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# Environmental and Economic Impact of Carbon Credit in Makassar City in Indonesia

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## 1. Introduction

Recently, global warming is recognized as a global-scale problem. The average world ground temperature has risen during 1880-2012 at 0.85°C according to the fourth evaluation report of Intergovernmental Panel on Climate Change (IPCC). And it is also clarified that the average world ground temperature in each ten year interval in the past 30 years shows a higher temperature as compared with those in any ten years after 1850. Moreover, it has been reported that there is a possibility that the water temperature rises in the oceanic depths of more than 3000m during 1992-2005. It has been said that, in order to suppress an increase in the global temperature as compared with that at the end of 20th century by 2°C, it is necessary to reduce 15-50% of current CO<sub>2</sub> emissions by 2050. It is thought that such a change in the natural environment exerts a large impact on our society. It is forecasted that there is a risk of receiving the loss of about 20% of world GDP in our society due to a decrease in firms profits or an increase in countermeasure costs through the dryness of the fresh water resource and the aggravation of the food problem through the impact on agriculture and fishery industries and a change in the biota. It is considered that measures for controlling global warming are urgent matters because it is expected that the cost for suppressing the global warming gases is estimated to be smaller than the recovering cost of the damage by the global warming.

Economic measures are advanced toward environmental problems in EU nations. The economic approach imposes a constant economic load on activities negatively affecting the environment, and it is also a technique for giving a constant profit for activities conserving the environment. The whole society is expected to be environmental-friendly state by this incentive. Moreover, this method has the advantage for inventing new technologies and efficient production processes. The direct regulation is pointed out as an environmental conservation measure. However dependence on the regulatory control has the anxiety to reduce the economic vitality of firms. Therefore, the economic approach that does not decrease inventiveness and the autonomy of each firm becomes important.

Carbon credit can be taken as one of the economic measures for controlling global warming. The upper limits of CO<sub>2</sub> emissions are assigned to each firm or country, and the carbon credit is defined as a credit of the volume of CO<sub>2</sub> emissions generated by economic activities. The mechanism in which the total CO<sub>2</sub> emission is controlled by buying and selling the carbon credit is called emission right trading.

The present study focusses on the carbon credit. Although researches on environmental and economic impact by carbon credit at a country level have already been conducted, studies on such a topic in developing countries emitting large CO<sub>2</sub> and/or a city level have hardly been found. Hence, the present study analyzes the environmental and economic impact of introduction of carbon credit in Makassar City, which is a main city in east Indonesia, by employing a computable general equilibrium (CGE) model.

The reason selecting Indonesia as a study country is that CO<sub>2</sub> emissions in Indonesia considering the slash-and-burn agriculture and the peaty land are ranked at the third position in the world. The reason selecting Makassar City as a study region is that there is an enough forest in surroundings of Makassar City and a big amount of the CO<sub>2</sub> forest absorption can be expected for issuing the carbon credit. Moreover, it is another reason that there is an input-output table in Makassar City, and data that is necessary to construct a computable general equilibrium model is available.

In this paper, Makassar City is assumed to issue a carbon credit and sell it to other regions. Numerical

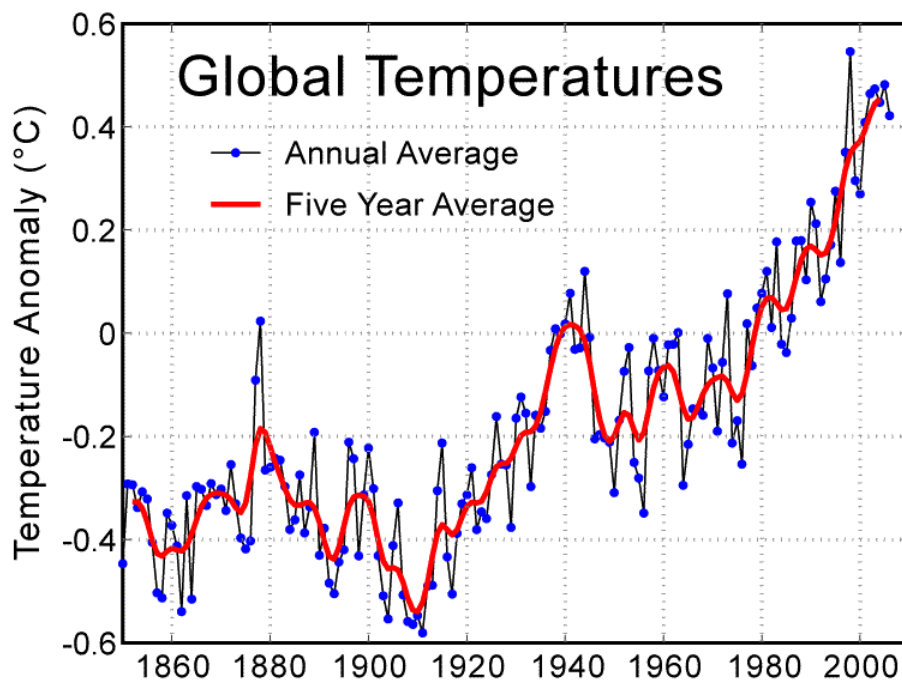
simulations are implemented to analyze the environmental and economic impact of the carbon credit.

