

**Studies on Economic and
Environmental Efficiency of Makassar
City in Indonesia:
AHP and CGE Modeling Approaches**

June, 2014

DOCTOR OF ENGINEERING

Any WAHYUNI

TOYOHASHI UNIVERSITY OF TECHNOLOGY

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Supervisor: Professor Yuzuru MIYATA

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Abstract

Economic action and the environment affect one another's performance. Economic and environmental changes affect the welfare of society. Environmentalists and economists agree that indifference to the environment has caused the depletion of natural resources and environmental degradation. The underlying reason for the underestimation of assets is that not all environmental goods and services are included in the economic analysis of programs and policies. Environmental problems must be prevented, and the damage caused by economic development must be reduced. Economic development can be sustainable, or it can be compatible with the viability of natural systems. Economic and environmental development requires an analytical instrument to evaluate the most appropriate economic and environmental strategies.

Indonesia is a developing country that is expanding in every economic sector. However, Indonesia's government has scarce financial resources that must be allocated efficiently for development. CO₂ emissions and the decline of natural resources due to of human economic activity intended to improve the standard of life cause green-house-gases (GHG) that can alter the natural balance and the climate-change process.

This study addresses economics and the environment using a methodology to analyze the efficiency of resource allocation. Resource allocation is a trade-off that can be resolved by the price mechanism. This study attempts to achieve the best possible result for the environment while assuming the lowest possible loss of economic objectives.

This study examines the following issues: (1) the provision of public goods such as road construction on the Maros-Watampone Road; and (2) the urban economics of Makassar City. This study applies an analytic hierarchy process (AHP) to design efficiency with respect to selecting the best type of road construction in a conservation area. We refer to Wicksell's theory (1977) that in a perfectly competitive market, a voting system returns the same results as a price mechanism for decision-making. However, the public cannot explain references to the public goods. Economists have proposed a public participation method (AHP) concept by substituting the criterion entity for the person entity. Therefore, efficiency is a feasible environmental solution where the value of one criterion can only be achieved by degrading the value of at least one other criterion. The evaluation method to determine the efficiency of economic resources provides an integrated framework to evaluate an investment from a public perspective. AHP enumerates all of a particular project's direct costs and benefits to society assigns monetary values, discounts them to a net present value and adds them into a single number to evaluate the project.

The Maros-Watampone Road crosses a critical geometric conservation area that is a barrier to development. Previous studies recommend the three following alternative constructions: an elevated bridge, a cut and fill, or tunnel system. The government invited community members to participate in selecting the best construction in their region. Using the AHP, the results showed that the criterion of benefits (0.300) is the major factor in determining construction priority; the second major factor is environmental criteria (0.224). Construction costs (0.081)

and maintenance criteria (0.054) had no significant effect. An elevated bridge is the most suitable type of construction (0.528), followed by cut and fill (0.248) and the tunnel system (0.223). The higher contributions of benefit and environmental criteria indicate that community preferences cannot be measured using the price system. In addition to relatively large energy consumption, construction activity simultaneously created CO₂ emissions. Thus, an estimation of CO₂ emissions indicates that elevated bridge construction has lower emissions (1.31 TonCO₂/km) than tunnel construction (1.79 TonCO₂/km). The decision-making process showed that the public has begun to pay attention to quality of life and the environmental effect caused by development activity. We evaluated the efficiency of economic resources based on the following analyses: benefit-cost, net present value (NPV), and internal rate of return (IRR). Evaluating the investment feasibility of the best construction shows that the public's decision is the correct choice to support the government's decision. Public participation in economic development is one way to achieve efficiency in economic resources.

The second research method uses a computable general equilibrium (CGE) model that adds environmental objectives to urban economic objectives in Makassar City. After calibrating the model to Makassar's economy and choosing the reduction of CO₂ emissions as the environmental objective, we can establish efficient economic development. Accordingly, we can estimate how much economic growth must be sacrificed for each environmental goal. It is also possible to determine in which direction the mixed policy should be reformulated

to obtain combinations of efficient economic activity and minimal environmental impact.

The model examines the impact of the carbon tax based on the 2006 input-output (I-O) table for Makassar City and estimates a social accounting matrix (SAM) table for the same year. In CGE models, general equilibrium is achieved through the price mechanism. The model assumes a static economy with no time-related elements. Twenty-eight industrial sectors and two production factors, labor and capital are used in this study. A model economy contains a single representative household that establishes its consumption to maximize its utility subject to its budget constraint. The utility function used is the constant elasticity of substitution (CES), in which the household maximizes utility subject to a budget constraint. Every industry uses an intermediate input to produce one commodity for each sector without a commodity by-product. Firms are assumed to maximize their profits by managing inputs and outputs subject to their production technology. Firms are assumed to be perfectly competitive and to have achieved equilibrium in 2006 through flexible price adjustments.

The carbon tax policy is assessed using two simulations. In the first simulation, a carbon tax is imposed on all industries without household transfer, and in the second simulation, the tax revenue is transferred to households. The government transfers funds to households in an amount equal to its carbon tax revenue. In theory, the implementation of a carbon tax will reduce CO₂ emissions and increase government revenues. Furthermore, household welfare will increase, output prices will increase and households will reduce their consumption.

The results of all simulations of the CGE model indicated that a carbon tax is able to reduce the volume of CO₂ emissions by eight percent. In general, output prices and production volumes declined. The demand for capital tended to be fixed, and labor demand declined after tax revenues were transferred to the representative household. Household consumption declined following the imposition of carbon taxes but increased in response to the transfer of carbon tax revenues. Therefore, household welfare increased after receiving transfers from the government.

It is crucial to effectively manage efforts to reduce CO₂ emissions. Managing emissions involves not only production-side efforts related to environmentally-friendly technology but also prevention of a decline in commodity consumption preferences.

This research describes two approaches to allocate resources efficiently and can be used to choose policy that favors both the environment and human wellbeing without sacrificing economic development.

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Chapter 1

Introduction

1.1 Economy and Environmental Interactions

Every economic action can have some effect on the environment, and every environmental change can have an impact on the economy: every economic change is usually associated with a change in the welfare of society (Meadows, 1972; Hanley et al, 1997; Wainwright, 2009). Human activity in the environment impacts human welfare. There is an interaction between the economy and the environment. This interaction is dynamic because the economy and the environment continually change one another.

In describing interactions between economics and the environment, economy refers to economic agents, institutions (government, firms and household) and connections between agents and institutions, such as markets. With respect to the environment, life exists on the Earth's surface, the atmosphere and the geosphere; flora and fauna include life forms, energy and material resources (Nisbet, 1991; Hanley et al, 1997). Humans affect the environment through economic activities such as market production and consumption. The environment supplies resources, either as a partial recycling factory or as a waste receptacle. The production sector extracts resources from the environment and transforms them into outputs for the consumption sector. These sectors produce waste from their activities, and they return waste to the environment.

The economy and the environment connect in several ways (Hanley et al, 1997). The environment supplies material and energy resource inputs, waste assimilative

capacity, amenities and educational and spiritual values; and global life of the planet supports to the economic process. Figure 1.1 describes the interaction between economics and the environment. Economic exchanges of goods, services and factors of production occur between the production and consumption sectors in the market. There is a partial recycling process within the production and consumption sectors, as shown by R_1 and R_2 . E_1 , E_2 and E_3 denote the environment, and E_4 denotes the all-encompassing boundary. The production sector extracts energy and material resources from the environment and transforms them into outputs as consumer goods and services and waste products (e.g., carbon dioxide (CO_2)).

Wastes derived from the production and consumption sectors are returned to the environment either directly or indirectly. These wastes are biologically or chemically processed by the environment. However, the environment has limited space for waste. Environmental capacity for waste depends on its volume. Figure 1.1 shows that using the environment for any purpose can reduce its ability to supply other services. The three circles E_1 , E_2 and E_3 overlap, which indicates conflicts in resource use.

The many conflicting demands on the environment cause scarce resource; simultaneously, Absolute scarcities of environmental services are increasing (Daly, 1991). The primary cause of absolute scarcity is economic growth, which can increase demand for materials and energy, waste output and environmental quality. However, if environmental resources are fixed, then absolute scarcity will

increase with world economic growth (Haley, 1991). Economics plays a role in allocating resources to conflicting demands.

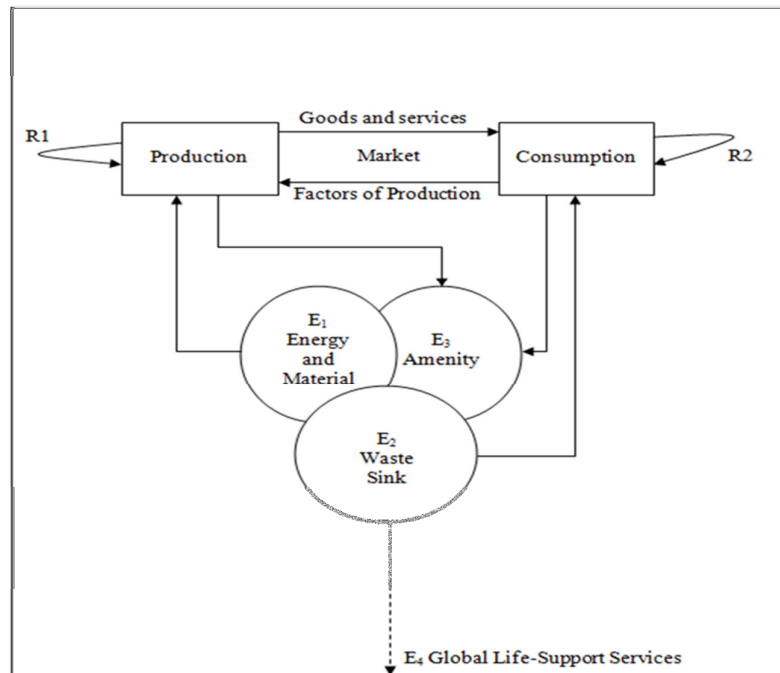


Figure 1.1: Economy-Environment Interactions (Hanley, 1997)

1.2 Economic Development and Sustainable Environment in Indonesia

Economic growth has led to increased action on the environment. Economic growth is economic development that has already occurred. Economic development is usually a long-term process that promotes growth, encourages competitiveness, increases employment opportunities and wages, enhances higher education, reduces poverty and diminishes inequalities (Munier, Nolberto, 2004). Based on this definition, economic development offers an improved standard of life. According to the World Commission on Environment and Development, sustainable development is development that allows the current population to

meet its needs without compromising the ability of future generations to meet their needs. Sustainable development indicates that resources must be used wisely development.

Economic development and a sustainable environment are inextricably linked. Development increases the demand for energy resources, whereas the availability of those resources stimulates even more development by allowing trade and economic specialization. Industrialization in economic development has created a considerable need for energy in the production and consumption sectors. The availability of natural resources is one method of measuring region's prosperity. The amount and quality of natural resources are the result of economic development, which further encourages sustainable development.

Sustainable Development and the Indonesia Environment

Indonesia has experienced many advances in economic development. Indonesia's economy began as one that was traditional and agriculture-based currently, however, manufacturing and services predominate. Economic progress has improved societal welfare, reflected in the increase in per capita income and improvement of social and economic indicators such as the Human Development Index (HDI). Between 1980 and 2010, Indonesia's HDI increased from 0.39 to 0.60.

Indonesia also plays a growing role in the global economy. Currently, Indonesia ranks as the 17th largest economy in the world. Prior to the global economic crisis, various international agencies noted Indonesia's success.

Indonesia is rapidly developing and requires considerable energy to support that development. Energy demand and development will increase simultaneously, with economic and population growth, particularly in the industry sector. Indonesia's domestic needs are still primarily met by its energy resource, which also produce commodities and foreign exchange revenues. The considerable and continuous use of energy resources has caused the depletion of Indonesia's energy reserves. Therefore, we need wiser environmental management to preserve those resources.

Undang-Undang Dasar 1945 (UUD 1945) is Indonesia's constitution and the primary source of its development policy. In 2002, the Indonesian government incorporated the principle of a sustainable environment in the fourth amendment to that constitution. Indonesia's national economy is based on economic democracy and the principles of togetherness, efficiency, sustainability, the environment, independence and maintaining a balance of economic growth and national unity. With the adoption of the principles of sustainable development and sustainable environment, Indonesia's constitution became "green". It guarantees the rights of every community to health and a clean environment.

The government has implemented several macroeconomic policies for achieving economic growth with sustainable development and environment. For example, the state maintains the availability of energy resources has increased the use of renewable energy and has improved the quality and quantity of the supporting infrastructure. Efficiency in production and consumption improve the quality and management of the carbon emissions programs and the environment.



Figure 1.2 Economic Growth of Indonesia (2001-2010)
 (Source: Statistics Indonesia, 2010)

The growth of the national economy parallels the growth of the industry sector. Figure 1.2 shows that the economic growth of Indonesia has increased almost every year. Most industrial activities utilize fossil fuels that are used for electricity and heat production. Fossil fuels also supply industrial processes such as those of the fertilizer industry (natural gas), the steel industry (coal) and the chemical industry (kerosene and gasoline). Based on the “Handbook of Energy and Economic Statistics of Indonesia” (Ministry of Energy and Mineral Resources), the industry sector’s share of total commercial energy consumption in Indonesia is approximately 53% (including supply for industrial processes), or approximately 47%, if natural gas to supply the fertilizer production process is not included.

Table 1.1 compares Indonesia’s primary energy supply and final energy consumption over the past 11 years. Growth increased every year by 3.7% for energy supply and by 3.4% for final energy consumption. On average, Indonesia’s annual economic growth during the period was 5% per year (Ministry of Finance of Indonesia 2010).

Table 1.1: Energy Supply and Consumption in Indonesia

Year	Primary Energy Supply	Final Energy Consumption
	BOE	
2000	995,741,609	777,925
2001	1,041,252,219	802,325
2002	1,070,035,892	799,926
2003	1,131,058,046	839,748
2004	1,144,483,636	875,261
2005	1,166,487,651	864,601
2006	1,175,503,577	880,153
2007	1,230,902,805	916,720
2008	1,262,003,306	906,846
2009	1,294,631,364	978,380
2010	1,429,328,278	1,067,529
2011	1,516,241,607	1,114,767

Source: Handbook of Energy and Economic Statistics of Indonesia (Ministry of Energy and Mineral Resources 2010)

With its plantations and mineral resources, Indonesia intends to become the center of world food security and an agricultural products processing center. Without ignoring the principles of sustainable development, Indonesia also expects to become a global logistics center based on the potential mobility and geographic advantages of its resources.

The energy demand of various industry sub-sectors is expected to increase and to follow their production capacity growth. On average, energy utilization in the Indonesian industry sector is not as efficient as in other countries because in industry subsectors, older technologies are still applied (Ministry of Energy and Mineral Resources of Indonesia, 2007).

1.3 Environmental Problems in Indonesia

Instead of increasing the standard of life, economic development usually imposes a heavy environmental burden. Economic development produces pollution, depletes non-renewable resources, increases waste and uses water. The growth and acceleration of economic development requires more resources for the production process will ultimately reduce the availability of existing resources and will increase the burden on the environment. Pollution or so-called an emission is a substance or energy introduced into the environment that has undesired effects, or adversely affects the usefulness of a resource. Pollution can disrupt the sustainability of an ecosystem and will reduce the quality of human life.

Climate change is the single largest environmental and humanitarian crisis of our time. We must act now to adopt cleaner energy sources because climate change is changing economies, health and communities in diverse ways. Scientists warn that if we do not aggressively curb climate change now, the results will likely be disastrous. In recent years, climate change caused by CO₂ emissions has become increasingly important for discussed. There is uncertainty as to the extent of global warming caused by, e.g., a doubling of current CO₂ levels, and even more uncertainty regarding the physical effects that this warming will have.

Environmentalists often argue that society should take action before that uncertainty is resolved. The costs of not acting immediately may be greater than the costs of preventative or anticipatory action particularly when failing to act immediately will lead to irreversible, undesirable environmental consequences (Taylor, 1991).

In 2005, baseline CO₂ emissions in Indonesia were estimated at 2.1 Gt-CO₂; these amounts make Indonesia the third largest CO₂ emitter in the world. CO₂ emissions in Indonesia are expected to grow by 1.9% per year and will reach 2.5 Gt-CO₂ in 2020. In 2005, the following five sectors generated the majority of Indonesia's emissions: forestry, agriculture, power, transportation and buildings and cement. Indonesia's climate change strategy proposes cutting emissions in the following three ways: developing geothermal powers, driving energy efficiency and reducing deforestation (Ministry of Finance of Indonesia, 2009). The CO₂ emissions generated from the energy sector were 244.31 million tons in 2000, and on average, those emissions increase by 4.82% per year. Meanwhile, from 2000-2010, Indonesia's energy resource reserves declined 4.61% per year, on average (Ministry of Energy and Mineral Resources of Indonesia; 2007, 2008, 2010).

The Ministry of Finance of the Republic of Indonesia has identified economic and fiscal policy strategies to mitigate climate-change. It recommends reducing carbon dioxide emissions using the policies that are the most cost-effective and efficient in both the short and long-terms. The strategies identified by the Ministry for the energy sector are as follows: (1) the implementation of a carbon tax on

fossil-fuel combustion; and (2) energy efficiency through the deployment of low-emissions technology.

Table 1-2: National Target Green House Gas (GHG) Mitigation

Sectors and Sub-sectors	Emissions	Emissions Target Self (26%)	Emissions Target from International (15%)	Total Emissions Target (41%)	
	2020	2020	2020	2020	
	Gt CO ₂	Gt CO ₂	Gt CO ₂	Gt CO ₂	(%)
1. Energy	1.070	0.039	0.022	0.061	5.13
Energy supply and transmission	1	0.03	0.010	0.040	
Industry	0.06				
Transportation	0.01				
2. Forestry	1.570	0.672	0.367	1.039	87.38
Peat land conservation	1.44	0.28	0.057	0.337	
Carbon sinks, forest sustainability Preventing and reducing deforestation fires	0.13	0.392	0.310	0.702	
3. Agricultural	0.060	0.008	0.003	0.011	0.93
Reducing weed burning Reducing the use of chemical fertilizers	0.060	0.008	0.003	0.011	
4. Waste	0.25	0.048	0.030	0.078	6.56
5. Other					
Coastal, small island, oceans, fisheries					
Total	2.950	0.767	0.422	1.189	

Sources: National Development Planning Agency, 2010

In 2011, to mitigate climate change, the government issued Presidential Regulation No. 61/2011 on the National Action Plan to Reduce Green House Gas Emissions and Presidential Regulation No. 71/2011 on the National Inventory of Green House Gas. Those mitigation efforts include not only quantitative targets to reduce emissions by sector and sub-sector but also the necessary time to achieve them. Moreover, on September 25, 2009, at the G-20 summit in Pittsburg (United States), Indonesia's President committed to a 26% reduction in CO₂ emissions by 2020. The Indonesian government's national mitigation targets for greenhouse gas (GHG) are described in detail in Table 1-2.

1.4 Economic and Environmental Conditions in Makassar City

The acceleration and expansion of Indonesian economic development has included the development of centers of economic growth through industry clusters and special economic zones (SEZ). Essential to this approach is the integration of sectoral and regional methods. Each region develops a product that becomes superior. The development of economic growth centers maximizes the benefits of agglomeration and explores potential areas of excellence to ameliorate the spatial inequality of Indonesia's economic development.

