	–6.68	–0.67	–1.51	–4.54	–6.97	–1.20	–1.82	–4.71	–6.91
Pulp and paper	–0.83	–1.53	–4.59	–7.03	–0.88	–1.62	–4.75	–7.27	–0.87	–1.40	–4.38	–6.66
Basic Chemical	–1.98	–2.68	–5.74	–8.91	–2.05	–2.80	–5.93	–9.21	–1.90	–2.43	–5.41	–8.39
Fertilizer	–6.44	–7.14	–10.20	–13.38	–6.42	–7.16	–10.30	–13.57	–4.27	–4.80	–7.79	–10.76
Pesticide	–1.24	–1.94	–5.00	–8.18	–1.32	–2.06	–5.20	–8.47	–0.80	–1.33	–4.31	–7.29
Resins and Paints	–2.34	–3.04	–6.10	–9.28	–2.43	–3.18	–6.31	–9.59	–2.33	–2.86	–5.84	–8.82
Chemical Products	2.21	1.52	–1.55	–4.72	2.19	1.45	–1.69	–4.96	1.53	1.00	–1.99	–4.96
Other Chemical Products	–0.87	–1.57	–4.63	–7.81	–0.89	–1.63	–4.77	–8.04	–1.02	–1.55	–4.53	–7.51
Petroleum	–1.77	–2.47	–5.53	–7.97	–1.84	–2.58	–5.72	–8.23	–1.44	–1.97	–4.95	–7.23

Table 4.4b—Continued

Sector	Sim 3				Sim 4				Sim 5			
	F	O	A	P	F	O	A	P	F	O	A	P
Liquid natural gas	0.67	–0.03	–3.09	–5.53	0.67	–0.07	–3.20	–5.72	0.42	–0.11	–3.10	–5.38
Rubber Products	3.81	3.11	0.05	–2.39	3.50	2.76	–0.37	–2.89	0.02	–0.51	–3.50	–5.78
Plastic Products	0.94	0.25	–2.81	–5.25	0.97	0.23	–2.90	–5.42	0.92	0.39	–2.59	–4.88
Glass Products	–1.57	–2.27	–5.33	–8.51	–1.63	–2.37	–5.51	–8.78	–1.41	–1.94	–4.92	–7.90
Cement	0.42	–0.28	–3.34	–6.52	0.43	–0.31	–3.45	–6.72	0.35	–0.18	–3.16	–6.13
Metal Products	–2.61	–3.31	–6.37	–8.81	–2.70	–3.44	–6.58	–9.10	–2.45	–2.98	–5.96	–8.24
Machine	–3.05	–3.75	–6.81	–9.25	–3.16	–3.90	–7.04	–9.55	–2.90	–3.42	–6.41	–8.69
Electrical Appliances	–3.91	–4.61	–7.67	–10.11	–4.05	–4.79	–7.92	–10.44	–3.65	–4.17	–7.16	–9.44
Machine Tool	–2.77	–3.47	–6.53	–8.97	–2.88	–3.62	–6.75	–9.27	–2.59	–3.11	–6.10	–8.38
Vehicle Industries	–0.43	–1.12	–4.18	–6.63	–0.46	–1.20	–4.34	–6.85	–0.32	–0.85	–3.84	–6.12
Other Industries	–1.86	–2.56	–5.62	–8.06	–1.92	–2.66	–5.80	–8.31	–1.75	–2.28	–5.26	–7.54
Electricity and Gas	3.38	2.75	–0.88	–5.08	3.48	2.81	–0.91	–5.24	3.22	2.77	–0.76	–4.70
Water	4.94	4.32	0.69	–3.52	5.09	4.42	0.70	–3.63	4.68	4.23	0.71	–3.23
Private Service	3.91	3.04	–0.37	–3.42	4.03	3.12	–0.38	–3.52	3.66	2.99	–0.34	–3.19
Transportation Service	–1.41	–1.55	–2.01	–2.48	–1.47	–1.62	–2.09	–2.58	–1.17	–1.28	–1.74	–2.18
Public Service	12.04	11.15	7.74	3.74	12.42	11.48	7.98	3.86	11.26	10.58	7.25	3.50

Source: Authors' simulations.
Note: F=farmer, O=operator, A=administrative, P=professional.

5. CONCLUSIONS AND IMPLICATIONS

The impact of global climate change can be analyzed through macroeconomic indicators, sectoral output, domestic commodity prices, labor impacts, and changes in exports and imports. Generally, global climate change as assessed using the MIROC A1B climate change scenario projections to 2030 could well worsen Indonesian economic performance. Real GDP will slightly decline relative to the baseline; and prices, measured in CPI are expected to rise. There is a real appreciation of the Indonesian Rupiah relative to US Dollar and net export performance is worsened as Indonesia has to allocate more resources to provide adequate supply in response to strategic food commodities (rice and maize) despite decreased household consumption. On the other hand, improvements from accelerated R&D investment, resulting in a 10-percent increase in productivity across the food crops sector, would overcome any negative climate change impacts and actually increase the performance of Indonesian GDP. The macroeconomic impact on GDP is even higher when beef productivity is also improved. Accounting for higher food prices as a result of climate change, however, will lower Indonesia's GDP.

Negative impacts for GDP are mostly due to the negative growth of agricultural sectors and agro-based industry. The largest negative output growth can be seen for soybeans, rice, and paddy. Decreasing output of paddy and rice will harm the food security condition in Indonesia because global climate change will directly increase production risk, particularly in irrigated areas, which use high levels of agrochemical inputs. As a result, domestic prices increase significantly for these crops, affecting the CPI. In line with the impact of global climate change on sectoral output, sectoral employment in agriculture and agro-based industries will decline, except for paddy and maize. An increase in food and beef productivity to counteract climate change impacts, as well as higher international prices of food as a result of climate change, will decrease labor absorption.

Integrated policy options are needed, including changes in the institutional infrastructure and enhanced stakeholder awareness to adapt to adverse climate change impacts. Indonesia is not the only country that is influenced by global climate change. Given that food prices will be generally higher under various climate change scenarios, it will benefit the Indonesian government to increase investments in agricultural research and development.

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