Makassar City is located in the southern area in Sraweshi island in Indonesia, and is a capital city of South Sraweshi state. The population is 1.33 million and the area size is 175.77 km<sup>2</sup>, and is main port in this area with the periodical domestic and international shipment. The role of Makassar City is important due to these periodical shipments.

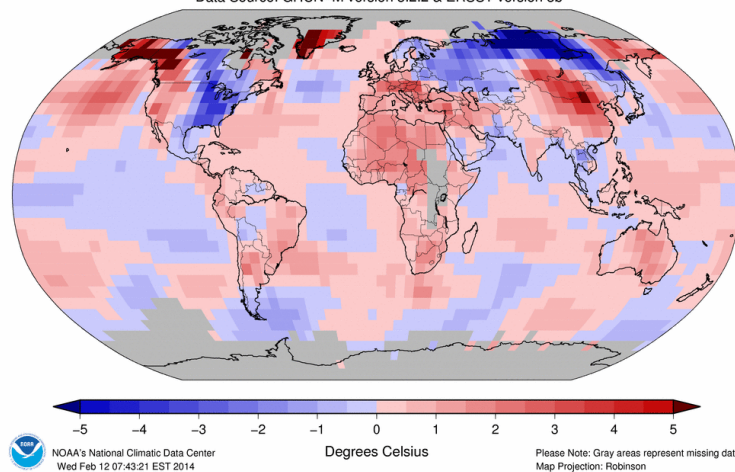
## 2. Carbon Credit

Carbon credit implies an economic method to reduce CO<sub>2</sub> emissions. That is, the trading of CO<sub>2</sub> emission right with a property right results in an economic loss if CO<sub>2</sub> emissions are not cut, and conversely it leads to an economic benefit if there is an effort to reduce CO<sub>2</sub> emissions.

Carbon credit also means a CO<sub>2</sub> reduction certificate which is tradable between different regions. If a country/



Land & Ocean Temperature Departure from Average Jan 2014  
(with respect to a 1981–2010 base period)  
Data Source: GHCN–M version 3.2.2 & ERSST version 3b



**Figure 1. Global Average Temperature**

region emits CO<sub>2</sub> over a permitted CO<sub>2</sub> discharge level which is necessary to archive a certain economic output, the country/region can purchase a necessary CO<sub>2</sub> discharge permit from a country/region where CO<sub>2</sub> emission permit is in surplus. This certificate of discharge is tradable between countries/regions as a credit.