One center of economic growth in Indonesia is Makassar City. The city is the gateway to and main development area of eastern Indonesia.

1.4.1 Economic Growth in Makassar City

Makassar is one of Indonesia's largest metropolises and the provincial capital of the South Sulawesi. The city is an industrial center and an international harbor for eastern Indonesia area. Accordingly, in recent years has experienced rapid development growth.

In 2006, Makassar's total population of Makassar was 1,223,540, its population density was 7.1 /km², its total area was 17,807.01 hectares and its population growth had reached 1.79% per year. In addition, the average annual population growth of people with low incomes is 5.7% per year. Urbanization has led to population growth, and poverty is increasing in this city. Municipalities carefully consider the problem of poverty. Since 2005, the government has operated free rice and fuel subsidy programs for the poor.

Figure 1.3 shows that from 1999-2010, Makassar's economic growth has increased every year by an average of 8.8%, indicating high rate of urbanization.

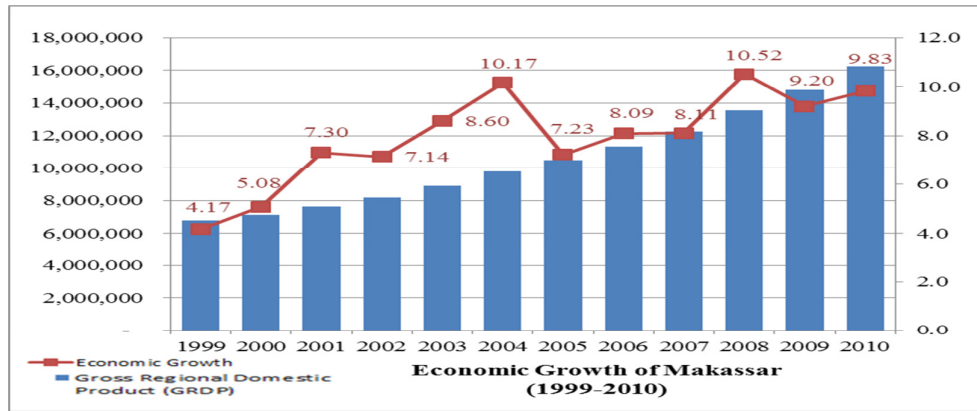


Figure 1.3: The economic growth of Makassar City from 1999-2010
(Source: Makassar City Statistical Bureau, 2010)

Makassar City is classified as a consumerist society characterized by higher levels of consumption than investment. This behavior has changed the city's urban structure and economic growth.

1.4.2 Environmental Conditions in Makassar City

Table 1.3 explains that the analysis of environmental data showed that Makassar City either met environmental standards or provided (on average) good environmental conditions. The city government has created a program to make the city a clean, comfortable, safe and healthy place to live and work. In 2011, Makassar City received ASEAN's Clean Air for Big Cities Certificate of Recognition at ASEAN's Environmentally Sustainable Cities (ESC) Award program. This award is given to ASEAN cities that have remained clean, green and livable notwithstanding their growth as centers of economic and industrial activity.

Table 1.3: Assessment of Environmental Sustainability in Makassar City, 2010

Component of Environment	Unit	Scala of Indicators					Description	Method of Analysis	Equipment
		1 Very Bad	2 Bad	3 Average	4 Good	5 Very Good			
I Climate									
1 Temperature	°C	< 35	31 - 30	28 - 30	21 - 27	16 - 20			
					27.5		Good	-	-
2 Rainfall	mm	< 50	51 - 100	101 - 200	201 - 250	> 250			
						306.6	Very Good	-	-
3 Humidity	%	> 100	85 - 100	80 - 85	75 - 79	56 - 74			
				82.7			Average	-	-
4 Wind velocity	km/hour	> 41	31 - 40	21 - 30	11 - 20	< 10			
						4.0	Very Good	-	-
II Physiography									
1 Topography	%	> 50	30 - 40	15 - 30	5 - 15	0 - 5			
						2	Very Good	-	-
III Quality of Water									
1 Residue dissolved	mg/l	> 1000	700 - 1000	400 - 699	200 - 399	< 200			Timbangan analitik
					244.0		Good	Gravimetric	kertas saring 0,45 µm
2 BOD	mg/l	> 6	6- May	3 - 4	2 - 3	< 2			Buret
					2.64		Good	Potensiometri	DO meter
3 COD	mg/l	> 10	8 - 10	5 - 7	2 - 4	< 2			
						10.91	Very Bad	Trimetri	Buret
4 Dissolved oxygen	mg/l	> 3	2.5 - 3	2 - 2.4	1.5 - 2.4	< 1.4			
			5.94				Very Bad	Titrimetri	Buret
							Very Bad	Potensiometri	DO meter
5 pH		> 10.5	9.5 - 10.5	8.5 - 9.5	7.5 - 8.5	6.5 - 7.5			
						6.2	Very Good	Potensiometri	pH meter
6 Detergent	mg/l	> 0.2	0.17 - 0.2	0.014 -	0.01 -	< 0.01			
			0.435				Very Bad	Spektrofotom	Spektrofotometer
IV Quality of Air									
1 SO ₂	µg/Nm ³	> 0.3	0.21 - 0.3	0.11 - 0.2	0.05 - 0.1	< 0.05			
					0.073		Good	Pararosanilin	Spektrofotometer
2 CO	µg/Nm ³	> 20	15 - 20	11 - 14	5 - 10	< 5			
						2.179	Very Good	NDIR	NDIR Analyzer
3 NO ₂	µg/Nm ³	> 0.21	0.15 - 0.2	0.1 - 0.14	0.05 - 0.09	< 0.05			
						0.005	Very Good	Saltzman	Spektrofotometer
4 TSP (Dust)	µg/Nm ³	> 250	200 - 250	121 - 199	51 - 120	< 50			
			108.18				Bad	Gravimetric	Hi - Vol
5 Lead (pb)	µg/Nm ³	> 2	1.5 - 1.9	1 - 1.4	0.5 - 0.9	0 - 0.4			
				1.195			Average	Gravimetric	Hi - Vol
6 O ₃ (Oxidants)	µg/Nm ³	> 250	200 - 250	121 - 199	51 - 120	< 50			
						45.65	Very Good	hemiluminescen	Spektrofotometer
7 PM ₁₀ (Particle < 10 µm)	µg/Nm ³	> 2	1.5 - 1.9	1 - 1.4	0.5 - 0.9	0 - 0.4			
						0.006	Very Good	Gravimetric	Hi - Vol
8 Noise level	dB A	> 70	61 - 70	51 - 60	46 - 50	41 - 45			
			75.63				Very Bad	-	-
V Social and Population									
1 Populatin density	population/ km ²	> 20,000	15,000 -	10,000 -	5,000 -	< 5,000			
					7,620		Good	-	-
2 Level of education	%	< 20	20 - 40	41 - 55	56 - 75	> 75			
						90.96	Very Good	-	-
VI Economical									
1 Unemployment	%	> 75	56 - 75	41 - 55	20 - 40	< 20			
						7.43	Very Good	-	-
2 GRDP people per capita	million	< 2	2.1 - 5	5.1 - 10	10.1 - 20	> 20			
						27.630.409	Very Good	-	-
VII Community Health									
1 Type of building	%	< 15	15 - 25	26 - 50	51 - 75	76 - 100			
					56.47		Good	-	-
2 Water supply	%	< 25	25 - 50	51 - 70	71 - 90	> 90			
				56.34			Average	-	-
3 Sanitation	%	< 25	25 - 50	51 - 70	71 - 90	> 90			
						95.74	Very Good	-	-
4 Level of community nutrition	%	< 20	21 - 40	41 - 60	61 - 85	> 85			
					82.39		Good	-	-
5 Level of health service	%	< 20	21 - 40	41 - 60	61 - 85	> 85			
						83.33	Good	-	-
Total		4	1	3	8	12			
Value of Indicators = Σ I x Scala		4	2	9	32	60			
Score of Indicators = 28 x S Scala		28	56	84	112	140			
Total of Value				107					Good

Sources: Authors' calculation; The Central Board of Statistics of Makassar City (2011); Ministry of Environment of Indonesia (2011); Sari (2003)

Nevertheless, it is possible that with increasing development activity, elements of environmental pollutants will increase every year. Considering an increase of economic growth and population, an increase in environment degradation is also possible.

Industrial activities and traffic congestion are sources of CO₂ emissions in Makassar (BLHD Makassar, 2012) because the industrial and transportation sectors are the city's largest energy users. Highway transportation consumes 80% of the energy primary in all transportation sectors.

1.5 Economic Efficiency for Environmental Protection

A variety of criteria have been used to measure the performance of an economic system and to evaluate economic policy: one such criterion is efficiency. Generally, efficiency in the economy refers to “how well” or “how effectively” a maximum output is produced from a combined set of inputs. Efficiency is the percentage of attainable production that is actually achieved and that can be distinguished from productivity, which considers the amount of output produced from a particular amount of input (Graham, 2004).

The allocative efficiency of resources can achieve success by satisfying some of the following assumptions:

- The market is in a perfectly competitive condition.
- The household or industries cannot control price, but instead are price-takers.
- Households have perfect information regarding the quality of all available products and prices, and the industry has perfect knowledge of technology and input prices.

- Decision makers always consider all of the costs and benefits of their decisions and thus, there are no external costs.

These conditions present perfect competition in the economy. Perfect competition provides the following results:

- Resources among industries are allocated efficiently.
- Final products among households are distributed efficiently.
- The economic system will produce goods and services for household utility.

Economic development will require more resources to produce goods and will produce an undesirable output, such as emissions.

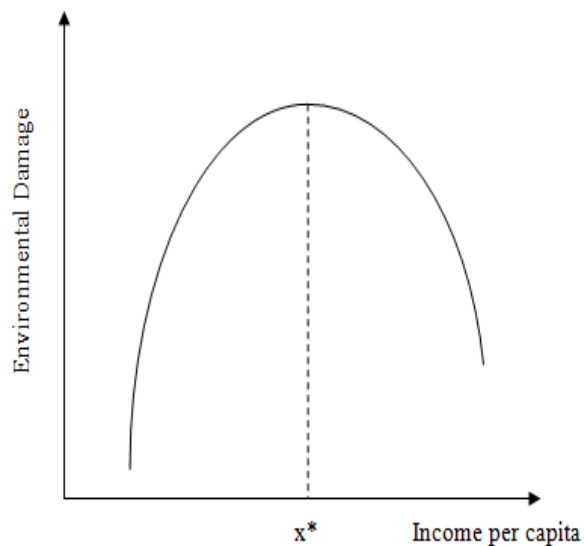


Figure 1.4: Environmental Kuznets Curve

Economic development and environmental quality have a correlation that is depicted in Figure 1.4. Figure 1.4 shows the hypothesis of an inverted U-shaped relationship between economic output per capita and several measures of environmental quality. Figure 1.4 shows that economic development initially may

increase but then may actually decrease or reach zero because the physical system is so badly damaged that there are simply no more costs as environmental damage increases.

In some cases of environmental management, there is uncertainty about the environmental effects of activity and the impact on humans of subsequent environmental changes. The extent of this uncertainty is considerable.

Economic efficiency for environmental protection applies efficient policies to achieve economic and environmental objectives. Efficiency is desirable when considering environmental concerns with the lowest possible costs. Similarly, economic targets should be pursued with minimum environmental impact.

However, the efficiency of the economy versus that of the environment can differ significantly, depending on the characteristics and source of the pollution. An emission charge requires continuous data on the quantities of emissions from controlled sources. Regulators must also have the administrative capacity to use the data to establish and collect appropriate penalties.

In recent years, economists' focus has returned to an important issue: the efficiency of scarce resource allocation. Most developing economies can no longer expect large aid inflows and commercial financing from developed economies. This study examine two objectives: increasing development and reducing CO₂ emissions through the efficiency of resource allocation.

This study addresses economics and the environment using a methodology to analyze the efficiency of resource allocation. Resource allocation can be viewed as a trade-off that can be resolved by the price mechanism.

1.6 Conclusions

CO₂ emissions and the decline of natural resources caused by human economic activity to improve the standard of life two causes of GHG, which can alter both the natural balance and the climate-change process. Environmental degradation must be prevented, and the damage caused by economic development must be reduced. Economic development can be sustainable or compatible with the viability of natural systems. Economic and environmental development required an analytical instrument to evaluate the most appropriate economic and environmental strategies. This study attempts to achieve the best possible result for the environment while assuming the smallest possible loss of economic development.

This study examines both the provision of public goods such as road construction and urban economics. It applies an analytic hierarchy process (AHP) to design efficiency with respect to the selection of the best road construction in a conservation area. We assume that the government is concerned with only two objectives: (1) increasing development through road improvement; and (2) maintaining environmental balance, including the reduction of CO₂ emissions. Economists have proposed a public participation method AHP concept by substituting the criterion entity for the person entity (economics). Accordingly, efficiency is a feasible solution for the environment where the value of one criterion can only be achieved by degrading the value of at least one other criterion.

We extend the research approach by using a computable general equilibrium model by that adds environmental objectives to of economic objectives. After calibrating the model to the Makassar City economy and choosing the reduction of CO₂ emissions as the environmental objective, we can establish efficient economic development. Accordingly, we can estimate how much economic growth must be sacrificed to achieve each environmental goal. It is also possible to determine in which direction the mixed policy should be reformulated to obtain combinations of efficiency economic activity and minimal environmental impact.

Chapter 2

An Analytic Hierarchy Process (AHP) Approach to Economic and Environmental Policy

2.1 Introduction

Environmentalists and economists agree that indifference to the environment has caused environmental degradation and the depletion of natural resources. The underlying reason for the underestimation of assets is that not all environmental goods and services are included in the economic analysis of programs and policies. Many of the advantages provided by natural resources are public goods with no market price. When natural resources are supplied to one person, they are also available to others.

Roads are a public good; therefore, the government should provide roads because no single person wants to pay for good, that had benefits everybody. Several issues to consider are which development programs should be applied, and how much money should be provided by the government for road development; it is an issue. We cannot apply a price system to determine the efficiency of economic resources for provided it. Wicksell's theory (1977) found that the political process is important for managing resource allocation in the economy. Wicksell argued that in a perfectly competitive market, using the voting system in decision-making would achieve the same results as using the price mechanism. However, the public cannot explain references to the public good. In a democratic society,

voting should reflect both preferences and a willingness to pay for public services.

Voting distribution and preferences determine voting results.

Road construction is a specific sector in which the use of professionals is one method of public participation that enables decision-making. The relevant professionals are the community of experts in road planning and development. The complexity of professional knowledge and understanding of planning and development can be simplified through an analytic hierarchy process (AHP) approach. This method is a mathematical concept to structure a problem with a matrix. All factors are arranged and selected, and then descend a hierarchy structure to criteria and alternatives on successive levels. Determination of the criteria for road construction selection is not the main parameter for road construction but should be considered in decision-making.

Although the construction sector is one of the major contributors to Indonesia's economic development, the construction process and operation consumes considerable energy and creates CO₂ emissions. We must estimate the amount of CO₂ emissions that are produced by construction activities to prevent or ameliorate their environmental impact. Public preferences for the best type of construction must support the government's CO₂ emissions reduction.

The government of Indonesia has scarce financial resources, which therefore, must be allocated efficiently. Selection can be conducted by evaluating the efficiency of economic resources. This evaluation will consider the most efficient allocation of resources and allow us to accomplish more with fewer resources.

Road investment benefits the community. The method of evaluating an economic

resource provides an integrated framework to evaluate investment from a public view point. The evaluation method is based on analyses of the benefit-cost (B/C), net present value (NPV) and internal rate of return (IRR). The method will prove that public reference is the best choice for implementation.

2.2 Urban and Regional Economy

Movement of people and goods is the lifeblood that creates wellbeing and prosperity and makes the development of road networks a government priority (Keiron Audain, 2011). Population densities tend to follow patterns and thus, new roads improve sustainable economic growth (Donald R. Glover, 1975; Miyata et al., 2008). There are two reasons of building or widening roads. The first reason increases road capacity by adding lanes or building new construction alongside pre-existing construction. The second reason involves building new roads in areas of development. Roads have both horizontal and vertical curvature and should be designed to fit the terrain to achieve the desired aesthetic qualities and harmonize with the surrounding environment (Mackay City Council, 2008).

Recently, environmental issues have gained public attention, and people have become more aware that the consumption of goods and services has an impact on natural resources. The public and private sectors have started to consider reducing adverse effects, and evolving methods to prevent such impacts. Selection of the highest-quality construction and material is one tool to evaluate sustainability and adverse environmental and societal impacts. Economic criteria, aesthetic value,

environmental factors and design factors, must be considered before choosing material and a method of construction (Hovarth, 1997).

Road construction has both benefits and consequences. The purpose of road construction is to maximize safety, serve the community, shorten distances and travel times and increase economic output and quality of life. Vehicle speed greatly affects the benefits achieved. Geometric conditions also limit street services (Zheng, 1997). The planning and construction of roads located on steep slopes must be carefully examined because of their impact on sedimentation (Beverly C W., et al, 2001; Reid 1981). Complicated geographic conditions and thus, road construction must be realistic considering lower level of service (LOS) and environmental constraints.

Planning for road construction should consider all these factors and account for environmental and human change as the main factor forming processes against environmental policy (Mac Harg, 1969). The success of a design depends on the character design of the model and environmental responses that create a balance between the design and the overall environment (Hough, 1984).

Road infrastructure in Indonesia is vital to national transportation: the existing road network serves approximately 92% of passenger and 90% of transportation modes. Continuous infrastructure development positively impacts the region's economic competitiveness in the national economy and expands the national economy an international level (Ministry of Public Works of Indonesia, 2010). This purpose is appropriate for Indonesia's economic development strategy, which is pro-green, pro-jobs and pro-poor. The best alternatives for infrastructure

policies that are chosen by the public yield benefits that can alleviate the problem (Simon H, 1947).

2.3 Objectives

Our objective is to evaluate the best type of construction for a regional road in Indonesia. The road passes through a critical geometric conservation area that is a barrier to development. There are two approaches to the attributes under consideration. One direction can be interpreted as “the best is better” and implies a maximization process; the other can be interpreted as “less is better” and implies a minimization process. Maximizing economic growth and minimizing the environmental damage and CO₂ emissions are typical examples of objectives within a public context.

2.4 Methodology

The type of construction is selected by the public, and the evaluation of the efficiency of the economic resources is determined using a public approach.

2.4.1 The Analytic Hierarchy Process (AHP) approach

Decision structure and pairwise comparison method

This approach builds the formed matrix of relative weights among the criteria performed through the value of the preference. The AHP method is used to determine the type of construction. This method was first developed by Saaty (1988) and is commonly used by decision-makers to determine policy by synthesizing several options in a single method. The main idea of this analysis is

to transform a subjective assessment into a whole that has a value or weight. Acquisition of data weighting is derived from the analysis of the survey interview, which asks respondents the question of the weight of an interest rate criterion compared to other criteria. The criteria used are the results of the identification of the item that has a major influence on choice, not on achieving the goal. Relative weights among the criteria are used to obtain comparisons weighting is normalized and importance is determined among the compared criterion variables. Relative preference values are obtained by analyzing interviews and questionnaires administered to respondents, who assess the importance level on a nine-point scale. Table 2.1 shows the scale of the interest rate criterion.