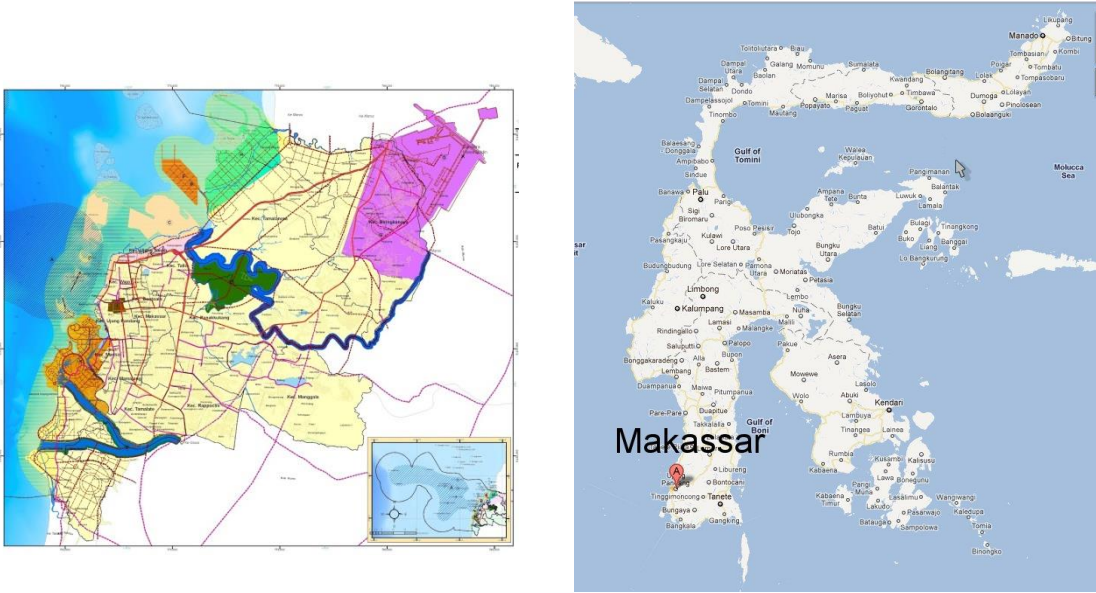


Figure 2. Location of Makassar City

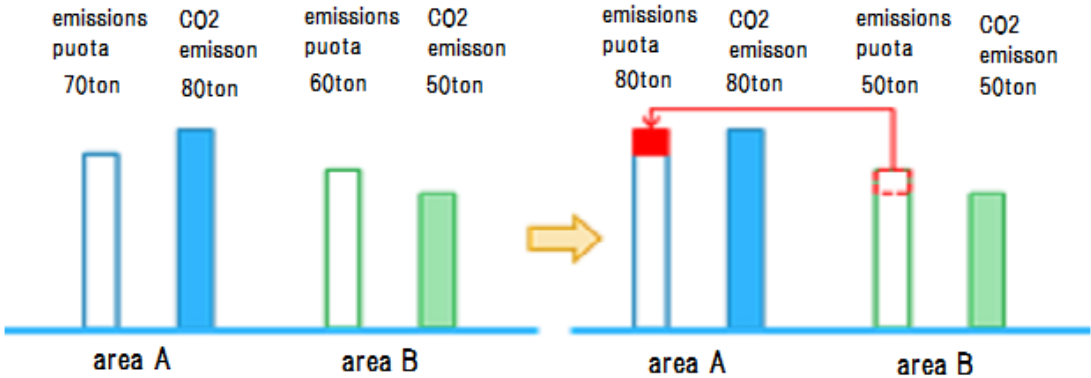


Figure 3. Trading of Carbon Credit

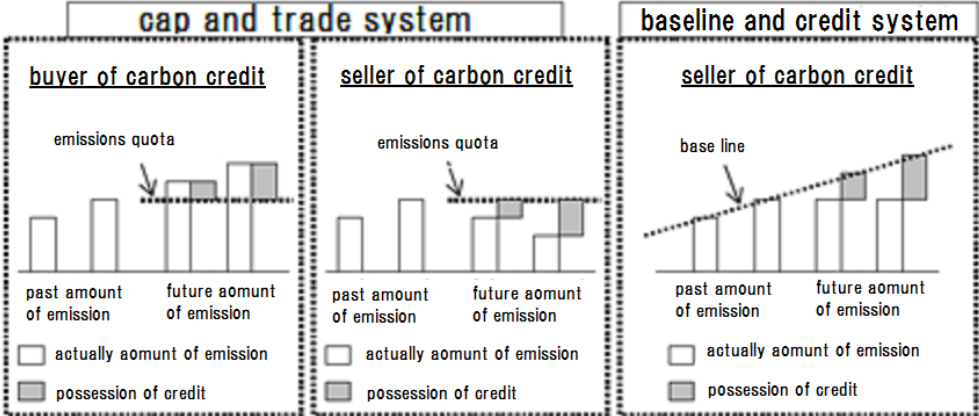


Figure 4. Design of Carbon Credit Trading Scheme

There are two basic institutional schemes in CO<sub>2</sub> emission trading, namely, Cap & Trade scheme and Baseline & Credit scheme. In the Cap & Trade scheme, firstly, a CO<sub>2</sub> emissions quota (cap) is assigned to each firm or region. Firms or regions with CO<sub>2</sub> emissions surplus can sell that surplus as a credit to other firms or regions which need to emit CO<sub>2</sub> more than the cap. Conversely if a firm or region with shortage of allowance, the firm or region must buy the credit to achieve the CO<sub>2</sub> reduction target (trade). Trading of CO<sub>2</sub> emissions permit in Kyoto Protocol and the European Union Greenhouse Gas Emission Trading Scheme (EUETS) are the representative carbon credits.

The Baseline & Credit scheme is an institution in which some projects are assumed to reduce CO<sub>2</sub> emissions. In the Baseline & Credit scheme, future CO<sub>2</sub> emissions without a CO<sub>2</sub> emission reduction project are forecasted based on the past trend of CO<sub>2</sub> emissions. This future volume of CO<sub>2</sub> emissions is set up as a standard value (baseline). On the other hand, if the project can reduce CO<sub>2</sub> emissions under the baseline, the difference between the baseline and the reduced CO<sub>2</sub> emissions is given to the project conductor as a credit. This is a description of the Baseline & Credit scheme. Famous examples of this scheme are pointed out as Clean Development Mechanism in Kyoto Protocol and Joint Implementation (JI).

From the sources of CO<sub>2</sub> generation, CO<sub>2</sub> emission trading quota is classified into Assigned Amount Unit (AAU), Removal Unit (RMU), Certified Emission Reductions (CER) and Emission Reduction Unit (ERU). AAU implies CO<sub>2</sub> emissions (amount of the greenhouse gas emissions measured by t-CO<sub>2</sub>) assignment to each country or region. RMU depicts the carbon credit issued with CO<sub>2</sub> emission absorption by afforestation and reforestation. CER expresses a carbon credit issued with a reduction in CO<sub>2</sub> emissions by technological aid for developing countries. ERU refers to a carbon credit issued with a reduction in CO<sub>2</sub> emissions generated by joint project between developed countries. Each scheme enables to cancel a part of CO<sub>2</sub> emissions corresponding to a reduction in CO<sub>2</sub> emissions in each scheme. The carbon credit market has been being growing showing 30% growth from 2008 to 2011.