Table 2.1: The Scale of Assessment Between Criteria

Interest Rate	Definitions	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Moderately favor one over the other
5	Essential importance	Strongly favor one over the other
7	Very strong importance	Strongly favored and dominant over the other
9	Extreme importance	Most favored
2, 4, 6, 8	Intermediate values	Indicate that compromise is required
Reciprocals	If the inverse element i has one of the above rates when compared to element j , then it has the reciprocal value when compared to the element i .	
Rational	Rations arising out of the scale	If consistency were to be forced by obtaining n numerical values to span the matrix

Source: Saaty (1990)

Respondents are assumed consistent in providing an assessment of each pair-wise of criteria and all n criteria have the same value when each is compared against itself. Each criterion has n elements, namely: $w_1, w_2, w_3, \dots, w_n$, where the value of the comparison n criteria can be described by the equation: $\frac{1}{2} n (n-1)$. Overall comparison of each pair-wise in this analysis forms the reciprocal square matrix illustrated below:

	A ₁	A ₂	A ₃	.....	A _n
A ₁	w_1/w_1	w_1/w_2	w_1/w_3	.....	w_1/w_n
A ₂	w_2/w_1	w_2/w_2	w_2/w_3	.....	w_2/w_n
A ₃	w_3/w_1	w_3/w_2	w_3/w_3	.....	w_3/w_n
:	:	:	:		:
:	:	:	:		:
A _n	w_n/w_1	w_n/w_2	w_n/w_3	.....	w_n/w_n

The results of calculation of each row in the matrix comparisons will obtain the value of the eigenvector which is the weighted value of the normalized average of each factor in each row.

The weight matrix of pair-wise comparisons has a characteristic maximum value of n as positive, and both simple and characteristic vectors are associated with a positive (Theorem of Perron in Garminia, 2010). Therefore, the pair-wise comparison matrix has a consistency index of zero.

For the consistency index (CI) of the n matrix,

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{2.1}$$

where

CI = consistency index

λ_{\max} = the largest eigenvalue of n matrix

and the consistency ratio is defined as

$$CR = \frac{CI}{RI} \quad 2.2$$

where

CR = consistency ratio

CI = consistency index

RI = ratio index

The ratio index is the average value of the consistency index obtained randomly, as shown in Table 2.2.

The decision will be consistent if the value of the consistency ratio is no more than ten percent.

Table 2.2: Value of Ratio Index (RI)

N	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51

Selection of Road Construction

The government and previous study (Badriana, 2009 and Ibrahim F, 2010) have identified nine criteria for choosing a type of road construction. The problem is to decide which three candidate constructions to apply. Thus, we begin by structuring the problem as a hierarchy.

The top level shows where the selection is the best type of construction. At the second level are the nine criteria that contribute to the selection of the best type of road construction. The criteria are as follows:

1. *Benefits*: Traffic safety, comfort and convenience;
2. *Environmental*: Minimization of pollutants, appreciation of natural environment, environmentally friendly material and technology;
3. *Economical*: Raising the economic growth of the region, increasing household income;
4. *Cost of construction*: Efficient, and rapid rate return;
5. *Technology*: Safe, quiet, minimization of pollutants, applicable;
6. *Maintenance costs*: Low cost, easy to repair, durable;
7. *Esthetics value*: Harmonized with area;
8. *Ease handling of implementation*: simple, humble; and
9. *Time of construction*: Self explanation.

These criteria are the important considerations used in the selection of construction based on the problem. Pair-wise, the matrix of the criteria results in a vector of priorities, which is the principal eigenvector. This calculation gives the relative priority of the criteria measured on a scale of a ratio.

In the third level, pair-wise comparisons of the types of construction with respect to the superiority of one over the other are suitable for each criterion at the second level. There are nine 3x3 matrices of judgments. We invited and collected preferences from the respondents, who are experts in the planning and development of road construction and included government officials, planners,

engineering supervisors and academics. The respondents are not representative of the population as a whole because each group is represented by ten people. However, the respondents are considered to represent the entire community. Selection hierarchy is shown in Figure 2.1.

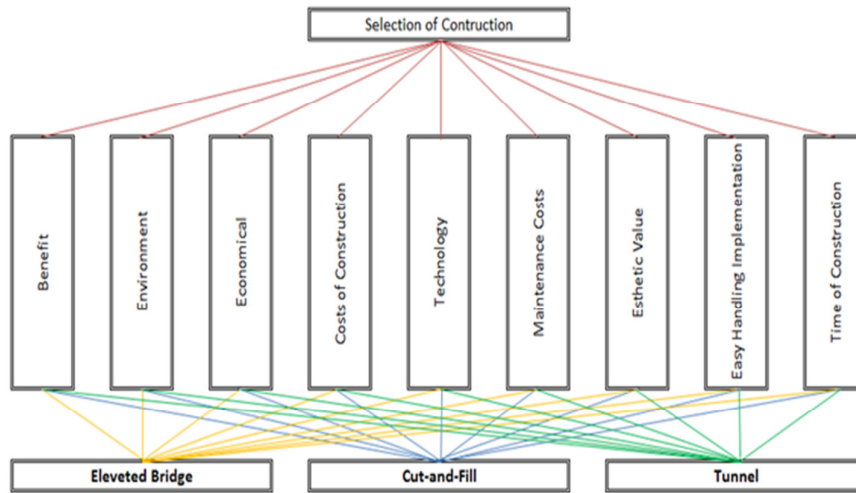


Figure 2.1: Selection of the Types of Constructions Hierarchy

Analyses were performed using the expert choice program in which respondents' perceptions made pair-wise comparison matrices.

2.4.2 CO₂ emissions calculation

Calculation of the approximate number of environmental impacts such as CO₂ emissions caused by the best type of construction uses the value of the emission factor results of several published, scientific studies. Because of the limited data and literature available, we made many of assumptions to simplify the calculation. We assumed that the value of the emission factors had indicators and geographical conditions similar to the previous research. The main construction used the results of the greenhouse-gases calculations performed by Kato et al (2005), Srippl

(2001), Rajagopalan (2007) and Forsythe (2011). Emissions caused by the transportation mode refer to the results of scientific research by Rose (2010). The calculation results depend on the actual construction design.

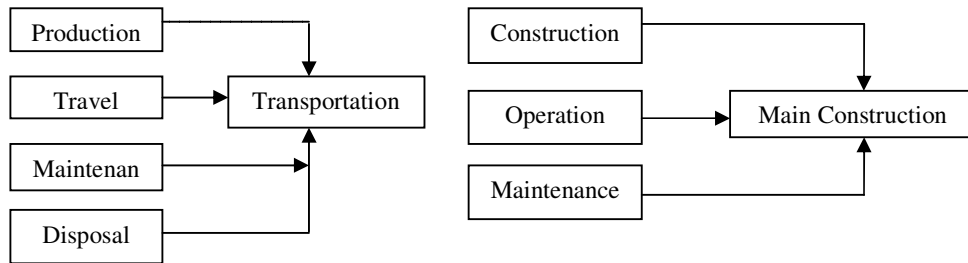


Figure 2.2: Calculation of CO₂ emissions by investigated of qualification of environmental load emission

Table 2.3: Embodied CO₂ Emissions for Construction and Road Activities

Type of Construction	Ton CO ₂ /KM			
	Main Construction		Transportation	
	Construction	Maintenance	Construction	Maintenance
Elevated Bridge	3,680	120	0.000045	0.000039
Tunnel	5,310	210		
Cut-and-fill	164.8- 892.5	259		
Asphalt Surface	47.09	10.41		

Source: Kato., et al, 2005; Stipple, 2001; Rajagopalan, 2007; Rose, 2010; and Forsythe, 2011

2.4.3 Efficiency of economic evaluation

Cost-benefit analysis is a formal process for evaluating a project based on economists and government agencies seeking an efficient allocation of resources (Jones et al, 2013; World Bank, 2004; Ninan, 2008). Cost-benefit analysis an important problem-solving tool in policy work that is one of the most widely accepted and applied methods because it provides many benefits. These benefits

include a model of rationality; creating, evaluating and comparing alternatives, including different scales for those alternatives; and monetizing costs and benefits (Munger, 2000; Nickel, Ross & Rhodes, 2009). Cost-benefit analysis enumerates all direct costs and benefits to society of a particular project, assigns monetary values, discounts them to a net present value and adds them into a single number to evaluate the project (Nickel, Ross & Rhodes, 2009).

The policy implementation calculated economic variables through an analysis of the B/C of the best construction, thus supporting decision-making. This analysis is used for activities that could potentially interfere with the environment and the public interest. The concept is measured by the value of the benefits and costs of a comparably sized activity. Activities will lead to the allocation of factors of production more efficiently if the value of the benefit is greater than cost. The highway development and management IV method calculated vehicle operating costs (VOC) based on the preliminary design simulations assuming the current price and geometric parameters. The value of time was calculated by using the integrated road management system (IRMS) and the gross output (human capital approach) approach to obtain the cost of accidents.

An expansion of the analysis of benefits cost is to use the NPV to calculate investment feasibility, the IRR and B/C ratio. Test sensitivity was calculated based on the optimistic scenario of eligibility conditions (increase in benefit cost of 25% and decrease in investment cost of 25%) and the condition of pessimism (decrease in the benefit cost of 25% and increase in investment cost of 25%).

2.5 Case Study

Project Descriptions

The Maros-Watampone Road is located in South Sulawesi, Indonesia. The road was built by the Dutch colonial government and is important for regional economic activity between the provinces of South Sulawesi and Southeast Sulawesi. This road is 145 km long with an average width of six meters in one line; it passes through several mountain areas with steep contour conditions. In general, the cross slope is more than 17%, the horizontal curvature radius is an average of 13 meters, and the critical length is greater than 175 meters. These features can slow vehicle to speed 4.6 km/h with limited visibility. Daily traffic has increased by 7.5%, which causes an accident rate that is 2.9% higher every year. The condition of the road has become damaged by a geometric path that is unsuitable to Indonesia's road-construction standards. Geometric conditions of 40 kilometers must be repaired to maximize services on the road. The government performs maintenance only because the road is constrained by geographical conditions and is protected by natural habitat on the surrounding streets. Several segments have experienced a decrease in services such as regional economic flows, comfort and safety.

From 2007 to 2009, the government conducted a study and discussion to improve the performance of Maros-Watampone Road. The plan recommended three alternate geometric road construction options: the elevated bridge, cut-and-fill and the tunnel system. Implementation of these three alternatives could negatively impact the environment. Thus, special attention must be paid to the topography

and geology, along with the choice of construction techniques and methods to maintain the ecosystem sustainability in the national parks and heritage areas alongside the road.



Figure 2-3: Existing Geometric Conditions in the Area of Babul National Park

The reason for the road development is to increase road capacity either by building new construction along the existing line or by constructing other lines, depending road line conditions.

2.6 Analysis Results

2.6.1 Decision by AHP

The results of the pairwise comparison showed that the preferences of the respondents are consistent. This is evidenced by an inconsistencies value of less than 0.10 (0.08), and the weight of the criterion and alternative options given in Table 2.4.

Benefits and the environment are the top sequence in the selection of criteria for consideration of construction type. This top sequence indicates that the type of construction chosen should provide maximum benefits to society and minimize environmental impact. The benefits criteria for consideration contributed the most

to the respondents' construction choices because they understand the importance of the service that they will receive from this development. The road was built because of its benefit. The respondents prioritize benefits but still consider the resulting environmental effects and therefore, they make the environmental criteria into their second consideration. People realize that the road's benefits must be balanced with its impact on development sustainability. Development of the road will increase mobility so that the economic growth of the area, traffic safety and comfort will also be increased.

Table 2.4: The Weighting of Criteria and Alternatives

Criteria	Global Weighting	Alternative Weighting			Inconsistency
		Elevated Bridge	Cut-fill	Tunnel	
Benefit	0.300	0.534	0.150	0.316	0.03
Environment	0.224	0.519	0.304	0.177	0.02
Technology	0.130	0.493	0.311	0.196	0.05
Economical	0.104	0.570	0.270	0.160	0.03
Construction Costs	0.081	0.550	0.210	0.240	0.02
Maintenance Costs	0.054	0.523	0.284	0.193	0.09
Esthetic Value	0.041	0.489	0.332	0.180	0.09
Easy Handling Implementation	0.038	0.581	0.282	0.137	0.04
Time of Implementation	0.029	0.534	0,316	0.150	0.03
Inconsistency	0.090	0.528	0.248	0.223	0.08

Source: Authors' calculations

The use of environmentally friendly construction materials greatly affects the sustainability of bio diversity conservation in the surrounding area. The use of alternative materials is required to minimize the environmental impact. The technology criterion was chosen for the next sequence. This sequence shows that technology should be able to solve geometric problems without ignoring its impact on the environment.

The economic criterion and the cost of construction and maintenance costs, concern the use of fund allocation for construction during the period of the plan. The community does not consider the appropriate construction and maintenance costs. This decision shows that the community understands the benefits and that the balance of natural resources requires environment-friendly technology with a significant implementation cost. These criteria can be calculated in several ways that will be discussed in the section on the efficiency of economic evaluation.

Harmony between construction and the environment must be considered by using esthetic criteria to avoid the impression of a patchwork landscape. The criteria for easy handling and time of implementation tend to have an equal weight in terms of priority because they are directly proportional to one another. If construction is not difficult to implement, the work time will be faster and as well as the opposite. Synthesis analysis of the weight of the criteria and the weight of the alternatives showed that elevated bridge construction has the highest priority value at 0.528. This value shows that elevated bridge construction is suitable to solve geometric problems on that road. The cut-and-fill (0.428) and tunnel (0.223) approaches

occupy the second and third priorities, respectively. The results of the sensitivity analysis are demonstrated in Figure 2.3.

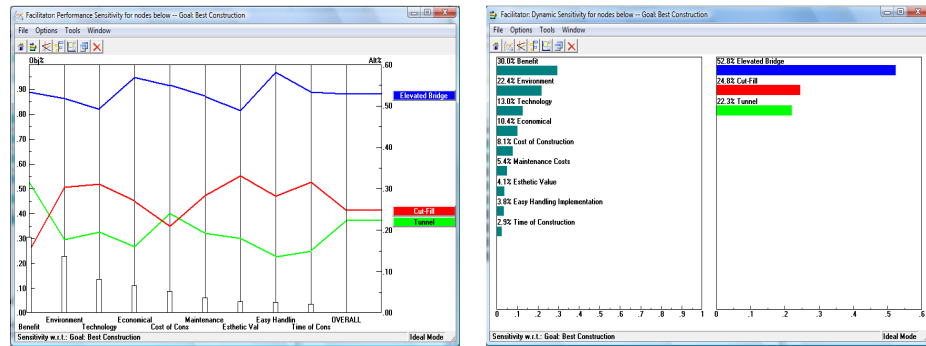


Figure 2.4: Graph of Sensitivity
 Source: Authors' calculations

All the considerations criteria contributed the highest value for the elevated bridge construction. Criteria benefit (0.150) and the construction costs (0.210) give less priority to the cut-and-fill weights than the tunnel (0.316 and 0.240, respectively). However, other criteria contributed enough weight to cut-and-fill construction to make it the second priority for possible application.

The choice of elevated bridge construction as the most suitable to be applied for the Maros-Watampone Road is correct because its implementation will not change the landscape and will have little effect on nature. Wildlife habitat will be maintained in the conservation area. It is assumed that the construction pillar/abutment used with a high-tension electric tower can legally traverse several conservation areas. Using environmental friendly technology, it will be possible to comply with appropriate geometric standards with limited land use. However, based on economic value, the cost of construction and maintenance is higher and compared to other types of construction, elevated bridge construction requires

special implementation expertise and considerable time. These criteria are not dominant influence on the value of contribution.

When compared to other types of construction the tunnel and cut-and-fill approaches may destroy the balance of the ecosystem that surrounds the road. To obtain a road grade of 10%, both constructions must realign and extend the trace, thus requiring more land, which could damage the rock massif that is widely available around the site. Esthetic value (0.489) renders the elevated bridge superior because it promotes harmony between development and high-value conservation areas that could eventually increase community incomes.

The most important advantage of road improvement includes greater potential for the transportation of goods, reduced costs pertaining to problems caused by low-quality roads and a notable effect on the region's vitality.

2.6.2 Application of Elevated Bridge Construction

The assumptions regarding elevated bridge construction design are revealed by considering several parameters using the land development and 3dsMax programs, as seen in Figure 2.4.



Figure 2.4: Simulation of Elevated Bridge Construction

Table 2.5: Geometric Change Parameters

Road Condition	Before Implementation	After Implementation	Unit
Length	10	11.5	Km
Width	4.5	7	M
Width shoulder	1	2	M
Topography condition	Hill	Flat	-
Average slope rise(RR)	22.5	2.5	m/km
Average slope falling (FR)	22.5	3.5	m/km
Slope rise + falling (TTR)	45	5	m/km
Degree of turn (DTR)	200	15	°/km
Surface condition (IRI)	5	7	m/km
Average speed	40	65	Km/jam

Source: Authors' calculations

Table 2.5, shows the geometric changes in an existing conditions when construction of an elevated bridge is implemented. Several geometrical conditions that cannot be adapted to the National Road Standard because we are trying to be realistic about conservation zones and critical areas that use lower levels of services.

2.6.3 Construction Impacts on CO₂ Emissions

Considering the amount of CO₂ emissions generated by construction activities, transport must be considered because this road is in a conservation area, which is an oxygen and water reserve for the South Sulawesi province. The use of environmental construction materials can preserve the environmental sustainability of both the area and the region.

The study conducted by Horvath (1997), shows that during the construction phase (for example, during the concrete process), the bridge imposes a lower environmental burden. This is similar to the results of our simple calculation comparing the three types of construction, which shows that elevated bridge construction produces the lowest CO₂ emissions during its process and maintenance.

Table 2.6 illustrates the CO₂ emissions and relative contributions of construction, maintenance and transportation related to both the existing construction and to the two construction alternatives. Cut-and-fill construction is post-dispatch construction and therefore, we cannot display data about its resulting CO₂ emissions.

Table 2.6: Estimate of the Total Emissions Produced by Each Type of Alternative Construction

Type of Construction	Ton CO ₂ /KM			
	Main Construction		Transportation	Total
	Construction	Maintenance		
Elevated Bridge	1.05	0.03	0.23	1.31
Tunnel	1.50	0.07	0.23	1.79
Cut-and-fill	4.89-11.09	0.26	0.23	5.38-11.58
Asphalt Surface	0.05	0.01	0.29	0.35

Source: Authors' calculations

Overall CO₂ emissions resulting from elevated bridge construction (1.31tCO₂/km) is lower than from tunnel construction (1.79tCO₂/km). Contribution of CO₂ emissions from the process and maintenance of the main construction has a major

impact on the value of the total emissions produced. The process and maintenance of tunnel construction (1.57tCO₂/km) causes greater emissions than does the elevated bridge construction (1.08tCO₂/km). Transport emissions contribute equivalent value to both types of construction because their concrete surfaces in the construction are the same. This construction is in accordance with Indonesian regulations that ban the use of two types of construction on road construction surfaces.

The calculation of the emissions of existing construction has a lower value because without considering the road grade, acceleration and vehicle speed factor in the evaluation, but the emissions are produced by the asphalt surface only. Therefore, the value contribution of transportation to total emissions in each alternative construction is the same.

2.6.4 Analysis of the Efficiency of Economic Resources

Component of Benefit Cost

VOCs decreased after the construction was implemented. Table 2.7 shows that trucks incur many benefits from by the project improvement. This condition supports of the smooth shipping of goods between the South and Southeast Sulawesi provinces, both of which use trucks. Regional economic activity will also increase. Public transport fare reductions (in the amount of 938, 537 or 3984) can also be implemented because of the large decline in value after the project is operational. Energy efficiency varies widely depending on the driving cycle and type of vehicle.

Table 2.7: Operational Cost of Vehicle

Vehicle	Before Project	After Project	Different VOC
Sedan/City Car	3,720	3,133	588
Sport Utility Vehicle	4,678	3,740	938
Mini Bus	8,140	7,603	537
Bus	11,568	7,584	3,984
Light Truck	7,725	6,670	1,055
Medium Truck	12,901	11,208	1,693
Heavy Truck	14,813	8,671	6,142

Source: Authors' calculations

Private users of sedans/city cars (588) are not greatly impacted and thus, it is likely that people will switch to using public transportation, which has a decreased tariff. If more people use public transportation, the energy consumption and emissions generated by transport activities will decrease. Thus, impact on the environment can be further reduced.

Table 2.8: Time Value of Travel Before and After the Project

Vehicle	Before Project	After Project	Time Rate
Sedan/City car	73,821	45,428	28,393
Sport Utility Vehicle	53,176	32,724	20,452
Mini Bus	106,352	65,447	40,905
Bus	212,703	130,894	81,809
Light Truck	14,960	9,206	5,754
Medium Truck	14,960	9,206	5,754
Heavy Truck	14,960	9,206	5,754

Source: Authors' calculations

Geometric changes will have a major impact on travel time. Average vehicle travel times will be reduced by 20-30% compare with original condition. The accident rate will decrease. Overall changes in travel time before and after the project are set forth in Table 2.8.

Feasibility and Sensitivity Analysis of Investment

Table 2.9 illustrates the value of the benefits arising out of the application of elevated bridge construction under different conditions. The values of the work implementation are evaluated according to a scale of feasible priorities and investments.

Table 2.9: Sensitivity Test on 25% Change in Profits and Costs

Test	NPV (in Billion Rupiah)	IRR (in Billion Rupiah)	BCR (12%)	BCR (15%)
Scenario 1: no accident cost savings	899,849	20.07%	2.78	2.21
Condition				
Test 1: cost investment up 25%, benefit down 25% (condition pessimistic)	385,052	17.91%	1.78	1.41
Test 2: cost investment down 25%, benefit up 25% (condition optimistic)	1,459,639	21.32%	4.34	3.45
Scenario 2: with accident cost saving	1,078,678	20.36%	3.09	2.45
Condition				
Test 1: cost investment up 25%, benefit down 25% (condition pessimistic)	563,881	18.60%	2.03	1.61
Test 2: cost investment down 25%, benefit up 25% (condition optimistic)	1,638,468	21.43%	4.73	3.75

Source: Authors' calculations

2.7 Conclusions

An AHP method has been applied to select of the best type of road construction on Maros-Watampone Road, Indonesia. To support decisions related to this geometric construction on Maros-Watampone Road should consider non-economic aspects such as benefits, the environment, technology, the economy, construction costs, maintenance costs, esthetic value, easy and time for implementation. All the criteria must contribute significantly to the construction process and operation to keep development sustainable.

The results of the analysis showed that elevated bridge construction is the best alternative for geometric improvements on Maros-Watampone Road. This decision is supported by the results of a simple analysis of the environmental impact and evaluation of the economic aspects of the selected road construction. Overall, the selection of elevated bridge construction provided great benefits, had little impact on the environment (as seen by its low level of carbon emissions) and achieve of geometric standards through technology. The value of $BCR > 1.0$ indicates that the cost of the benefit is greater than the cost of investing in an optimistic and pessimistic condition. In addition to these benefits, elevated bridge construction has an esthetic value that can support increased conservation in an area of natural and cultural heritage.

If governments invest in road development, the quality and quantity of roads will increase. Therefore, the regional potential for transportation will be improved, which can increase economic growth and create greater income for the government. Furthermore, problems such as accidents and gradual damage to

vehicles caused by low-quality roads will be reduced. Therefore, the roads will be safer and drivers will incur less damage. Finally, a region with a vast number of high-quality roads is more likely to prosper; it will provide people with more opportunities for access to various resources and will lead to greater development.

The calculation of the project's ecological impacts will function, but it must be prepared as a follow-up to the calculation of CO₂ emissions. Future study should be concentrated on the environmental impact of energy consumption, especially in construction and transportation activities that involve all aspects of construction, maintenance and transportation.

Chapter 3

Computable General Equilibrium Models for Economic and Environmental Policies

3.1 Introduction

Computable general equilibrium (CGE) modeling is an analysis that attempts to use the general equilibrium theory to empirically analyze resource allocation and the economy as a whole. The general equilibrium theory is a formalization of the simple but has a fundamental observation that markets in real-world economies are mutually interdependent (Bergman et al. 2003). This theoretical analysis has provided important insights into the factors and mechanisms that determine relative prices and the allocation of resources within and among market economies.

3.2 Computable General Equilibrium: An Overview

With the development of fast computers and software suitable for policy analysis, Johansen (1960) who developed the Norwegian multi-sector growth model, presented the first CGE model. Since the beginning of the 1990s, many CGE models have been developed to analyze environmental policy and natural resource management issues for example, development issues have been analyzed by Dervis et al. (1982) and taxation and international trade issues have been analyzed by Shoven and Whalley (1992) in a manner to that of Buehrer and Mauro (1995).

Today, the CGE model has been extended to analyze development planning, public finances, the environment and resource management, reconciliation of structural changes and market transitions (Yeah et al. 1994). For example, the ORANI model is a CGE model of the Australian economy, built by Dixon (1992), which analyzes the impact that policy has on resource allocation and economic structure, social welfare and income distribution (Oktaviani 2000). CGE modeling has become popular because of the increasing need to analyze of policies related to resource allocation issues, and it is often applied in many developing countries. A CGE model for Indonesia was first implemented in 2005 to calculate the impact of fuel price increases on income distribution and social welfare.

A CGE model is a nonlinear equation that stimulates the economy to accommodate price adjustments and quantities as the equilibrium market for production factors and commodities (Lewis, 1991). Arrow (2005) has found that a CGE is the best method to analyze the economy-wide impact of policies, which is influenced by inter-linkages between sectors or markets. Similarly, Hosoe (2010) has proposed that CGE models can numerically depict a “world” in which a general equilibrium is attained by the price mechanism.

A CGE model is one of the rigorous quantitative methods that can be used to evaluate the impact of policy shocks throughout the economy. Today, this model is considered to provide the most realistic evaluation of the entire economic structure and all existing economic transactions among economic agents (production sectors, households and the government, among others). This is because of the ability of CGE analysis to capture the economic impact derived

from shocks or the widespread implementation of a specific policy reform. This approach is useful when the expected effects of policy implementation are complex and materialize through different transmission channels. Therefore, this model is the best option to evaluate a climate change shock, which involves analyzing static/dynamic, direct/indirect and short- and long-term effects.

3.3 Computable General Equilibrium as Economy Modeling

The structure of the CGE model, in that it describes interactions among economic agents, was built on microeconomic theory in the form of a behavioral equation system. CGE models analyze the interaction between macroeconomic variables and the microeconomics sector and the impact of economic policy on the economy as whole. According to this model, the market is perfectly competitive, achieving efficiency in production and resource allocation. This relationship among utilities with respect to one another is known as the pareto optimum condition. Three efficiencies in the pareto optimum concept are fundamental to building a CGE model; efficiency of resource allocation (production equilibrium), efficiency of commodity distribution (consumption equilibrium) and efficiency of product combination (equilibrium of the production and consumption sectors).

To run the CGE model, three primary resources are required;

- 1) Time: constructing and running a CGE model take longer than performing an analysis through the use of alternative quantitative methods;
- 2) Special software to run the model;

- 3) A significant amount of data, such as productive sectors (i.e., input-output table), the existing flows of transactions among economic agents (i.e., social accounting matrix) and parameter values, among others.

3.4 Application of Computable General Equilibrium

The important step in CGE application for clearly defining the problem to be analyzed is how to choose the type, features and detail level of the model. The type of problem to be analyzed will indicate the necessary degree of disaggregation and the economic sectors that function must specify the most. The theoretical refinement of the model will also be affected by practical constraints such as information availability. Applied general equilibrium involves a trade-off between the researchers' intent to faithfully represent the economy's structure and the ad hoc constraints established by the available statistical information.

In any process model, to analyze various types of problems and to create the model's particularities, one should always use the following specifications (Andre et al, 2010):

- The number and type of goods (consumer goods, production goods, primary factors, etc.);
- The number and type of consumers (possibly classified by income, age, qualifications, tastes, etc.);
- The number and type of firms of productive sectors (simple or joint production, type of revenues of the production function, technological development, etc.);

- The characteristics of the public sector (attitude of the government as a demander or producer, fiscal system, budget, etc.);
- The characteristic of the foreign sector (related enterprises and sectors, degree of international integration, established tariffs and custom duties, etc.); and
- The concept of equilibrium (with or without unemployment, with or without public and/or foreign deficit, etc.).

3.4.1 The Economic Agents

Following is a brief description of the economic agents of the applied CGE model (Andre et al, 2010., Hosoe, 2010., Variant, 2010, Pauw, 2003, Shoven and Walley, 1992, Leontief, 1986):

3.4.1.1 Industries

Industry is the production of a good or service within an economy and therefore, it is often referred to as production or supply. Several factors can affect production: the price of the commodity, input prices, production costs, production factors, production technology and government policies. Production is expressed as a mathematical relationship to the factors affecting it, known as the production function. Production technology is usually represented by a so-called nested production function. Producers are assumed to maximize their profits, and this maximization results in supply functions for each good.

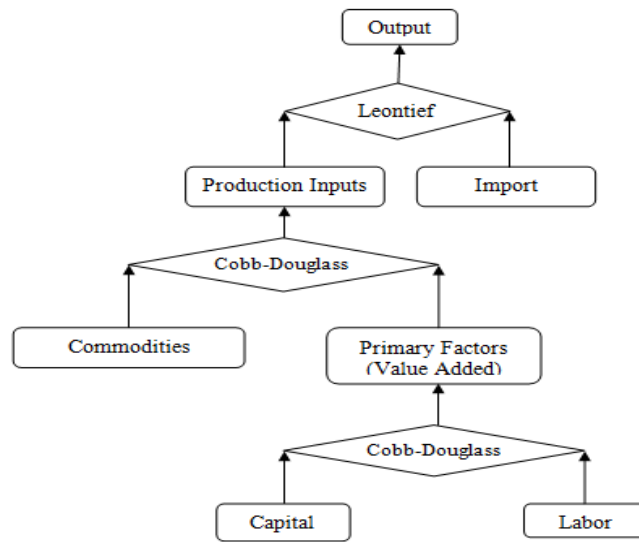


Figure 3.1: Nested production structure

Source: Authors' elaboration

Figure 3.1 shows a simple example of such a function. In this example, the domestic (or internal) production sector uses production inputs, which typically include intermediate outputs from other sectors (commodities) along with primary factors (labor and capital). Primary factors are combined using production technology to provide the value added by each sector. Total production (output) is the result of combining domestic production (production inputs) with imports using, a specific function, which usually confirms Armington's (1969) hypothesis to simplify the analysis. This hypothesis considers that the analyzed country or economy is small enough to have an influence on foreign trade. At the first and second levels of the nest, either the Cobb-Douglass or the constant elasticity of substitution (CES) functions may be found. The activity output level (top-level) is often defined as a Leontief function.

3.4.1.2 Consumer

The final demand comes from household demand for consumer goods and the non-consumer demand sectors of investments and exports. Factors affecting consumer demand include commodity prices, input prices, preferences or utility, income, population, the estimated future prices, income distribution and producer's efforts to increase sales. The demand function is the demand expressed as a mathematical relationship with the factors that influence it. It provides the optimal amounts of each of good as a function of consumer prices and income.

In general, there are n possible types of goods identified by their productive sectors, and one or more representative consumers (perhaps grouped by categories according to income source, income level, activity type, etc.) who demand consumer goods. Each consumer possesses initial endowments and a set of preferences. The representative consumer's purchases are primarily financed by revenues from the sale of the initial factor endowments. Available consumer income not used for consumption is savings. The representative consumer's disposable income is calculated by totaling all capital and labor earnings, plus transfers received, minus the direct taxes for which the consumer is liable:

$$\begin{aligned} \text{Disposable Income} &= \text{Labor Income} + \text{Capital Income} + \text{Transfer} - \\ &\text{Direct Taxes} \end{aligned} \tag{3.1}$$

The consumer's objective is to maximize the utility function, U , which depends on consumer goods, CG_j , and savings, SG , subject to the budget constraint:

$$\max U (CG_1, \dots, CG_n, SG) \tag{3.2}$$

Market demands are the result of adding all individual consumer demands together. Market demands are price dependent; they are also continuous, non-negative and homogeneous of zero degree, and they satisfy Walras's law.

3.4.1.3 Public sector

The public sector is usually represented by the government. This study focuses on policy making; therefore, the model should include several hypotheses regarding how the government makes decisions. The government taxes economic transactions, thus collecting tax revenues and influencing the consumer's disposable income. It also makes transfers to the private sector and demands goods and services from different productive sectors j . The difference between the government's revenues and its outlays represents the balance (surplus or deficit) of the public (government) budget according to the following calculation:

$$\text{Government budget (GB)} = \text{Revenues} - \text{Public expenditures} \quad 3.3$$

where both income and expenditures are measured in monetary terms. Expenditure is the aggregation of (the nominal value of) public consumption and transfers made to the private sector. The applications present in this study, the government activity (public expenditure and taxation) is perceived by economic agents as exogenous and by the government as decision variables. The government revenues will be transferred to the household: that is the specificity of our model.

3.4.1.4 External Sector

In the model, the focus will be on the domestic sphere; it will adopt the common simplifying assumption that the general equilibrium model is to take the activity of the foreign sector as fixed. This is consistent with Indonesia's status as a small country: the hypothesis is that the rest of the world is not affected by any domestic change introduced in our country. The external sector (Ex) is denoted by:

$$\text{Ex} = \text{Exports} - \text{Imports} \quad 3.4$$

3.4.1.5 Investment and Savings

Introducing dynamic factors such as investment and savings is an inconsistency in the static model in which this study will be developed. However, investment cannot be ignored because it comprises a significantly large share of final demand. Our study incorporates an investment model in several ways, despite the fact that it is not completely consistent with economic theory.

Savings and investment normally use a so-called savings-driven model. This model is one in which the closure rule defines investment behavior. Usually, investment is taken to be exogenous; savings are determined by the public sector (or the government), the foreign sector and consumers to maximize their utility and deficits; and public- and foreign-sector investment are left to be determined endogenously according to the following accounting identity:

$$\text{INV} = \text{GB} + \text{SG} \cdot \text{inv}p + \text{Ex} \quad 3.4$$

where INV is the aggregated nominal value of investment and *invp* is the price of investment goods.

3.4.1.6 Input Markets

Labor and capital demands are calculated assuming firms minimize the cost of producing value added in input markets. It is commonly assumed in the short term that total capital supply is inelastic, although more-complex specifications could also be used. Typically, labor supply is a difficult element to address. One problem is that CGE models are built on the assumption that all markets clear in equilibrium. Conversely, one of the aims of applied work is to reproduce reality as closely as possible. This implies the recognition of unemployment. However, such recognition is inconsistent with the equilibrium assumption because since unemployment means an excess supply of labor. This study will solve the problem in our model.

3.4.2 Choosing functional forms

Various well-known functional forms, such as the Cobb-Douglas function, the Leontief function and the constant elasticity of substitution (CES) function, are used frequently in economic modeling in which functions are often regarded as the family of “convenient” forms. The major constraints on the specification of demand and production functions in applied models is that they be consistent with the theoretical approach and be analytically tractable (Shoven and Whalley, 1992). The first constraint involves choosing functions that satisfy several restrictions, such as Walras’s law for demand functions. The second constraint requires that the economy’s demand and supply responses be reasonably easy to evaluate for any price vector, considering a candidate equilibrium solution for the economy.

Table 3.1: Properties of Function Forms

Properties	Cobb-Douglass	CES
	Functions	
Demand functions	$X_i = \frac{\alpha_i I}{P_i}$	$X_i = \frac{\alpha_i I}{P_i^\sigma \cdot \sum_j \alpha_j P_j^{(1-\sigma)}}$
Own-price (uncompensated) elasticity	-1	$-\sigma - (1-\sigma)\alpha_i P_i \gamma^{-1}$
Own-price (compensated) elasticity	$-(1-\alpha_i)$	$-\sigma((1-\sigma)P_i^{(1-\sigma)} \cdot \gamma^{-1})$
Income elasticity	1	1
Cross-price (uncompensated) elasticities	0	$-(1-\sigma)\alpha_j P_j^{(1-\sigma)} \gamma^{-1}$
Indirect utility function	$U = I \cdot \prod \left(\frac{\alpha_i}{P_i} \right)^{\alpha_i}$	$U = I \cdot \left(\sum_j \alpha_j P_j^{(1-\sigma)} \right)$
Expenditure function (true cost-of-living index)	$E = \prod \left(\frac{P_i}{\alpha_i} \right)^{\alpha_i}$	$E = \left(\sum_j \alpha_j P_j^{(1-\sigma)} \right)^{(1-\sigma)}$

Source: Shoven and Whalley (1992)

The specific form chosen typically depends upon how elasticities are to be used in the models. This point is best illustrated by considering the model's demand side. Demand derived from Cobb-Douglass utility functions is easy to work with but has the restrictions of unitary-income and uncompensated own-price elasticities and zero uncompensated cross-price elasticities. These restrictions are typically implausible, given the empirical estimates of elasticities applicable to any particular model, but can only be relaxed by using additional general functional forms. With CES functions, unitary own-price elasticities no longer apply. However, if all expenditure shares are small, the compensated own-price

elasticities equal the elasticity of substitution in preferences, and it may be unacceptable to model all commodities as having essentially the same compensated own-price elasticities.

Once all these elements have been specified, it is time to apply the equilibrium hypothesis. We assume that markets tend to equilibrium in the sense that supply equals demand in all markets as long as consumers and producers make optimal decisions. We applied the model for finding the equilibrium fit and solving a system equation using a computational program. The complexity of this system is model dependent but must include, at least, the supply functions (one for each output and input), the demand functions, the market-clearing conditions and all the relevant accounting identities.

The zero degree homogeneity of the demand functions and the linear homogeneity of profits in relation to the prices mean that only relative prices are significant; absolute prices have no impact on the resulting equilibrium. Therefore, equilibrium is characterized by relative prices and by certain production levels in each industry in which market demand equals supply for all goods. The assumption that producers maximize their profits means that in the case of constant scale revenues, no activity offers positive economic profits at market prices.

There is not one single general equilibrium model; rather, there are as many models as there are different combinations of decisions to be made (number of sectors, functional forms, etc.). The choice of specific functional forms usually depends on how elasticities are used in the model. The method most often applied

is to select the functional form that best accounts for the key parameter values (such as price and income elasticities) without damaging the model's feasibility.

3.5 Model Closure

CGE models always contain more variables than equations, which have a relation to one another that enable to be both endogenous and exogenous. Several of the variables set outside the model are called exogenous. Variables determined by the model are termed endogenous. The choice of which variables are to be exogenous is called the model closure. Strategies for the choice of model closure include:

1. Identifying variables that describe each equation;
2. Automatically deeming variables that are not described in the equation system as exogenous; and
3. Accounting for matrix size variables.