**Table 1. The World Market of Carbon Credit Trading (Volume and Value)**

	2008		2009		2010		2011	
	volume of carbon emission trading (billion tons)	value of carbon emission trading (billion dollars)	volume of carbon emission trading (billion tons)	value of carbon emission trading (billion dollars)	volume of carbon emission trading (billion tons)	value of carbon emission trading (billion dollars)	volume of carbon emission trading (billion tons)	value of carbon emission trading (billion dollars)
Total	4.8	135	8.7	143.7	8.8	159.1	10.3	176
EU-ETS (EUA)	3.1	100.5	6.3	118.5	6.8	133.6	7.9	147.8
Primary (pCER)	0.4	6.5	0.21	2.7	2.2	2.7	0.26	3
Secondary CDM (sCER)	1.1	26.3	1.1	17.5	0.22	20.5	1.7	22.3
Independent Market	0.06	0.42	0.05	0.34	0.07	0.41	0.09	0.57

### 3. The Structure of the Model

In this section, the structure of the model is described. The model examines 2006 Makassar City economy and includes an aggregate household, 28 industries, the government and the external sector. The markets in this model are 28 commodity markets, one labor market and one capital market. They are assumed to be in equilibrium in 2006.

#### 3.1 Behavior of the Economic Agents

##### (1) Industries

In industries, intermediate goods, labor and capital are inputted to produce goods. Industries have the *Cobb-Douglas* technology with respect to intermediate input and labor and capital inputs, and Leontief technology for value added inputs. Due to linear homogeneity of degree one in the production technologies, we consider a cost minimization problem which is as follows:

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

with respect to  $x_{ij}$ ,  $L_j$  and  $K_j$

subject to

$$X_j = \min \left[ \frac{1}{a_{10j}} f_j(L_j, K_j), \frac{x_{1j}}{a_{1j}}, \dots, \frac{x_{ij}}{a_{ij}}, \dots, \frac{x_{28j}}{a_{28j}} \right] \quad (2)$$

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  $j$

**Table 2. Industrial Classification in the Model**

number	Sector
1	Food Crops
2	Plantation Crops
3	Livestock
4	Forestry
5	Fishery
6	Mining of oil and gas and non-oil and gas
7	Manufacture of food, beverages and tobacco
8	Manufacture of textiles, clothing and leather
9	Manufacture of wood, bamboo and furniture
10	Manufacture of paper and paper product, printing and publishing
11	Manufacture of chemicals, petroleum, coal, rubber and plastic products
12	Manufacture of cement non-metallic mineral
13	Manufacture of basic metals
14	Manufacture of fabricated metal
15	Other manufacturing
16	Electricity, gas and water supply
17	Construction/building
18	Trade
19	Hotel
20	Restaurants
21	Highway transportation
22	Other transportation
23	Communication
24	Banks and other financial institutions
25	Leasing, real estate and business services
26	Education
27	Health
28	Social services and other services

$a_{ij}$  : input coefficient

$A_{ij}$  and  $\alpha_{ij}$ : technological parameters in industry  $j$

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

$$x_{ij} = a_{ij} X_j \quad (3)$$

$$LD_j = \left[ \frac{(1-\alpha_j)r}{\alpha_j w} \right]^{\alpha_j} \frac{a_{0j} X_j}{A_j} \quad (4)$$

$$KD_j = \left[ \frac{\alpha_j w}{(1-\alpha_j)r} \right]^{(1-\alpha_j)} \frac{a_{0j} X_j}{A_j} \quad (5)$$

where

$x_{ij}$  : conditional intermediate demand for good  $i$  in industry  $j$

$LD_j$ : conditional demand for labor in industry  $j$

$KD_j$ : conditional capital demand in industry  $j$

Zero profit condition is realized in the industries under the perfect competition.

$$profit = p_j X_j - \sum_{i=1}^{28} p_i x_{ij} - (1 + tp_j)[w \cdot LD_j + r \cdot KD_j] = 0 \quad (6)$$

## (2)Households

Households in Makassar City are assumed to be homogeneous with the fixed number of households. Thus one can consider that households share an aggregate single utility function. Households share a CES utility function of the current and future goods. Here the current good is defined as a CES composite of current consumption goods and leisure time, while the future good is derived from saving.

Households choose a bundle of the current and future goods so as to maximize the utility function with a budget constraint. Then the current good is divided into a composite consumption good and a leisure time (labor supply).

Household income consists of full wage income, which is obtained when households supply their full 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 part of household wage income and capital income is transferred to the external sector.

Household direct tax is imposed on the after-current-transfers income. Then households are assumed to allocate their after-direct-tax income on current and future goods. Here direct tax is supposed to include all current transfers from households to the government for simplicity.

To explain the household behavior, first, derivation of future good is described here. The future good implies the future consumption which derived from household saving, however, the saving formulates capital investment. Therefore capital good can be regarded as saving good. Investment is made by using produced goods, and let their portions in investment be denoted by  $b_i$ . Then investment can be written as equation (7) with the assumption of *Leontief* type.

$$I = \min \{I_1/b_1, \dots, I_{28}/b_{28}\} \quad (7)$$

where  $I_i$  : input of good  $i$  associated with investment  $I$

Investment  $I$  is assumed to be implemented so as to minimize the investment cost  $\sum_{i=1}^{28} p_i I_i$ , then commodity demand associated with investment  $I$  is written as  $I = b_i I$ . Denoting the price of investment good by  $p_I$ ,  $p_I I = \sum_{i=1}^{28} p_i I_i$  is realized. Then the price of investment good is expressed as

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

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

$$r_s = (1-ty)(1-k_o)(1-k_r)r\delta / p_s \quad (8)$$

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

$\delta$ : ratio of capital stock measured by physical commodity unit to that by capital service unit.

It is assumed that the expected returns of saving finance the future consumption. Regarding the price of the current consumption good as the price of future good under the myopic expectation, and denoting the household real saving by  $S$ , the following equation holds.

$$p \cdot H = (1-ty)(1-k_o)(1-k_r)r\delta \cdot S \quad (9)$$

This yields  $[p_s p / (1-ty)(1-k_o)(1-k_r)r\delta] H = p_s S$ , and we set the price of future good  $p_H$  associated with the real saving  $S$  as;

$$p_H = p_s p / (1-ty)(1-k_o)(1-k_r)r\delta \quad (10)$$

Then  $p_s S = p_H H$  is realized. By employing the above-mentioned future good and its price, household utility maximization problem is now specified in the following. Regarding current good, it will be described in a later part.

$$\max_{G,H} u(G,H) \equiv [\alpha^{1/\nu_1} G^{(\nu_1-1)/\nu_1} + (1-\alpha)^{1/\nu_1} H^{(\nu_1-1)/\nu_1}]^{\nu_1/(\nu_1-1)} \quad (11)$$

subject to

$$p_G \cdot G + p_H \cdot H = (1-ty)FI - TrHC \quad (12)$$

$$FI \equiv (1-l_o)w \cdot E + LI + (1-k_o)(1-k_r)r \cdot KS + KI + TrGH + TrOH \quad (13)$$

where

$\alpha$ : share parameter

$\nu_1$ : elasticity of substitution between the current good and future good

$G$ : household present consumption

$H$ : household future consumption

$p_G$ : price of current good



$p_H$  : price of future good

$FI$  : household full income

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

$l_o$  : rate of labor income transferred to the external sector

$E$  : household initial labor endowment, which is set up as the double of real working time. This is based on the actual working time and leisure time in Makassar City.

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

$KS$  : initial capital stock endowed by households

$KI$  : 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

Solving this utility maximization problem, demand functions for current and future goods are obtained yielding a household saving function.

$$G = \frac{\alpha[(1-ty)FI - TrHO]}{p_G^{v_1} \cdot \Delta} \quad (14)$$

$$H = \frac{(1-\alpha)[(1-ty)FI - TrHO]}{p_H^{v_1} \cdot \Delta} \quad (15)$$

$$S = p_H H / p_s \quad (16)$$

$$\Delta \equiv \alpha p_G^{1-v_1} + (1-\alpha) p_H^{1-v_1} \quad (17)$$

Then we 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.

$$\max_{C,F} G \equiv [\beta^{1/v_2} C^{(v_2-1)/v_2} + (1-\beta)^{1/v_2} F^{(v_2-1)/v_2}]^{v_2/(v_2-1)} \quad (18)$$

subject to

$$p \cdot C + (1-ty)(1-l_o)w \cdot F = (1-ty)FI - TrHO - SH \quad (19)$$

where

$\beta$  : share parameter

$v_2$  : elasticity of substitution between composite consumption and leisure time

$C$  : composite consumption

$F$  : leisure time

$p$  : price of composite consumption good

$SH$  : household nominal saving ( $= P_s \cdot S$ )

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

$$C = \frac{\beta[(1-ty)FI - TrHO - SH]}{p^{v_2} \cdot \Omega} \quad (20)$$

$$F = \frac{(1-\beta)[(1-ty)FI - TrHO - SH]}{[(1-ty)(1-l_o)w]^{v_2} \cdot \Omega} \quad (21)$$

$$LS = E - F \quad (22)$$

$$\Omega = \beta p^{(1-v_2)} + (1-\beta)[(1-ty)(1-l_o)w]^{(1-v_2)} \quad (23)$$

where  $LS$  : household labor supply

Substituting composite consumption (34) and leisure time (35) into (32), the price index of the current good is derived as follows:

$$p_G = [\beta p^{1-v_2} + (1-\beta)((1-ty)(1-l_o)w)^{1-v_2}]^{1/(v_2-1)} \quad (24)$$

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

$$\max \prod_{j=1}^{28} C_j^{\gamma_j} \quad \left( \sum_{j=1}^{28} \gamma_j = 1 \right) \quad (25)$$

subject to

$$\sum_{j=1}^{28} p_j \cdot C_j = (1-ty)Y - TrHO - SH \quad (26)$$

where

$C_i$  : household consumption good produced by industry  $i$

$p_i$  : price of good  $i$

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

From this optimization problem, consumption good  $i$  is derived.