3.6 Building Benchmark Equilibrium Data sets

The benchmark equilibrium data set for the model is crucial in the calibration process. The data set is constructed under the assumption of an observable equilibrium and meets the equilibrium conditions for the model being studied. If equilibrium is to be reflected in an assembled set of national accounts, demand must equal market supply for all commodities, and supply and demand must be separately disaggregated by agent. Ultimately, each agent has incomes and expenditures consistent with his or her budget constraints.

Equilibrium conditions must be satisfied by most of the constructed benchmark equilibrium data sets (Shoven and Whalley, 1992) as follows:

- (1) Demands equal supplies for all commodities
- (2) Non-positive profits are made in all industries;
- (3) All domestic agents (including the government) have demands that satisfy their budget constraints; and
- (4) The economy is in external sector balance.

The benchmark data sets are constructed for use as a business-as-usual condition in applied general equilibrium models. Various adjustments are necessary to block data that are available separately but are not arranged on a micro-consistent basis. The nature of these adjustments, which are made on a case-by-case basis, varies.

3.8 The Advantages and Disadvantages of Applied CGE Models

CGE modeling (Hosoe, 2010, Horison, 1997, Ayres and Kneese, 1969, Debreu, 1959) has certain advantages:

- Its potential to capture a much wider set of economic impacts that includes all transactions of economic agents as a whole and therefore, the effect of a policy can be quantitatively analyzed with respect to macro- or microeconomic performance.
- Its potential to include substitutions between production factors so that price changes in the production factor will cause the consumer to change he or her composition in the consumption of production factors.

- Its ability to evaluate not only the implementation of a policy reform but also its distributive effects within the economy at different levels of disaggregation.
- Its relatively small data requirements considering the size of the model (for particular benchmark years).
- Its high level of rigor and elegance analysis, which extend to compass externalities and environmental resources with public goods characteristics.

However, CGE modeling also has several disadvantages:

- Its significant data and time requirements. Collecting updated, high-quality, multiregional data, building a social accounting matrix, and programming and calibrating a CGE model are very time-consuming processes.
- The CGE model is complicated and using many assumptions cause the black box problem to appear, which makes it difficult to explain why the estimation result may not correspond to the economic theory or prediction.
- The CGE model requires the primary assumption of perfectly competitive market equilibrium with a constant return to scale condition.
- The CGE model depends on calibration of the parameter's benchmark with the value calculated from other model calculations. Therefore, for a developing country, it is difficult to obtain precise data. Interpretation of results focuses on magnitudes, directions and distributive patterns, not the numeric outcomes themselves. Therefore, results from CGE models should be complemented with additional analytical work using alternative quantitative methods for policy implementation.

Chapter 4

Constructing a CGE Model for Economic and Environmental Policies in Makassar City

4.1 Introduction

Our study introduces a standard structure of CGE model that conforms to a basic of the Walrasian equilibrium to perform a joint analysis of economic and environmental policies; moreover, the model incorporates information about both the key economic variables and the environmental impact of economic activity. Taxes and government activity are taken to be exogenous for households and industries, whereas they are considered as decision variables for the government.

We present the industrial behaviour by the technology structure in a nested production function. Consumer behavior is represented by a single household that makes decisions about consumption and savings while trying to maximize his or her utility function subject to a budget constraint. CO₂ emissions are introduced following a short-term approach according to which the intensity of CO₂ emission is assumed to be fixed. The basic structure of the model is completed by a description of input markets, the external sector, commodities prices and the closure rule, which links investment, saving and government balances. The model also assumes that the activity level of the external sector is fixed in the sense that imports and exports are not sensitive to policy changes implemented by the government. This assumption is consistent with a small country hypothesis and a short-term approach to policy design.

The relative prices and the activity levels of the production sectors are endogenous variables. The equilibrium of the economy is given by a price vector for all goods and inputs, a vector of activity levels, and a value for government income such that the household is maximizing his or her utility; the production sectors are maximizing their profits (net of taxes); the government income equals the payments of all economic agents; and supply equals demand in all markets.

The main database used in the calibration process is Makassar's social accounting matrix.

4.2 Model Framework

The results of the simulations produced using the CGE comparative-static model were reported as deviations from a baseline scenario (BAU). Instead of presenting changes over time, the model reports differences with respect to the baseline scenario at a given point in 2006. Such results are generally considered to represent economic responses over a period of approximately two years (McDougall, 1993). The model is consistent with price levels and real economic activity. The price is determined exogenously and acts as the numeraire in the model.

Figure 4.1 presents an example of a comparative static model. The figure depicts the equilibrium relationships between demand and supply before and after the imposition of a carbon tax. This study assumed that the city's industries produce products and CO₂ emissions as a by-product. In the figure, x is a commodity, p is

the price of the commodity, t is the tax per unit of the commodity, and the commodity supply function will shift upward by t .

This figure indicates that the price of the commodity before the tax has been imposed (x_2) is p_2 and that the price of the commodity after the tax has been imposed (x_2) becomes $p_2 + t$. Equilibrium is achieved when the demand function (D) and the supply function (S) intersect at point E (x_0, p_0). After the tax is imposed, equilibrium occurs at point E_1 (x_1, p_1), which is the intersection of the demand function (D) and the supply function (S_1) after the tax has been imposed.

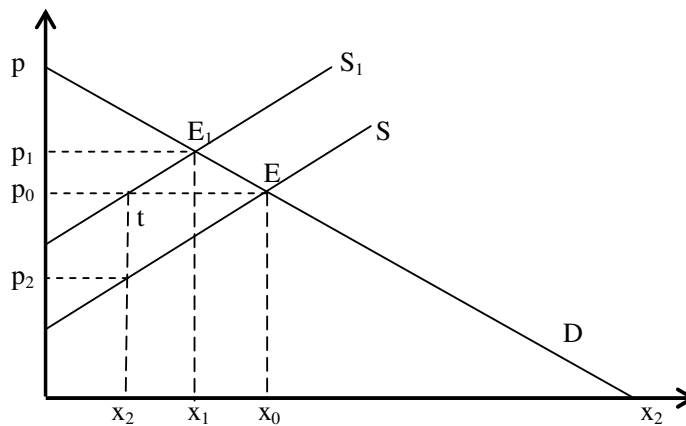


Figure 4.1: Equilibrium before and after the imposition of a carbon tax

The model simulations indicate that the tax will result in percentage changes in industrial output of $100 \cdot (X_1 - X_0) / X_0$ and demonstrate how the policy might affect industrial output and economic performance.

4.3 Setup of the Economy

In the model, production requires the use of two production factors: one unit of labor and one unit of capital. In the model economy, there are twenty-eight

industry representative firms that produce twenty-eight commodities. There is a single representative household that consumes all the commodities in the economy in a way that maximizes its utility. The household supplies the firms with two production factors in return for income. The supply and demand for these commodities and production factors are in perfectly competitive equilibrium in 2006.

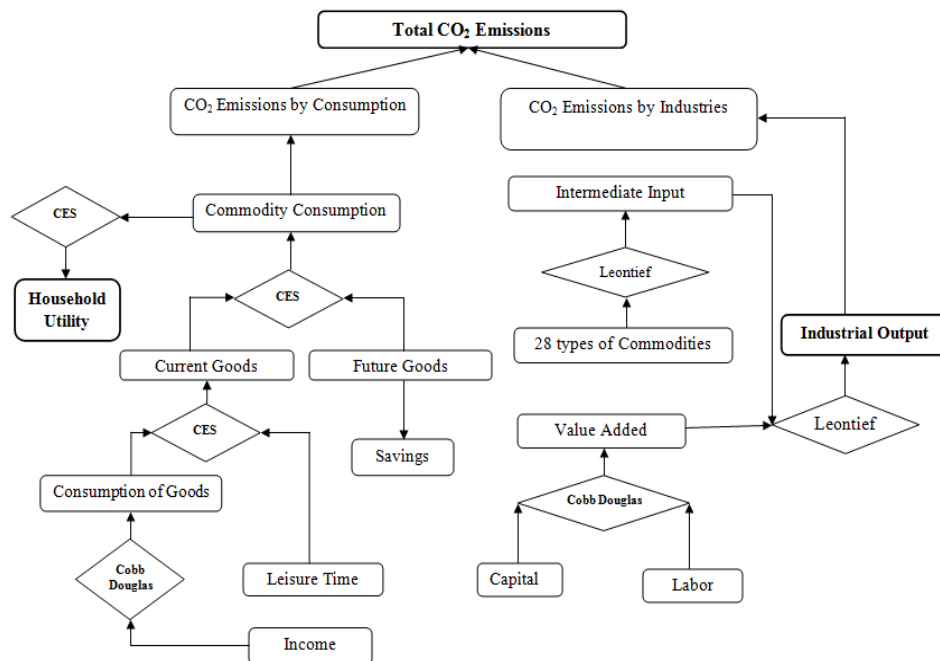


Figure 4.2: Hierarchical structure of the model

4.4 Behavior of Economic Agents

4.4.1 Industries

The model comprises twenty-eight production sectors matching the aggregate 2006 Social Accounting Matrix (SAM) of Makassar city, which is used to calibrate the model. The production technology is given by a nested production function.

The industries use intermediate inputs, labor and capital to produce goods. Industries combine the intermediate, labor and capital inputs using the Leontief production function and apply a Cobb-Douglas production function for the value-added inputs (see Figure 4.3). The firm's cost minimization problem can be written as follows:

$$\min \sum_{i=1}^{28} p_i x_{ij} + (1+tp_j)(wL_j + rK_j) \quad (j=1, \dots, 28) \quad (4.1)$$

with respect to x_{ij} , L_j and K_j

subject to

$$X_j = \min \left[\frac{1}{a_{0j}} f_j(L_j, K_j), \frac{x_{1j}}{a_{1j}}, \dots, \frac{x_{ij}}{a_{ij}}, \dots, \frac{x_{28j}}{a_{28j}} \right] \quad (4.2)$$

$$f_j(L_j, K_j) \equiv A_{1j} L_j^{a_j} K_j^{(1-a_j)} \quad (4.3)$$

where

p_i : price of commodity i

x_{ij} : intermediate input of industry i 's product in industry j

tp_j : net indirect tax rate imposed on industry j 's product (indirect tax rate-subsidy rate)

w : wage rate

r : capital return rate

L_j : labor input in industry j

K_j : capital input in industry j

X_j : output in industry j

a_{0j} : value added rate in industry j

a_{ij} : input coefficient

A_j, α_j : technological parameters in industry j

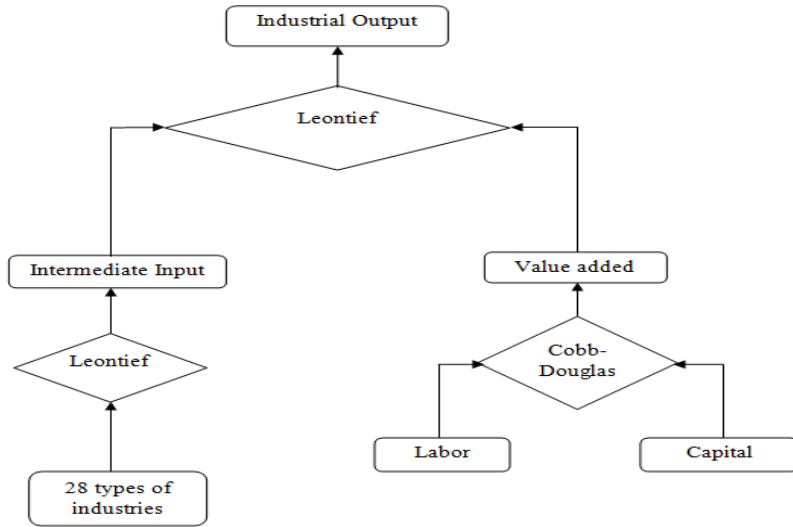


Figure 4.3: Hierarchical structure of industries

The conditional demands for intermediate goods, labor and capital in the production process are as follows:

$$x_{ij} = a_{ij} X_j \quad (4.4)$$

$$LD_j = \left[\frac{(1 - \alpha_j)r}{\alpha_j w} \right]^{\alpha_j} \frac{a_{0j} X_j}{A_j} \quad (4.5)$$

$$KD_j = \left[\frac{a_j w}{(1 - a_j)r} \right]^{(1 - a_j)} \frac{a_{0j} X_j}{A_j} \quad (4.6)$$

where

LD_j : conditional demand for labor in industry j

KD_j : conditional capital demand in industry j

The industries conform to the zero profit condition under perfect competition.

$$profit = p_j X_j - \sum_{i=1}^{28} p_i x_{ij} - (1 + tp_j)[w \cdot LD_j + r \cdot KD_j] = 0 \quad (4.7)$$

4.4.2 Households

A fixed number of households in Makassar City are assumed to be homogeneous.

Thus, these households are assumed to share a common aggregate utility function.

The households share a *CES* utility function with respect to the consumption of current and future goods. In this model, the current good is defined as a *CES* composite of current consumption goods and leisure time and the future good is derived from savings. The household utility function is thus illustrated in Figure

4.4:

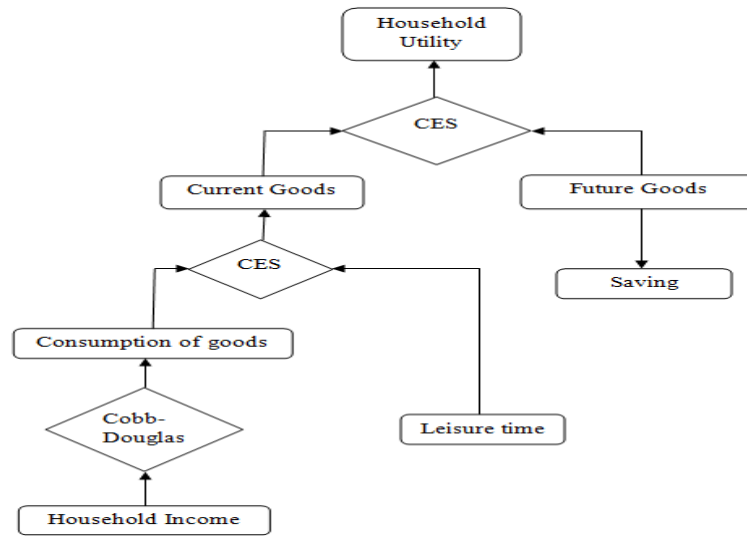


Figure 4.4: Hierarchical structure of households

Households select a bundle of current and future goods to maximize their utility function subject to a budget constraint. The current good is then divided into a composite consumption good and leisure time (labor supply).

Household income consists of full wage income (which is obtained when households supply their entire labor endowment), capital income after capital depreciation, current transfers from the government, labor income, property income and other current transfers from the external sector. A share of household wage and capital income is transferred to the external sector.

A direct tax is imposed on household income upon receiving transfers. Households are then assumed to allocate their after-direct-tax income to current and future goods. Here, for purposes of simplicity, the direct tax is assumed to include all current transfers from households to the government.

To explain household behavior, future goods consumption is derived here. The future goods indicate future household consumption derived from household savings; however, household savings also forms the basis for capital investment. Therefore, the capital good can be interpreted as a savings good. Investment is made using produced goods, and their shares in total investment are denoted by b_i .

When the price of the investment good is denoted by p_I , $p_I I = \sum_{i=1}^{28} p_i I_i$ is

realized. The price of the investment good is then expressed as

$p_I = \sum_{i=1}^{28} b_i p_i$. This price can be regarded as the price of the saving good

p_s .

Because the returns to capital net of the direct tax on a unit of capital investment is expressed by $(1-ty)(1-k_o)(1-k_r) r\delta$, the expected rate of return on the price of saving good p_s , that is, the expected net return rate of household saving r_s is written as follows:

$$r_s = (1-ty)(1-k_o)(1-k_r) r\delta / p_s \quad (4.8)$$

where

ty : direct tax rate imposed on households

k_o : rate of transfer of property income to the external sector

k_r : capital depreciation rate

δ : ratio of capital stock in units of a physical commodity to that in units of capital service.

Here, the assumption is that the expected returns to savings finance future consumption. Interpreting the price of the future good as the price of the current consumption good under myopic expectations, and denoting real household savings S , we observe that the following equation holds.

$$p \cdot H = (1 - t_y)(1 - k_o)(1 - k_r)r\delta \cdot S \quad (4.9)$$

This equation yields $[p_s p / (1 - t_y)(1 - k_o)(1 - k_r)r\delta]H = p_s S$, and setting the price of the future good p_H associated with real savings S yields the following:

$$p_H = p_s p / (1 - t_y)(1 - k_o)(1 - k_r)r\delta \quad (4.10)$$

Then, $p_s S = p_H H$ is realized.

Employing the above-mentioned future good and its price, the household utility maximization problem is now specified as follows. The maximization of household utility with respect to current good consumption will be described in a subsequent section.

$$\max_{G, H} u(G, H) \equiv \{ \alpha^{1/v_1} G^{(v_1-1)/v_1} + (1 - \alpha)^{1/v_1} H^{(v_1-1)/v_1} \}^{v_1/(v_1-1)} \quad (4.11)$$

subject to

$$p_G \cdot G + p_H \cdot H = (1 - t_y)FI - TrHO \quad (4.12)$$

$$FI \equiv (1 - l_o)w \cdot E + LI + (1 - k_o)(1 - k_r)r \cdot KS + KI + TrGH + TrOH \quad (4.13)$$

where

α : share parameter

v_1 : elasticity of substitution between the current good and future good

G : current household consumption

H : future household consumption

p_G : price of the current good

p_H : price of the future good

FI : household full income

$TrHO$: current transfers from households to the external sector

l_o : rate at which labor income is transferred to the external sector

E : initial household labor endowment, which is specified as twice the actual working time based on actual working and leisure time in Makassar City.