$$C_j = \frac{\gamma_j}{p_j} [(1-ty)Y - TrHO - SH] \quad (j = 1, \dots, 28) \quad (27)$$

The price of composite consumption is calculated as follows:

$$p = \prod_{j=1}^{28} \left[ \frac{p_j}{\gamma_j} \right]^{\gamma_j} \quad (28)$$

### (3)The Government

The government sector in this study consists of the national and local governmental activities in Makassar City. Thus, the concept of the government corresponds to the definition of SNA framework. The government obtains its income from direct and net indirect taxes of Makassar City, and current transfers from the external sector, and then it spends the income on government consumption, current transfers to households, and current transfers to the external sector. The difference between income and expenditures is saved. Nominal consumption expenditures on commodities/services are assumed to be proportional to the government revenue with constant sectorial share. These are denoted by the following balance of payment.

$$\sum_{i=1}^{28} p_i \cdot CG_i + TrGH + TrGO + SG = ty \cdot Y + \sum_{i=1}^{28} tp_i (w \cdot LD_i + r \cdot KD_i) + Tr r O \quad (29)$$

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

### (6) 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. Then, it spends the income on Makassar City's exports, current transfers to households and the government, labor and property income transfers. These are also expressed by the following balance of payment.

$$\sum_{i=1}^{28} p_i \cdot EX_i + TrOH + TrOG + KI + LI + SO = \sum_{i=1}^{28} p_i \cdot EM_i + TrHG + TrGO + KIO + LIC \quad (30)$$

where

$EX_i$ : export of commodity  $i$

$EM_i$ : import of commodity  $i$

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

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

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

### (7) Balance of Investment and Savings

Household, government, the external sector's savings and the total capital depreciation determine the total investment.

$$\sum_{i=1}^{28} p_i \cdot I_i = SH + SG + SO + \sum_{i=1}^{28} DR_i \quad (31)$$

where

$I_i$ : demand for commodity  $i$  by investment

$DR_i$ : capital depreciation in industry  $i$

### (8) Commodity Prices

From the zero profit condition in the industries, commodity prices can be determined by the following equation:

$$p_j X_j = \sum_{i=1}^{28} p_i x_{ij} + (1 + tp_j) [w \cdot LD_j + r \cdot KD_j] \quad (32)$$

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

$$P = [I - A']^{-1} [(1 + tp_j) (w \cdot ld_j + r \cdot kd_j)] \quad (33)$$

where

$P$ : vector of commodity prices

$A'$ : transposed matrix of industries' input coefficients

$[ \cdot ]$ : column vector whose elements in the brackets are  $ld_j \equiv LD_j / X_j$  and  $kd_j \equiv KD_j / X_j$

### (9) Market Equilibrium Conditions

Markets in our model consists of 28 commodity markets, one labor market and one capital market, and the equilibrium conditions are written as follows:

#### Commodity markets

$$X = AX + C + CG + I + EX - EM \quad (34)$$

#### Labor market

$$LS = \sum_{j=1}^{28} LD_j \quad (35)$$

#### Capital market

$$KS = \sum_{j=1}^{28} KD_j \quad (36)$$

where

$X$ : industrial output vector

$A$ : input coefficient matrix

$C$ : household consumption vector

$CG$ : government consumption vector

$I$ : investment vector

$EX$ : export vector

$EM$ : import vector

$KS$ : capital stock endowment

However those equilibrium conditions are insufficient to solve all endogenous variables in the model, thus all equations in the model are necessary to obtain the equilibrium solution. Since the linear homogeneity of degree one is assumed in the production technologies, commodity prices are determined by equation (33) given a wage rate and a capital return rate. Moreover industrial outputs are determined to meet the demands corresponding to those commodity prices.

Hence the *Walras* law in this model is reduced to *value of excess labor demand + value of excess capital demand = 0*. This equation implies that the equilibrium solution can be obtained if a wage rate or a capital return rate clears the labor market or the capital market. In this study, letting labor be a numeraire ( $w = 1$ ), the capital return rate which clears the capital market is calibrated by employing *Newton-Raphson* method.

### 4. Simulation Cases

Three cases are considered in this study. The scale of carbon credit is assumed to be 10 % of the total CO<sub>2</sub> emission in Makassar City (2,568,928 t-CO<sub>2</sub>) taking into account the CO<sub>2</sub> absorption in Makassar metropolitan area. Since the price of carbon credit varies corresponding to the demand and supply, the equilibrium price is calibrated as 12,817 rupiah / t-CO<sub>2</sub> by a demand and a supply functions. The description of the three cases is as follows:

#### (1) Base Case

Business as usual case without carbon credit.

#### (2) Case 1

A carbon credit of 256,892.8 t-CO<sub>2</sub> is assumed. The revenue of selling the carbon credit to other regions is assumed to be transferred to the Makassar government sector.