LI : labor income transferred from the external sector to households (exogenous variable)

KS : initial household endowment of capital stock

KI : property income transferred from the external sector to households (exogenous variable)

$TrGH$: current transfers from the government to households

$TrOH$: current transfers from the external sector to households

By solving this utility maximization problem, we obtain the demand functions for the current and future goods, which yields a household savings function.

$$G = \frac{\alpha[(1 - ty)FI - TrHO]}{p_G^{v_1} \cdot \Delta} \quad (4.14)$$

$$H = \frac{(1 - \alpha)[(1 - ty)FI - TrHO]}{p_H^{v_1} \cdot \Delta} \quad (4.15)$$

$$S = p_H H / p_s \quad (4.16)$$

$$\Delta \equiv \alpha p_G^{1-v_1} + (1 - \alpha) p_H^{1-v_1} \quad (4.17)$$

We then describe the derivation of demands for composite consumption and leisure time from the current good G . The current good G is a composite of consumption and leisure time, and G is obtained from the following optimization problem.

$$\max_{C,F} G \equiv \{ \beta^{1/v_2} C^{(v_2-1)/v_2} + (1 - \beta)^{1/v_2} F^{(v_2-1)/v_2} \}^{v_2/(v_2-1)} \quad (4.18)$$

subject to

$$p \cdot C + (1 - ty)(1 - l_o)w \cdot F = (1 - ty)FI - TrHO - SH \quad (4.19)$$

where

β : share parameter

v_2 : elasticity of substitution between composite consumption and leisure time

C : composite consumption

F : leisure time

p : price of the composite consumption good

SH : household nominal savings ($= P_S \cdot S$)

Solving this utility maximization problem yields the demand functions for composite consumption, leisure time, and labor supply.

$$C = \frac{\beta[(1-ty)FI - TrHO - SH]}{p^{v_2} \cdot \Omega} \quad (4.20)$$

$$F = \frac{(1-\beta)[(1-ty)FI - TrHO - SH]}{[(1-ty)(1-l_o)w]^{v_2} \cdot \Omega} \quad (4.21)$$

$$LS = E - F \quad (4.22)$$

$$\Omega = \beta p^{(1-v_2)} + (1-\beta)[(1-ty)(1-l_o)w]^{(1-v_2)} \quad (4.23)$$

where LS reflects the household labor supply

Substituting composite consumption (4.20) and leisure time (4.21) into (4.18), we derive the price index of the current good as follows:

$$p_G = \{\beta p^{1-v_2} + (1-\beta)[(1-ty)(1-l_o)w]^{1-v_2}\}^{1/(v_2-1)} \quad (4.24)$$

Moreover, the composite consumption good is disaggregated into produced goods by maximizing a Cobb-Douglas sub-sub utility function given household income and leisure time.

$$\max C \equiv \prod_{i=1}^{28} C_i^{\gamma_i} \quad \left(\sum_{i=1}^{28} \gamma_i = 1 \right) \quad (4.25)$$

subject to

$$\sum_{i=1}^{28} p_i \cdot C_i = (1 - ty)Y - TrHO - SH \quad (4.26)$$

where

C_i : household consumption good produced by industry i

p_i : the price of good i

Y : household income ($= (1-l_o)w \cdot LS + LI + (1-k_o)(1-k_r)r \cdot KS + KI + TrGH + TrOH$)

Consumption good i is derived from this optimization problem.

$$C_i = \frac{\gamma_i}{p_i} [(1 - ty)Y - TrHO - SH] \quad (i = 1, \dots, 28) \quad (4.27)$$

The price of composite consumption is calculated as follows:

$$p = \prod_{i=1}^{28} \left[\frac{p_i}{\gamma_i} \right]^{\gamma_i} \quad (4.28)$$

4.4.3 The Government

The government sector in this study consists of the activities of the national and local governments in Makassar City. Thus, the concept of government that we employ corresponds to the definition used in the SAM framework. The government sets taxes for public revenue, makes transfers to the private sector and demand goods and services from each sector, which leads to the final balance (surplus or deficit) of the government budget.

The government obtains its income from direct and net indirect taxes collected in Makassar City and current transfers from the external sector. Tax revenue

includes revenue raised by all direct and indirect taxes, including CO₂ emissions taxes. The government then spends this income on government consumption, current transfers to households and current transfers to the external sector.

The government saves the difference between income and expenditures. Nominal consumption expenditures on commodities/services are assumed to be proportional to the government revenue with a constant sectorial share. These expenditures are denoted by the following balance of payments.

$$\sum_{i=1}^{28} p_i \cdot CG_i + TrGH + TrGO + SG = ty \cdot Y + \sum_{i=1}^{28} tp_i (w \cdot LD_i + r \cdot KD_i) + TrOG \quad (4.29)$$

where

CG_i : government consumption expenditures on commodity I

$TrGH$: current transfers to households

$TrGO$: current transfers to the external sector

SG : government savings

$TrOG$: current transfers from the external sector

4.4.4 The External Sector

The external sector gains its income from Makassar City's imports, current transfers from the government, labor income transfers and property income transfers. The sector then spends this income in financing Makassar City's exports and imports, current transfers to households and the government, labor (employees in Makassar City) and property income transfers. These expenditures are also expressed by the following balance of payments.

$$\sum_{i=1}^{28} p_i \cdot EX_i + TrOH + TrOG + KI + LI + SO = \sum_{i=1}^{28} p_i \cdot EM_i + TrHO + TrGO + KIO + LIO \quad (4.30)$$

where

EX_i : export of commodity I

EM_i : import of commodity I

SO : savings of the external sector (= national current surplus)

LIO : labor income transfers to the external sector (= $l_o \cdot w \cdot LS$)

KIO : property income transfers to the external sector (= $k_o \cdot r \cdot KS$)

4.4.5 Balance of Investment and Savings

Savings accumulated by the representative household, the government, the local department and total capital depreciation determine the total investment.

$$\sum_{i=1}^{28} p_i \cdot I_i = SH + SG + SO + \sum_{i=1}^{28} DR_i \quad (4.31)$$

where

I_i : demand for commodity i by other investments

DR_i : amount of fixed capital consumption in industry i

4.4.6 Commodity Prices

Given the zero profit condition imposed on industry, we can determine commodity prices from the following equation:

$$p_j X_j = \sum_{i=1}^{28} p_i x_{ij} + (1 + t p_j)[w \cdot LD_j + r \cdot KD_j] \quad (4.32)$$

Given a wage and a capital return rate, we can calculate commodity prices as follows:

$$P = (I - A')^{-1} [(1 + tp_j)(w \cdot ld_j + r \cdot kd_j)] \quad (4.33)$$

where

P : vector of commodity prices

A' : transposed matrix of industries' input coefficients

$[\cdot]$: a column vector whose elements are presented in parentheses: $ld_j \equiv LD_j / X_j$

and $kd_j \equiv KD_j / X_j$

4.4.7 Derivation of Equilibrium

The equilibrium conditions in the model can be summarized as follows:

Commodity Market

$$\begin{bmatrix} X_1 \\ \vdots \\ X_{28} \end{bmatrix} = \begin{bmatrix} a_{11} & \dots & a_{128} \\ \vdots & \ddots & \vdots \\ a_{281} & \dots & a_{2828} \end{bmatrix} \begin{bmatrix} X_1 \\ \vdots \\ X_{28} \end{bmatrix} + \begin{bmatrix} C_1 \\ \vdots \\ C_{28} \end{bmatrix} + \begin{bmatrix} CG_1 \\ \vdots \\ CG_{28} \end{bmatrix} + \begin{bmatrix} I_1 \\ \vdots \\ I_{28} \end{bmatrix} + \begin{bmatrix} EX_1 \\ \vdots \\ EX_{28} \end{bmatrix} - \begin{bmatrix} EM_1 \\ \vdots \\ EM_{28} \end{bmatrix} \quad (4.34)$$

Labor Market

$$LS = \sum_{j=1}^{28} LD_j \quad (4.35)$$

Capital Market

$$KS = \sum_{j=1}^{28} KD_j \quad (4.36)$$

Chapter 5

Database for a Computable General Equilibrium

5.1 Introduction

The primary data used in this study are based on an input-output (I-O) table for Makassar City. Data from the social accounting matrix table along with other data sources such as elasticity values, exchange rate and others are used to complete the I-O table data. The integration of sector aggregation in input-out and social accounting matrix tables uses mapping between the sectors contained in the primary data sources. This chapter explains how to construct the data for a CGE model. The explanation will be started with an understanding of the data structures of the I-O and social accounting matrix tables. The model's coefficients and exogenous variables are estimated using the social accounting matrix tables. The CGE model requires elasticity parameters data and several of parameters.

The CO₂ emission data also required by our CGE model represent the intensity of each sector's CO₂ emissions. Those data are derived from I-O tables and each sector's energy consumption. The study assumes that one industry produces one commodity and therefore, each commodity generates CO₂ emissions through the energy consumption caused by its production.

5.2 Input-Output (I-O) Table for Makassar City

The I-O table developed by Leontief (1986) is a table of matrix transactions that describes the flows of production of all industries in each sector. This table

depicts the relationship between supply and demand among the various sectors in the regional economy. The equilibrium in the I-O table is included in the general equilibrium model.

The 2006 I-O table for Makassar City comprised 28 industries listed in Table 5.1 by producer price. Those sectors include the following: food crops; plantation crops; livestock; forestry; fishery; mining of oil and gas and non-oil and gas; manufacture of food, beverages and tobacco; manufacture of textiles, clothing and leather; manufacture of wood, bamboo and furniture; manufacture of paper and paper products, printing and publishing; manufacture of chemicals, petroleum, coal, rubber and plastic products; manufacture of cement and non-metallic minerals; manufacture of basic metals; manufacture of fabricated metal; other manufactures; electricity, gas, and water supply; construction/building; trade; hotels; restaurants; highway and other transportation; communications; banks and other financial institutions; leasing, real estate and business services; education; health; and social and other services. All the data in the I-O tables are presented in Indonesian rupiah.

The table describes the flow of goods and services in all the individual sectors of Makassar City's economy during 2006. The classification of 28 sectors is aggregated from the Statistics Indonesia I-O Table (2000), which contains 175. In principle, aggregation is the process of grouping a number of sectors into a single sector.

flow of materials, taxes, capital, labor and other costs. Each commodity is derived from local production or import from outside the city, outside the region or a foreign country. The industry used commodity as an input of current production and capital formation. Only domestically produced goods are included in the export column.

There are two demands: intermediate products and final demand. For intermediate input, we assumed that production used two production factors: capital and labor. The final demand consists of household consumption, government consumption, capital, changing stock, exports and imports. Value added consists of wage/salary, surplus, depreciation, indirect taxes and subsidies. Intermediate input consists of a 28 x 28 matrix transaction of 28 industries. The structure of an intermediate input matrix is such that some cells are zero. This means that some sectors do not correspond to other sectors. One of the sectors may use only a portion of intermediate input from the other sectors.

5.3 Construction of the Social Accounting Matrix (SAM) Table for Makassar City

A social accounting matrix (SAM) is a matrix that compiles all the monetary flows among the agents and sectors in a particular economy. It includes information about most transactions, such as the wages that firms pay to households, consumption of goods by households, and taxes and transfers administrated by the government. An SAM is a representation of all of an

economy's existing monetary transactions. Each cell represents a flow of funds from a source (column) to a recipient (row) (Breisinger et al. 2009).

CGE models analyze economic activities, which are transactions that involve goods and factors, and the concurrent flows of funds between economic agents. The flows of goods and services from the agents listed in the rows to the counterpart agents listed in the columns are described in the SAM data. The SAM data extend data from I-O tables that are comprehensive and consistent with a macroeconomic database written in a matrix-form table where agents are used as both row labels and column labels.

For empirical CGE analysis, we must construct our own SAM tables. Various coefficients and exogenous variables for developing a CGE model based on real data must be estimated by using the SAM. Therefore, this study estimated the SAM table for Makassar City based on the 2006 I-O table for Makassar City, the 2005 SAM table for Indonesia and related data such as Indonesia's 2005 National Account table in the same year.

The SAM of the our CGE model consists of "Production Activity", "Institution", "Production Factors", "Capital Accumulation", and "External Sector". In this SAM, "Production Activity" is subdivided into 28 industries; "Institution" is subdivided into government and households; and "Production Factors" is subdivided into capital and labor.

Almost all the data included in the SAM tables are provided in a 2006 I-O table for Makassar City. Data in the I-O tables can be transferred into the correct cells in the SAM table. In the SAM table construction, all the cells contained in the first

row and the first column “Households-Capital” and “Households-Labor” can be copied from IO tables. The important issue is how to fill the cells of SAM construction where the data cannot be derived from the I-O tables. To address this issue, column sums are equal to the corresponding row sums in the SAM tables. The empty cells can be filled immediately by applying the row-sum and column-sum equality rule (Hosoe et al., 2010). The following explanation will describe how to fill the cells based on data from I-O tables.

In the SAM table, “Production Activity” includes intermediate input demand for 28 industries in addition to the capital and labor input for production. In the column lines, all transactions are expenditure, including included intermediate input, wages and value added from tax. The row lines illustrate all transactions assumed as revenue from domestic production along with revenue. The total intermediate inputs of 28 industries production appear in the cell “Production Activity-Production Activity” (Rp. 450,059). Government consumption and household consumption appear in the cells “Production Activity-Government” (Rp. 181,321) and “Production Activity-Households” (Rp. 1,305,500), respectively. The cell labeled “Production Activity-Capital Accumulation” shows that the total of capital and changing stock (Rp. 438,340) and the cell labeled “Production Activity-External Sector” shows the domestic production (Rp. -1,060,325).

“Institution” consists of government and households, which consume “Production Activity”. “Government” cell shows that government expenditures (column lines) include subsidies, consumption of goods and services and some

transfers. The government revenue (row lines) comes from tax and transfers from household. The “Households” cell shows household revenue from the production factors of revenue and transfers. Household expenditure is indicated for household consumption of goods and taxes, and for saving a portion of capital. The transaction shown the “Government-Production Activity” (Rp. 20,171) cell demonstrates indirect taxes can be regarded as the production taxes collected by the 28 industries. The cell labeled “Households-Capital” (Rp. 476,730) shows business surplus and the “Households-Labor” (Rp. 301,787) cell shows household wage/salary from industry activity.

“Production Factors” consists of the capital and labor used for “Production Activity”. In the row lines, those cell show revenues derived from wages and illustrate the revenue of remittances and capital. The corresponding column lines indicated the revenue distributed to households as labor income, business surpluses as industry profits and depreciation. The cell labeled “Capital-Production Activity” (Rp. 476,730) illustrates the expenditure of industries to capital and “Labor-Production Activity” (Rp. 301,787) shows expenditures from industries to households.

The cell labeled “Capital Finance-Production Activity” (Rp. 66,148) shows depreciation in industry capital. The cells labeled “Capital Finance” and “External Sector” are exogenous and include capital. The corresponding row lines show the revenues from government and household savings. The column lines illustrate expenditures such as payment of production factors.

If there are unknown cells after the other cells are filled by applying the row-sum and column-sum equality rule, we seek data sources from the 2005 SAM table and Indonesia's 2005 National Account table. We determine Makassar City's government's savings and transfer to households, which are entered into the "Households-Government" (Rp. 180,499) and the "Capital Finance-Government" (Rp. 139,899), cells, respectively. Next, direct tax revenues and household savings are entered into the "Government-Households" (Rp. 46,925) and the "Capital Finance-Households" (Rp. 130,039), cells, respectively.

The row sums and the column sums in the SAM table show the total revenue and the total expenditure, and each row sum must match its corresponding column sum. That indicates that each cell transaction in the SAM tables is always in equilibrium. Finally, the compilation of the 2006 SAM table for Makassar City is complete, as shown in Table 5.2.

Table 5.2: The 2006 SAM table for Makassar City

Economic Sectors (in million rupiah)		Production Activities	Institution		Production Factors		Capital	External Sector	Total
		28 Industries	Government	Households	Capital	Labor	Accumulation		
Production Activities	28 Industries	450,059	181,321	1,305,500	0	0	438,340	-1,060,325	1,314,895
Institution	Government	20,171	0	46,925	0	0	0	434,623	501,719
	Households	0	180,499	0	476,730	301,787	0	523,448	1,482,464
Production Factors	Capital	476,730	0	0	0	0	0	0	476,730
	Labor	301,787	0	0	0	0	0	0	301,787
Capital Finance		66,148	139,899	130,039	0	0	0	102,254	438,340
External Sector		0	0	0	0	0	0	0	0
Total		1,314,895	501,719	1,482,464	476,730	301,787	438,340	0	

Source: Authors' calculations

5.4 Elasticity Parameters

In determining the results of policy simulations generated by any applied model, parameter values for functional forms are crucial. The procedure most commonly used to select parameter values has come to be labeled “calibration” (Mansur and Whalley, 1984).

The elasticity parameters used are elasticity of substitution for current goods and household utility. Other necessary parameters: include shared parameters in household utility, household expenditure (current and future consumption) and leisure time. In theory, the value of the parameter can be estimated from time-series data by using econometric analysis.

Elasticity of substitution shows how current goods and household utility respond in each sector by change in price input. For a CES utility function, goods consumption substitute for leisure time, and current goods substitute for future goods in the constant elasticity substitutions. This research applied elasticity substitution for all commodities (0.5) from a literature search, followed by calibration as needed, as is commonly performed in Indonesia case studies.

5.5 Estimation of Carbon Dioxide Intensity

An additional database was compiled from data collected by Nansai et al. (2002). The national greenhouse gas inventory guidelines published by Indonesia’s Ministry of the Environment (2012) were used as a reference and to adjust the results regarding embodied energy and emissions intensity in each sector.

These data used an I-O approach to calculate production induced by final demand for energy consumption and CO₂ emissions in a life cycle assessment

(LCA) inventory in the context of an environmental analysis (Nansai et al., 2002, Moriguchi et al., 1998). The I-O table provides input and output on inventory with minimal processing and without modification. The values and quantities table accompanying the I-O tables described the input for each sector in the form of quantities of key material, including energy products. In principle, material input per unit production by each sector can be obtained from a physical amount of total production for each commodity.

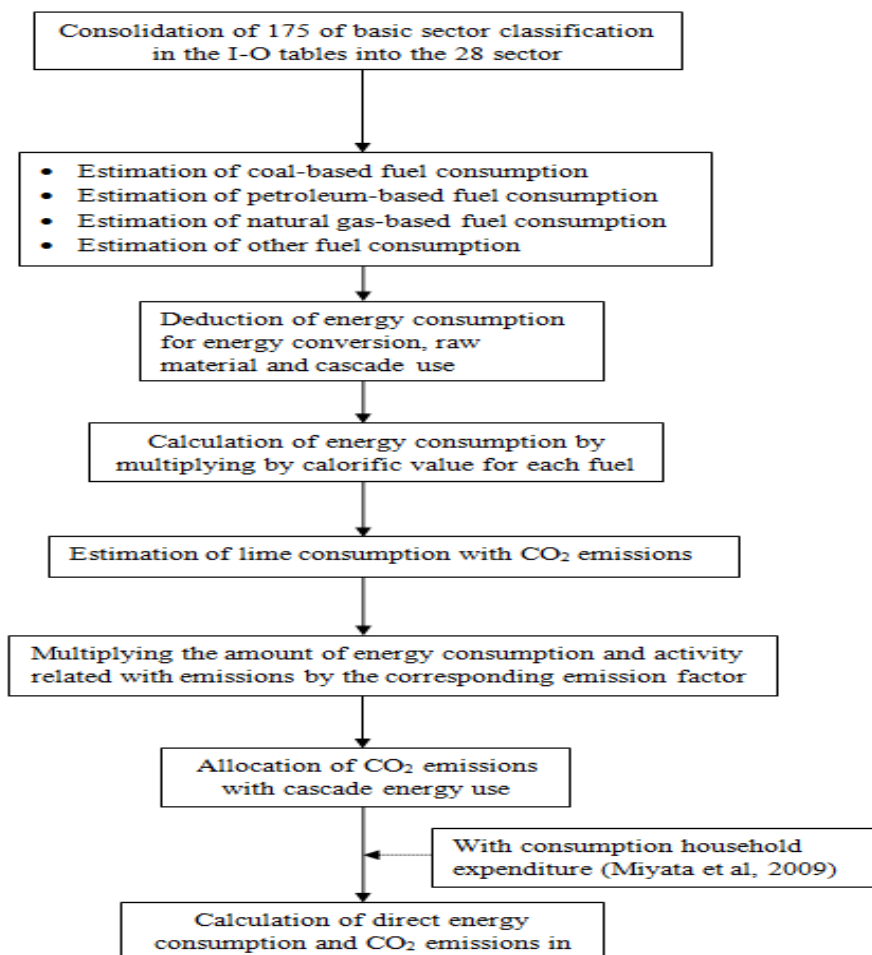


Figure: 5.1: Calculation Process for Embodied Energy and Emission Intensity in Each Sector (Source: Modification of Nansai et al., 2002)

Table 5.3: Emissions Intensities and Carbon Dioxide Emissions for Each Sector in 2006

No	Sectors	Intensity of CO ₂ Emissions t-CO ₂ /MRp	CO ₂ Emissions t-CO ₂
001	Food Crops	0.319	56,988.308
002	Plantation Crops	0.495	22,219.434
003	Livestock	0.251	6,807.967
004	Forestry	0.525	91.387
005	Fishery	1.386	294,518.322
006	Mining of oil and gas and non-oil and gas	0.495	3,130.547
007	Manufacture of food, beverages and tobacco	3.341	620,137.117
008	Manufacture of textiles, clothing and leather	1.071	4,448.002
009	Manufacture of wood, bamboo and furniture	0.126	2,826.503
010	Manufacture of paper and paper products, printing and publishing	1.782	9,232.334
011	Manufacture of chemicals, petroleum, coal, rubber and plastic products	20.364	87,726.732
012	Manufacture of cement non-metallic minerals	24.691	819,867.193
013	Manufacture of basic metals	7.173	22,680.110
014	Manufacture of fabricated metal	0.139	659.182
015	Other manufacturing	0.035	4.748
016	Electricity, gas and water supply	10.305	157,096.064
017	Construction/building	0.249	25,868.746
018	Trade	0.036	2,866.157
019	Hotels	0.044	0.972
020	Restaurants	0.168	3,122.555
021	Highway transportation	2.870	88,892.113
022	Other transportation	5.184	9,648.165
023	Communications	0.077	969.255
024	Banks and other financial institutions	0.008	639.886
025	Leasing, real estate and business services	0.037	1,955.915
026	Education	0.712	2,936.175
027	Health	0.246	131.187
028	Social services and other services	1.288	238,198.137
	Total of intermediate sectors	83.416	2,483,663.210
	Household consumption expenditures	0.065	85,264.657
	Total	83.481	2,568,927.867

Source: Authors' calculations

By using the I-O tables, we obtain embodied environmental burden intensity (embodied intensity) from the direct environmental burdens linked to goods' unit production activity.

In this database, the CO₂ emissions were calculated by multiplying the energy consumption value obtained for each fuel type by its corresponding carbon dioxide emission factor. Furthermore, in addition to fossil-fuel emissions, the CO₂ emissions emanating from limestone were considered. The direct emissions and CO₂ emission intensity of each sector were aggregated for each sector in the I-O table.

Using data from Miyata et al. (2009), we then used I-O analysis to calculate emissions intensities for consumption expenditures in the household sector. Table 5.3 presents emission intensities and CO₂ emissions based on the I-O table for Makassar City.

This research used Indonesia's 2012 Handbook of Energy and Economic Statistics of Indonesia (Ministry of Energy and Mineral Resources of Indonesia, 2012). However, not all necessary data were available and thus, this research used information data adjusted from the Japan data (Nansai et al, 2002). We assumed that Indonesia's technology is similar to that of Japan because most of Indonesia's sectors use technology made in Japan, especially automobiles, which consume a large amount of fuel. Japan's 399 sectors adjust to Indonesia's 175 sectors.

Chapter 6

The Impact of a Carbon Tax on the Economy of Makassar City

6.1 Introduction

A carbon tax is a policy instrument that can be applied to help constrain greenhouse gas emissions. Indonesia's policy goals in this respect were articulated in the Ministry of Finance Indonesia's Green Paper on Climate Change Commitment of the President of the Republic of Indonesia, presented at a G-20 conference (2010). The country's target is to reduce CO₂ emissions in 2020 to the equivalent of 6 % to 24 % below 2005 levels. The tax will be introduced at a rate that is calculated to reduce emissions to meet long-term goals.

The degree of abatement achieved is measured based on the estimated emissions level in 2006, which is considered the business-as-usual (BAU) scenario. In principle, the degree of abatement applies to all CO₂ emissions generated as a result of economic activity in at city. The use of fossil fuel accounts for 68.7 % of total emissions in Indonesia (2010).

Under the BAU scenario, the CO₂ emissions generated by the energy sector in Makassar City are estimated at 2.57 million tons for 2006. To achieve the target in the Green Paper, it will be necessary to reduce emissions by 154,000 to 616,000 tons relative to the BAU scenario. Under the scenarios considered in this study, a carbon tax is introduced at a rate that is calculated to reduce CO₂ emissions by 7 % to 8 % relative to 2006 levels. The tax applies to all commodities consumed

in the city. However, to avoid double taxation, the tax does not apply to either the export or distribution sectors.

6.2 Objectives

This study aimed to evaluate the impact of the carbon tax on urban economic performance which can be estimated in the change in household welfare.

6.3 Methodology

The study provides a detailed evaluation of the impacts of the carbon tax on production, consumption and urban economic performance. This research uses a computable general equilibrium (CGE) model, which is a quantitative method to estimates the impact of economic and policy shocks, particularly those affecting the entire economy. The model realistically reproduces the structure of the overall economy and therefore the nature of all existing economic transactions among diverse economic agents (productive sectors, household, the government, and external sectors). The results from the CGE model are expected to reveal that the carbon tax will have significant impact throughout the economy.

The main data used in this study are based on the 2006 input-output table with 28 sectors and a social accounting matrix table (SAM) for Makassar City. Data from other sources (such as elasticity values, exchange rate, etc.) are used to complete input-output table data.

The carbon tax will initially be set at a rate of Rp. 10,000/t-CO₂, which is equivalent to US \$1/t-CO₂. The model employs the carbon tax rate applied in

India and operates under the assumption that Makassar city exhibits an economic structure that is sufficiently similar to that of India. The results presented below estimate the effects of the carbon tax on the city's economic activity.

6.4 Simulation Scenarios

This article considers two representative CO₂ restriction policies, a carbon tax without transfers and a carbon tax in which all revenues are transferred to households. The impacts of these policies are compared with the BAU scenario.

This study considers three scenarios:

- (1) Baseline scenario (BAU): this scenario was simulated to reproduce the baseline SAM of Makassar City, Indonesia;
- (2) Scenario 1: a carbon tax of 0.01 MRp/t-CO₂ is imposed on all industries emitting CO₂; and
- (3) Scenario 2: a carbon tax of 0.01 MRp/t-CO₂ is imposed on all industries, and the revenues are transferred to households.

6.5 Business-as-usual (BAU) Condition

The BAU (the baseline or benchmark) condition is the starting point equilibrium. This scenario implies no policy when the economic growth has no limits. The BAU was determined by calibrating all the function's forms for all the economic agents in the model.

Table 6.1 shows that CO₂ emissions that are generated by industries and households are estimated at 2.57 million ton for 2006.

Table 6.1 Economic Conditions under the BAU Scenario

Industries	Denoted	CO ₂ Emissions	Industrial Outputs	Municipal GDP	Labor Demand of Industry	Capital Demand of Industry
	Total (Ind+Household)	2,568,927.867				
	Total	2,483,663.210	1,314,895	864,836	301,787	542,878
Food Crops	Sector 1	56,988.308	178,467	162,341	24,970	136,041
Plantation Crops	Sector 2	22,219.434	44,895	36,788	8,740	27,731
Livestock	Sector 3	6,807.967	27,156	21,477	4,060	17,183
Forestry	Sector 4	91.387	174	154	30	122
Fishery	Sector 5	294,518.322	212,552	171,646	38,444	132,429
Mining of oil and gas and non-oil and gas	Sector 6	3,130.547	6,327	5,743	2,210	3,410
Manufacture of food, beverages and tobacco	Sector 7	620,137.117	185,627	36,912	8,518	25,605
Manufacture of textiles, clothing and leather	Sector 8	4,448.002	4,153	1,569	314	1,228
Manufacture of wood, bamboo and furniture	Sector 9	2,826.503	22,433	11,200	2,968	7,921
Manufacture of paper and paper products , printing and publishing	Sector 10	9,232.334	5,182	2,270	598	1,589
Manufacture of chemicals, petroleum, coal, rubber and plastic products	Sector 11	87,726.732	4,308	292	106	165
Manufacture of cement non-metallic minerals	Sector 12	819,867.193	33,205	21,564	5,708	12,862
Manufacture of basic metals	Sector 13	22,680.110	3,162	598	197	351
Manufacture of fabricated metal	Sector 14	659.182	4,734	1,995	1,192	693
Other manufactures	Sector 15	4.748	136	45	17	24
Electricity, gas and water supply	Sector 16	157,096.064	15,245	8,235	1,774	6,360
Construction/building	Sector 17	25,868.746	104,079	41,208	22,417	16,619
Trade	Sector 18	2,866.157	78,734	71,421	16,095	50,479
Hotels	Sector 19	0.972	22	12	3	8
Restaurants	Sector 20	3,122.555	18,625	5,170	1,964	2,804
Highway transportation	Sector 21	88,892.113	30,969	24,566	5,445	18,725
Other transportation	Sector 22	9,648.165	1,861	911	251	638
Communications	Sector 23	969.255	12,580	10,245	2,744	7,358
Banks and other financial institutions	Sector 24	639.886	77,520	37,042	11,510	25,114
Leasing, real estate and business services	Sector 25	1,955.915	53,088	46,866	4,935	39,480
Education	Sector 26	2,936.175	4,121	714	493	206
Health	Sector 27	131.187	534	236	84	146
Social services and other services	Sector 28	238,198.137	185,006	143,616	136,000	7,587

Source: Authors' calculations

The largest CO₂ emissions were derived from the following: the manufacture of cement non-metallic minerals (819,867.19 t-CO₂); the manufacture of food, beverages and tobacco (620,137.12 t-CO₂); and the fishery (294,541.32 t-CO₂). These sectors are assumed that the greatest energy users in their industry technology process. On the production side, the sectors with the largest output are the fishery (212,552); the manufacture of food, beverages and tobacco (185,627); and social services and other services (185,006). The greatest income for the city

is that collected from the fishery (171,646); the food crops (162,341); and social services and other services (143,616).

The Largest demand for labor is predicted to come from food crops (136,000); the fishery (38,444); and the manufacture of food, beverages and tobacco (24,970).

The largest capital demand comes from food crops (136,041); the fishery (132,429); and the trade (50,479).

6.6 Simulation Results

The effects of the simulated scenarios were analyzed in terms of their impact on economic variables.

This section presents the simulation results with respect to certain important economic variables which are explained below.

6.6.1 CO₂ Emissions

The manufacture of cement and non-metallic minerals and the manufacture of food, beverages and tobacco generated the greatest CO₂ emissions in the baseline scenario: 819,867.19 tCO₂ and 620,137.12 t-CO₂, respectively. The carbon tax reduced overall CO₂ emissions by 8.04 % (scenario 1) and 8.25 % (scenario 2). Households responses to the carbon tax policies resulted in increased CO₂ emissions of 7.78 % in scenario 1 and 7.94 % in scenario 2.

CO₂ emissions declined in 13 sectors in scenario 1 and 14 sectors in scenario 2. The decline ranged from 0.17 % to 19.81 %. The largest changes occurred in the manufacture of cement and non-metallic minerals (19.81 % in scenario 1 and

19.77 % in scenario 2) and in the manufacture of chemicals, petroleum, coal, rubber and tobacco (17.71 % in scenario 1 and 17.39 % in scenario 2).

However, CO₂ emissions increased in 15 sectors in scenario 1 and in 14 sectors in scenario 2. The increase from 0.002 % to 656.86 % and the largest changes were observed in other manufactures (335.42 % in scenario 1 and 656.86 % in scenario 2) and forestry (101.98 % in scenario 1 and 125.65 % in scenario 2). Figures 6.1 and 6.2 depict the changes in each sector.

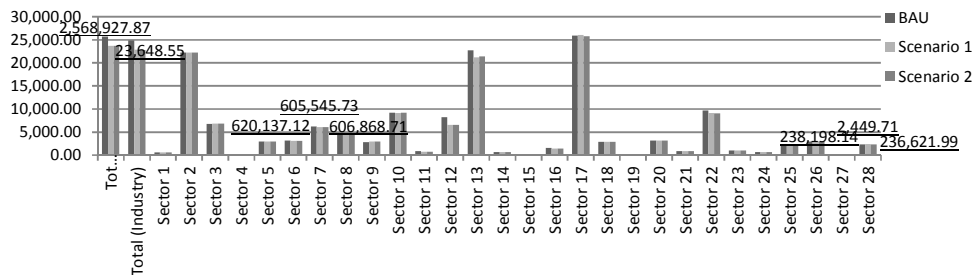


Figure 6.1: CO₂ Emissions

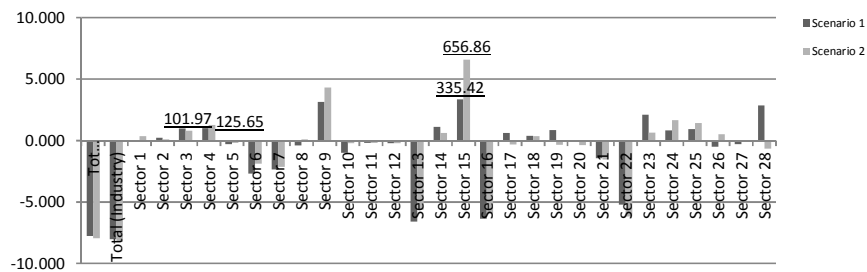


Figure 6.2: Changes in CO₂ Emissions

6.6.2 Industrial Outputs

The baseline scenario indicates that the largest sectors in terms of output were fishery; the manufacture of food, beverages and tobacco; and social services and other services. Conversely, the hotels, other manufactures and forestry sectors produced slightly higher output. The imposition of the carbon tax resulted in

changes to output. The changes in industrial outputs are depicted in Figures 6.3 and 6.4. Total industrial outputs of industry declined in each scenario by: 0.38 % in scenario 1 and 0.74 % in scenario 2.

Nearly identical numbers of sectors experienced changes in output (both positive and negative) in the scenario 1 and scenario 2. The following sectors exhibited increased output: food crops; plantation crops; livestock; forestry; the manufacture of fabricated metal; other manufactures; constructions/buildings; trade; hotels; restaurants; communications; banks and other financial institutions; leasing, real estate and business services; and social services and other services. The other manufactures (335.42 %) and forestry (101.98 %) sectors exhibited the greatest increases in output in scenario 1. Small increases were observed in other sectors. These increases indicate that these sectors benefited from the imposition of the tax. In contrast, the manufacture of cement and non-metallic minerals (19.81 %) and the manufacture of chemicals, paper products, printing and publishing (17.71 %) were harmed by the carbon tax, and these sectors exhibited the greatest declines in outputs. The declines observed in other sectors were relatively small.

The simulation results for scenario 2 exhibited relatively small differences from the values observed for scenario 1. Similar to scenario 1, increases in outputs occurred in food crops; plantation crops; livestock; forestry; the manufacture of fabricated metal; other manufactures; trade; communications; banks and other financial institutions; leasing, real estate and business services; education; and healthcare. The other manufactures and forestry sectors presented the largest increases in output in response to the city's policy: 656.86 % and 125.65 %,

respectively. Conversely, the largest declines were observed in the manufacture of cement and non-metallic minerals (19.77 %) and in the manufacture of chemicals, paper products, printing and publishing (17.39 %).

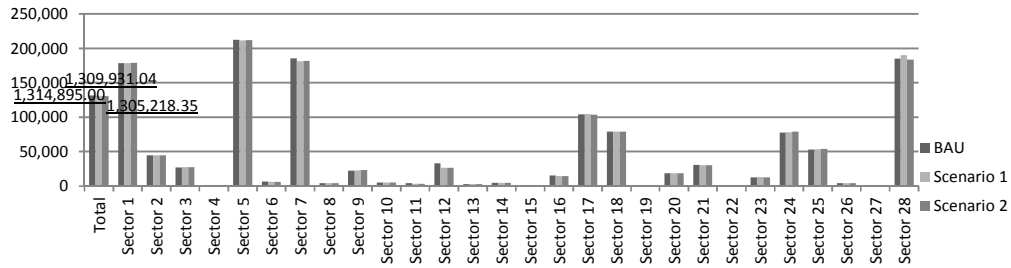


Figure 6.3: Industrial Output

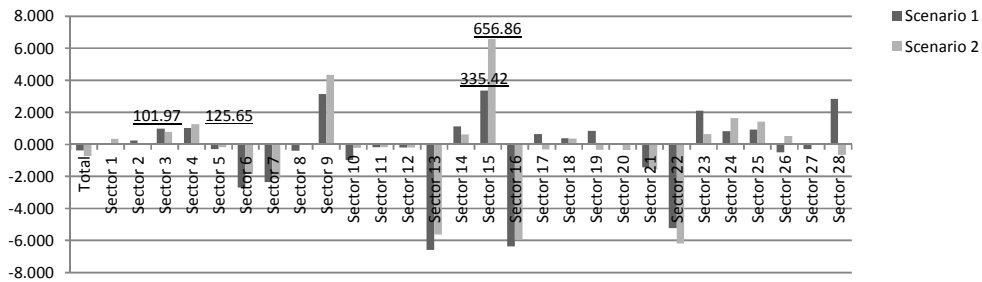


Figure 6.4: Changes in Industrial Output

6.6.3 Municipal GDP

The largest contributions to the municipal GDP under the BAU scenario were made by following sectors: fishery; manufacture of food, beverages and tobacco; and social services and other services. The impacts of the carbon tax policy are presented in Figure 6.5 and 6.6. Overall, the GDP has declined by more than 19 % for each scenario. In scenario 1, 13 sectors contributed to the decline in GDP, compared with fourteen sectors in scenario 1. Sectorial declines ranged from approximately 0.17 % to 19.80 %. The manufacture of cement and non-metallic

minerals and the manufacture of chemicals, petroleum, coal, rubber and plastic products exhibited the largest declines in each scenario.

However, these declines were accompanied by increases in other sectors. Contributions to increased GDP were observed 15 sectors in scenario 1 and 14 sectors in scenario 2, ranging in magnitude from approximately 0.004 % to 656.88 %. The largest changes occurred in the other manufactures (335.44 % in scenario 1 and 656.88 % in scenario 2) and forestry (101.98 % for scenario 1 and 125.66 % for scenario 2) sectors.

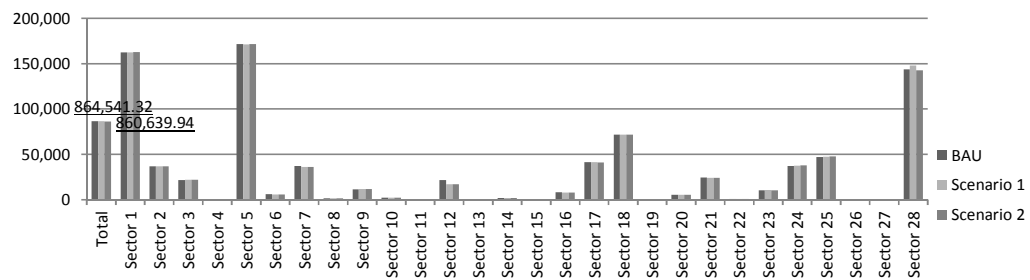


Figure 6.5: Municipal GDP

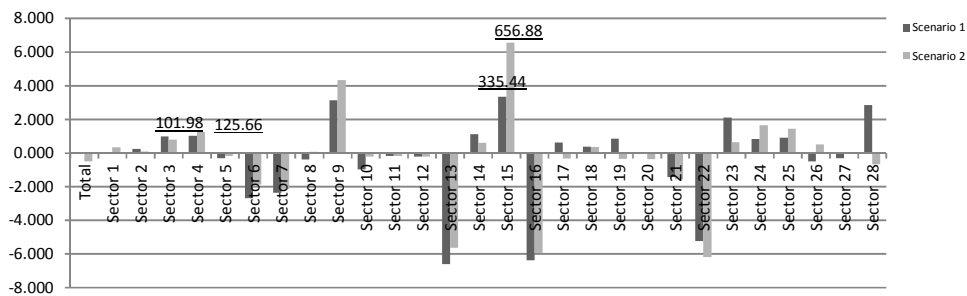


Figure 6.6: Changes in Municipal GDP

6.6.4 Labor Demand

Figures 6.7 and 6.8 indicate that labor demand generally responded negatively to the carbon tax policies in the sectors considered. Labor demand declined in 22 sectors in scenario 1 and twenty-one sectors in scenario 2; overall, labor demand

declined by approximately 0.01% to 1.2%. The greatest changes occurred in the manufacture of cement and non-metallic minerals (20.90 % in scenario 1 and 20.54 % in scenario 2) and the manufacture of chemicals, petroleum, coal, rubber and tobacco (18.70 % in scenario 1 and 18.09 % in scenario 2).