#### (3) Case 2

A carbon credit of 256,892.8 t-CO<sub>2</sub> is also assumed. The revenue of selling the carbon credit to other regions is

assumed to be transferred to households in Makassar City.

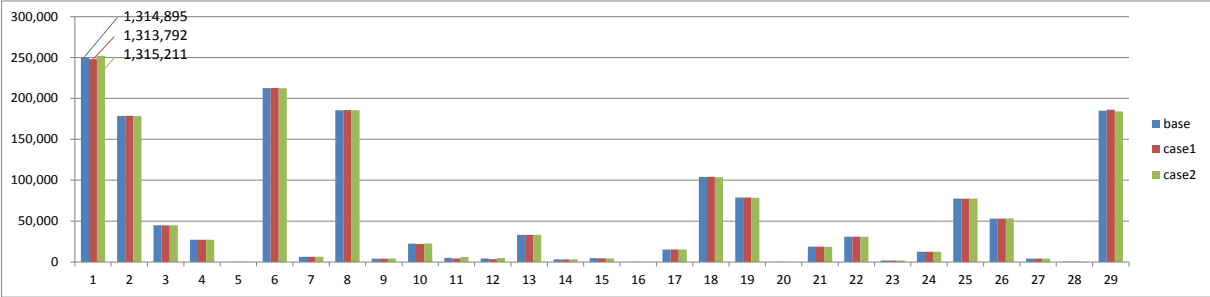
**5. Simulation Results**

**(1) Industrial Outputs**

Figures 5 and 6 show changes in industrial outputs in Cases 1 and 2 as compared with Base Case. Industries with large outputs in Base Case include Fishery (212,552 mil. rp.), Manufacture of food etc. (185,627 mil. rp.), Social services etc. (185,006 mil. rp.), Construction (104,079 mil. rp.). In Case 1, there are many industries with shrinking outputs including Other manufactures (-93.13%), Forestry (-76.76%), Manufacture of chemicals etc. (-17.62%), Manufacture of paper etc. (-16.66%) and Hotels (-15.67%). Conversely, industries with increasing outputs are only listed as Social services etc. (0.64%). These results are interpreted as consequences of changes of demand induced by transfers of the carbon credit revenue to the government.

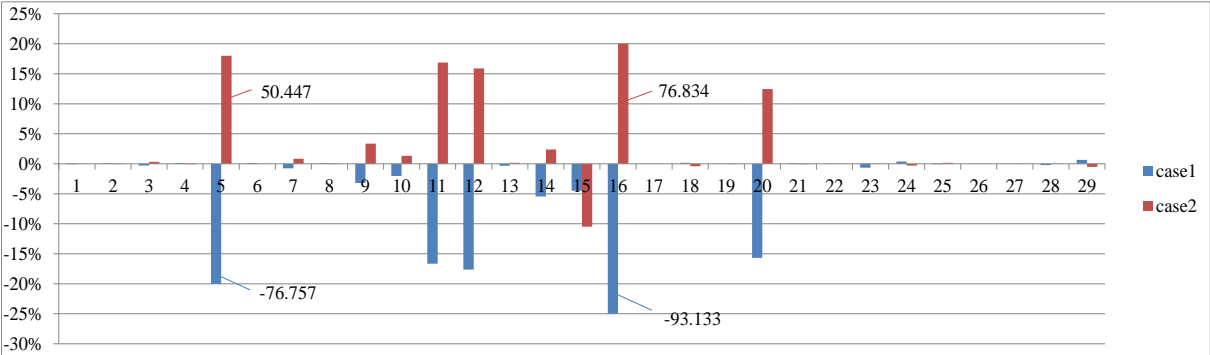
Case 2 illustrates reverse results as compared with Case 1. That is, there are many industries with expanding outputs. Those are Other manufactures (76.83%), Forestry (50.44%), Manufacture of paper etc. (16.85%), Manufacture of chemicals etc. (15.89%) and Hotels (12.45%). Manufacture of fabricated metal also shows a decreasing output (-10.47%) as in Case 1. These results reflect a growth in household consumption in Case 2.

The total industrial output depicts a decrease of -0.08% in Case 1 and an increase of 0.02% in Case 2 resulting from the changes in outputs mentioned above. The introduction of carbon credit trading gives a large impact on small industries leading to a small impact on the total industrial output.