Certain sectors responded positively to the carbon tax policies in terms of labor demand. In particular, six sectors in scenario 1 and seven sectors in scenario 2 exhibited increased labor demand, ranging from 0.1 % to 650.73 %. The other manufactures (98.80 % in scenario 1 and 123.15 % in scenario 2) and forestry sectors (330.41 % in scenario 1 and 650.73 % in scenario 2) exhibited the greatest increases in labor demand.

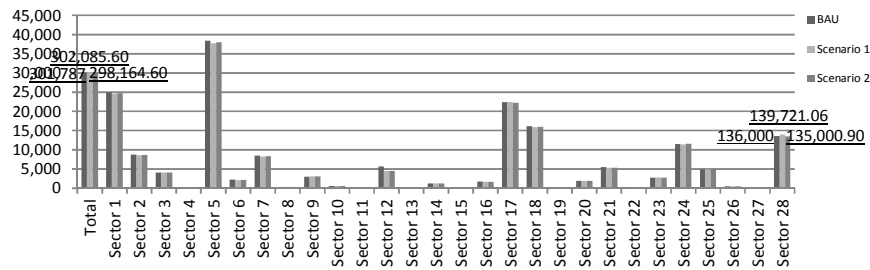


Figure 6.7: Labor Demand

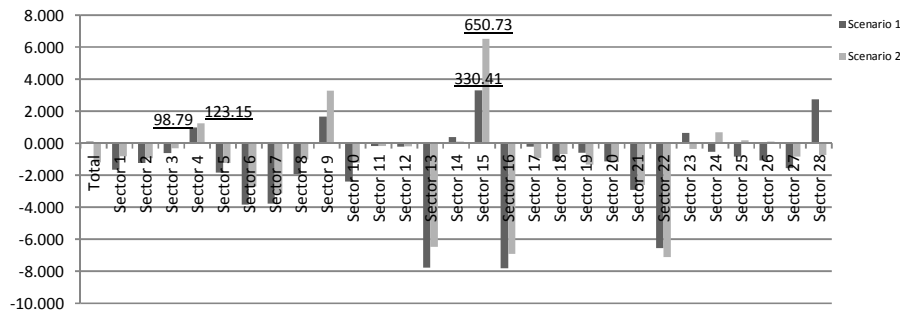


Figure 6.8: Changes in Labor Demand

6.6.5 Capital Demand

Regarding the changes in the demand for capital by industry depicted in Figures 6.9 and 6.10, the pattern of changes differs substantially from that observed for labor demand. Increased demand for capital is observed in 19 sectors in scenario 1 and in 20 in scenario 2. Thus, the demand for capital responded positively to the carbon tax programs. The largest positive responses were observed in the other manufactures (339.007 % in scenario 1 and 661.23 % in scenario 2) and forestry (102.77 % in scenario 1 and 126.27 % in scenario 2) sectors.

Declines in the demand for capital were observed in nine sectors in scenario 1 and in eight sectors in scenario 2; these declines range from 0.44 % to 19.43 %. The manufacture of cement and non-metallic minerals (19.32 % in scenario 1 and 19.43 % in scenario 2) and the manufacture of chemicals, petroleum, coal, rubber and tobacco (17.07 % in scenario 1 and 16.94 % in scenario 2) exhibited the largest declines.

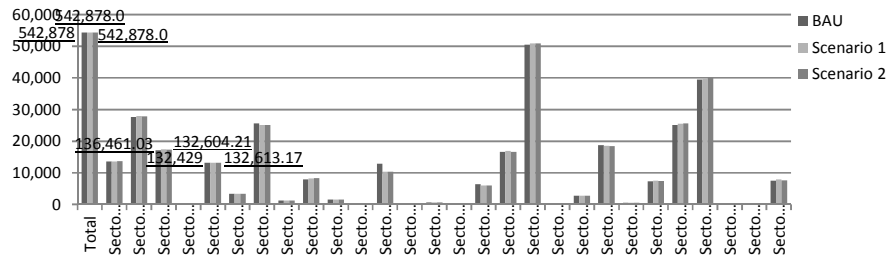


Figure 6.9: Capital Demand

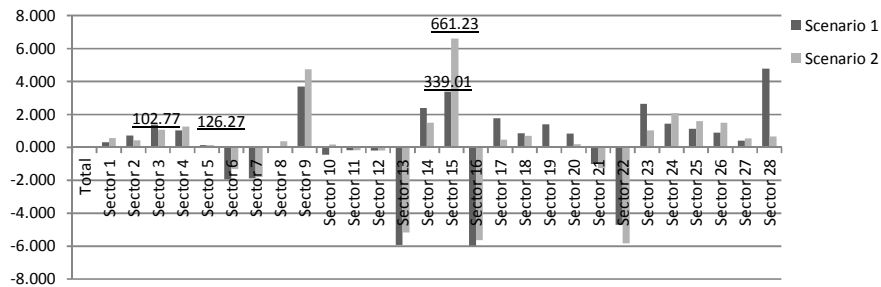


Figure 6.10: Changes in Capital Demand

6.6.6 Commodity Prices

Figure 6.11 shows price changes for all sectors. The carbon tax increased output prices by an average of 2.32 % in scenario 1 and 2.61 % in scenario 2, and these changes were particularly pronounced in sectors characterized by the heavy use of energy-intensive commodities. The differences between scenarios 1 and 2 with respect to price changes are not large.

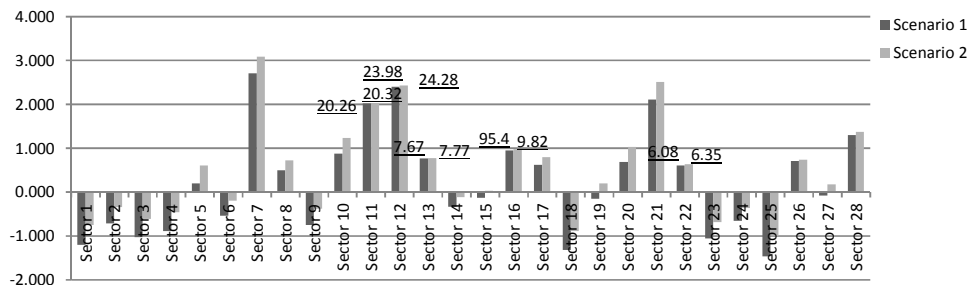


Figure 6.11: Commodity Prices

6.6.7 Other Variables

As depicted in Figures 6.12 and 6.13, household income did not change significantly, exhibiting an increase of 0.12 % in scenario 1. However, as the price of the composite consumption good increased by 0.34 %, household consumption declined by 0.17 %. Moreover, leisure time increased by 0.01 %, and household savings declined by 0.42 %. As result, equivalent variation reveals a welfare gain loss of 0.5 billion rupiah.

Regarding the government sector, in scenario 1, the imposition of a carbon tax reduced revenue from net indirect taxation by 4.3 %. However, total government revenue increased by 4.79 %, which led to increase government consumption and current transfers to households and the external sector and led to reduce government savings.

In scenario 2, household income increased by 1.3 %, including the effect of the direct tax on households. The household income net of the direct tax was increased by 1.28 % relative to the baseline scenario. Following the increase in household income, household composite consumption increased by 0.86 %, leisure time increased by 1.14 % and household savings increased by 0.82 %. As result, equivalent variation indicates a welfare gain of 1.33 billion rupiah.

Regarding the government sector, revenue from the net indirect tax declined by 3.82 %. Government revenues from households decreased by 0.26 %, whereas total government revenue increased by 0.61 %. Because of this increase, government expenditures, current transfers to households and to the external sector and government savings increased.

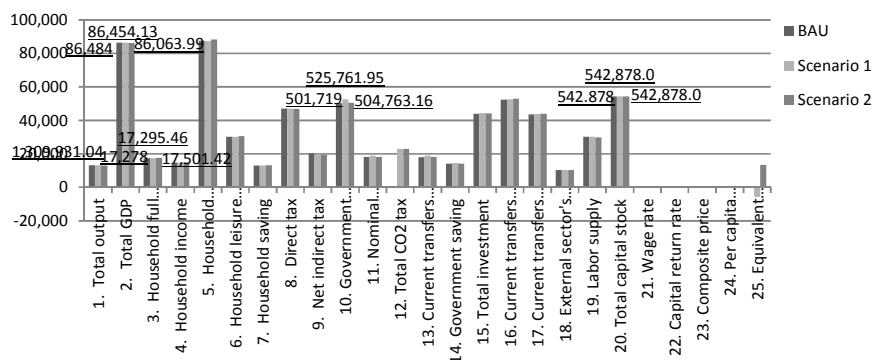


Figure 6.12: Other Variables

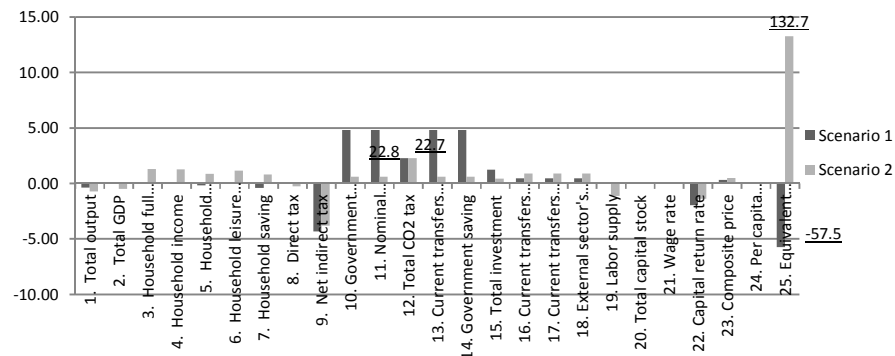


Figure 6.13: Changes in Other Variables

Note:

1) Industrial output, 2) GDP, 3) Full income, 4) Household income, 5) Composite consumption, 6) Leisure time, 7) Household saving, 8) Direct tax, 9) Net indirect tax, 10) Government revenue, 11) Government consumption, 12) Total CO₂ tax, 13) Current transfers from the government to households, 14) Government saving, 15) Total investment, 16) Current transfers from the external sectors to households, 17) Current transfers from the external sector to the government, 18) External sector's saving, 19) Labor supply, 20) Total capital stock, 21) Wage rate, 22) Capital return rate, 23) Composite price, 24) Per capita equivalent variation and 25) Equivalent variation.

6.7 Conclusions and Policy Implications

6.7.1 Conclusions

In 2003, fossil fuels accounted for approximately 95 % of primary energy used in Indonesia, which indicates that a carbon tax would thus impose costs on the economy. Simulating these scenarios against the baseline/benchmark shows the following:

- The impact of a carbon tax in scenario 1.

The carbon tax in scenario results in reduced CO₂ emissions (7.8 %), but it increases the prices of fossil fuels, which, in turn, raises production costs and ultimately drive up prices (2.39 %) for goods and services throughout the economy. The changes in prices encourage to the household to use less or to make changes that result in preferring and selecting commodities that involve lower emissions of commodities; using savings to consume such goods leads to a reduction in savings of 0.4 %.

The increased prices of fossil fuels also result in lowering the economy's total industrial outputs (0.378 %), thus reducing the real wages and the amount that people work, which ultimately decrease the overall supply of labor (characterized by an increase in labor demand of 0.1 %).

In summary, the carbon tax under scenario 1 reduces CO₂ emissions but also reduces economic growth, as shown municipal GDP decreasing by 0.03 % and because welfare as characterized by the equivalent variation value is negative during the same period.

- The impact of a carbon tax on all revenue in scenario 2.

The amount of CO₂ emissions continues to decline. Facing of the rise in commodity prices (2.69 %), all revenues from a carbon tax transferred to households lead to increased household income (1.3 %) and savings (0.8 %), which thus encourage to households to raise consumption (0.9 %).

Lower real wage effects include decreasing labor supply (1.1 %) and labor demand (1.2 %).

In summary, all revenue from a carbon tax reduce CO₂ emissions (8 %) and keeps economic growth in decline, as shown by decreasing municipal GDP 0.5 %, but the welfare of society increases, as shown by the positive value of equivalent variation value.

Based on the study results, it can be concluded that an urban economic change occurs and affects household welfare, which is characterized by the value of equivalent variation. As a result, the implementing of carbon tax policies generally had a negative impact on the economy of Makassar City in scenario 1 and a positive impact in scenario 2, despite the fact that the total municipal GDP declined in all the simulation scenarios. Because of the effects of government transfers on households, household consumption declined in scenario 1 but increased slightly in scenario 2. As a result, savings in the external sector increased.

Government revenue increased in all scenarios. The costs of production increased following declines in output prices. The declines in sectorial outputs resulted in a negative impact on household utility in scenario 1.

6.7.2 Policy Implication

The results of this study show that the implementing of a carbon tax to reduce CO₂ emissions will reduce economic growth. The tax levy motivates industries and households throughout the economy to undertake the least costly reductions in emissions. Strong efforts are required to encourage the application of the tax in manner that increases economic growth.

The government might allow certain types of exemption without jeopardizing the goal of minimizing the cost of reducing emissions. For example, it already exempts some sources of emission from the tax, such as commercial vehicles. The increase in production costs can be reduced by providing industrial incentives. Such incentives might be combined with the use of low-carbon intermediate inputs such that industry is able to raise the capital that ultimately raises real wages and encourages increases in labor supply. The energy supply side must reduce emissions and engage in carbon capture and storage.

The government should also impose regulations that encourage utilizing renewable energy resource and innovative low-carbon technologies to ensure that carbon emissions targets are met.

Chapter 7

Conclusions and Recommendations for Future Research

7.1 Conclusions

This dissertation studied environmental economic analysis based on an AHP using a structural economic model to establish efficient economic and environmental policy. Economic and environmental policy is efficient if the achievement is obtained with the minimum possible environmental impact without compromising its economic purposes. This study achieved its three primary objectives. This study's first achievement is its normative of the importance of evaluating the economy and the environment to achieve sustainable development. Theoretically, this study evaluated an environmental economic system through the efficiency of economic and environmental integration. This study's second achievement is its application of a standard approach to policy-making, the efficiency of which is demonstrated by sharing it with other approaches. This study empirically evaluated decision-making based on the economic and environmental indicators of community preferences for a regional road construction project in Makassar, Indonesia. This study's third achievement is its empirical simulation of how to reduce CO₂ emissions through carbon tax policy without sacrificing Makassar City's economic welfare. The final chapter summarized the primary results of this study.

Chapter 1 evaluated environmental economics through economic and environmental interaction for sustainable development. This interaction is the basis for environmental and economic accounting.

The study then took an AHP approach to policy-makers who set tentative targets to optimize decisions characterized by the existence of multiple conflicting objectives and interests. These observations were described in Chapter 2. This chapter presented the approach using criteria that significantly contribute to the operation and in road construction process to maintain environmental sustainability. This study broadened the method's scope to consider both its economic and environmental dimensions. This approach is particularly relevant to and suitable for current environmental concerns. Therefore, it stressed the joint determinant of environmental and economic policies. The approach can be helpful to make environmental and economic policy decisions in practice and to support policy-makers in the decision-making process. Chapter 2 demonstrated how to estimate the amount of CO₂ emissions caused by economic activities. The results showed that public preferences consider environmental sustainability without sacrificing economic growth, proven efficient through economic resource. The economic and environmental efficiency presented in the concept of the model showed that output production used resources with a lower environmental impact.

Chapter 3 reviewed general equilibrium theory beginning with its origins and discussed how the theory evolved into applied models. Chapter 3 also reviewed the economic agents of an applied equilibrium model and how to choose a functional form and build the benchmark equilibrium counterfactual for the simulation scenarios model.

Chapter 4 developed the standard structure of the static CGE model that followed the Walrasian tradition of Makassar City. All the models used in these

studies confirm the basic principles of the Walrasian equilibrium. Taxes and the government are considered exogenous by both households and industries. The model also includes an external sector, the activity level of which is assumed fixed in that total imports and exports are not sensitive to government policy changes. This assumption is consistent with the small-country hypothesis and a short-term approach to policy design. The equilibrium of the economy is given by a price vector for all goods and inputs, a vector of activity levels and a value for public income. Accordingly, the industry sector maximizes its profits, the household maximizes his or her utility, government income equals the payments of all economic agents, and supply equals demand in all markets. The model depicted that allocative efficiency is the economic unit's ability to minimize the cost of production for input prices that replace the inputs.

Apart from constructing a CGE model, this methodology requires several additional elements, such as a suitable database to calibrate the model and to make it applicable to and consistent with reality. These elements were described in Chapter 5, which presented several applications using data from Makassar. Chapter 5 also discusses an SAM table suitable for the model and considered CO₂ emission intensity based on an I-O table for Makassar City in 2006.

Chapter 6 showed the simulation results of scenarios after calibration. Chapter 6 also depicted counterfactual, business-as-usual scenarios and how emissions changes are incorporated into the model. These simulations described the impact of CO₂ emission reduction by imposing a carbon tax on industries, with all revenue from taxes transferred to households. The impact of the implementation

of the carbon tax varies among industries and the performance of Makassar City's. The results showed that a carbon tax had a negative impact on industry outputs, the commodity price increased, and the level of household consumption and welfare decreased. The change in welfare was quantified by equivalent variation. Equivalent variation is the adjustment in income that changes the household's utility equal to the level that would occur if the event had taken place. The welfare of households increased after receiving transfer carbon tax revenues from the government.

7.2 Discussion and Recommendations for future research

Several problems and limitations of this study and its analysis should be emphasized.

1. This research collected public preferences from professionals who were experts in road planning and development. These experts were government officials, planners, engineering supervisors and academics. Additional types of professionals would further develop the environmental criteria.
2. This research used simplified assumptions to keep the CGE model manageable, understandable and plausible to future developments. Simplifications were made regarding how different market interaction has been modeled. These generalizations included the small-country hypothesis and overlooking international relationship both at the economic and the environmental levels.

3. This research was confined to a static, short-term approach. Upgrading the model would be too complicated at this stage. A dynamic framework that could be developed in future extensions would address variety of interesting additional issues such as the long-term sustainability of environmental issues.
4. This research assumed that CO₂ emissions intensity is constant. More industry activity implies that more CO₂ emissions are a unidirectional effect of the economy on the environment. This assumption implicitly neglects the possibility that industries engage in abatement activities in clean technology. It might be relevant to conduct a long-term analysis that considers the opposite effect i.e., the impact of environmental quality on the economy.

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