Note: #1: total industrial output, #2 to #29: output by industry in Table 2

**Figure 5. Industrial Outputs**



Note: #1: total industrial output, #2 to #29: output by industry in Table 2

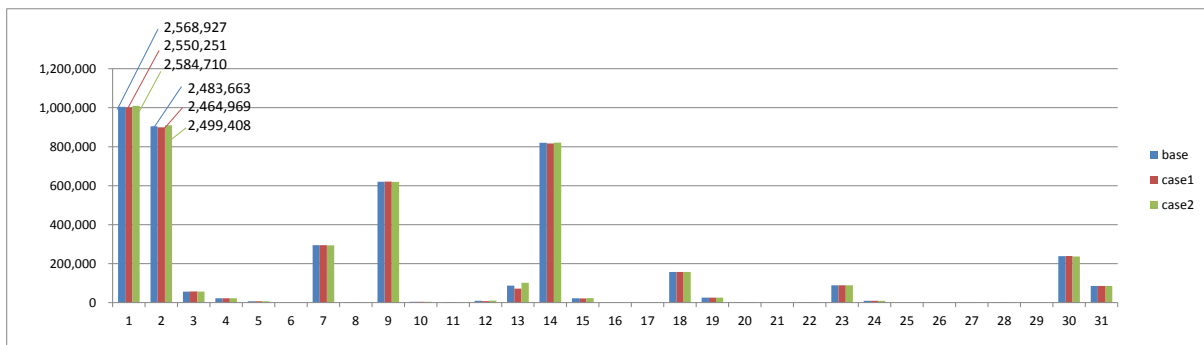
**Figure 6. Change Rates in Industrial Outputs**

## (2) CO<sub>2</sub> Emissions

Figures 7 and 8 illustrate changes in CO<sub>2</sub> emissions by sector. Industries with large CO<sub>2</sub> emissions in Base Case include Manufacture of cement etc. (819,867t-CO<sub>2</sub>), Manufacture of food etc. (620,137t-CO<sub>2</sub>), Fishery (294,518t-CO<sub>2</sub>), Electricity etc. (157,096t-CO<sub>2</sub>), Highway transport (88,892t-CO<sub>2</sub>), Manufacture of chemical (87,726t-CO<sub>2</sub>), Households (85,265t-CO<sub>2</sub>), Food crops (56,988t-CO<sub>2</sub>), Construction (25,869t-CO<sub>2</sub>), Manufacture of basic metals (22,680t-CO<sub>2</sub>) and Plantation crops (22,219t-CO<sub>2</sub>). It is a characteristic that large CO<sub>2</sub> emissions are generated by food related industries.

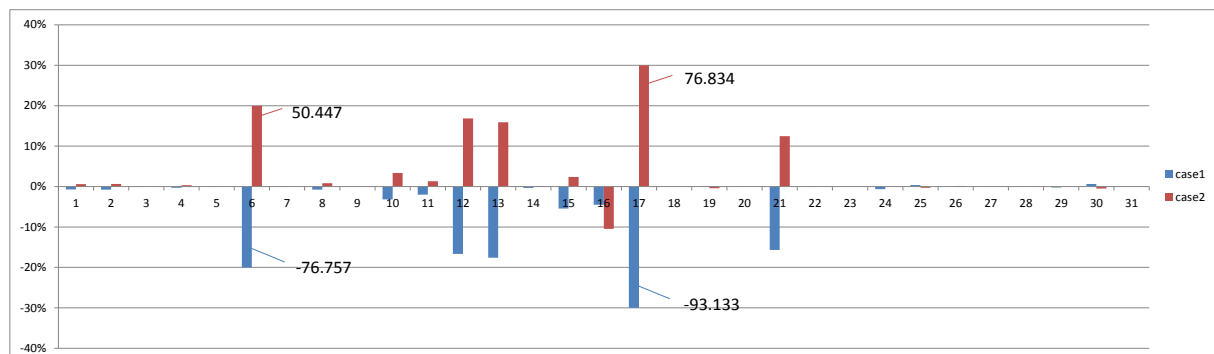
Since the volume of CO<sub>2</sub> emissions is proportional to industrial output in the model, changes in CO<sub>2</sub> emissions in Cases 1 and 2 are the same to those in industrial outputs. Hence there are many industries with reduced CO<sub>2</sub> emissions in Case 1. Industries with decreased CO<sub>2</sub> emissions are Other manufactures (-93.13%), Forestry (-76.76%), Manufacture of chemicals etc. (-17.62%), Manufacture of paper etc. (-16.66%) and Hotels (-15.67%). These decreases come from reductions in corresponding industrial outputs. Conversely a larger increase is found only in Social services etc. (0.64%).

Increasing CO<sub>2</sub> emissions are found in many industries in Case 2. Industries with a large growth rate in CO<sub>2</sub> emissions are Other manufactures (76.83%), Forestry (50.45%), Manufacture of paper etc. (16.85%), Manufacture of chemicals (15.89%), Hotels (12.45%). These increases are induced by a growth in household consumption. However an increase in household CO<sub>2</sub> emissions almost stays at a level of 0.04% rise. The number of industries with decreasing CO<sub>2</sub> emissions is small including Social services etc. (-0.51%) and Communications (-0.29%). There are only small changes in the total CO<sub>2</sub> emission showing -0.73% in Case 1 and 0.61% in Case 2.



Note: #1: total CO<sub>2</sub> emission, #2: total CO<sub>2</sub> emission by industry, #3 to #30: CO<sub>2</sub> emissions by industry in Table2, #31: household CO<sub>2</sub> emissions

**Figure 7. CO<sub>2</sub> Emissions by Industries**



Note: #1: total CO<sub>2</sub> emission, #2: total CO<sub>2</sub> emission by industry, #3 to #30: CO<sub>2</sub> emissions by industry in Table2, #31: household CO<sub>2</sub> emissions

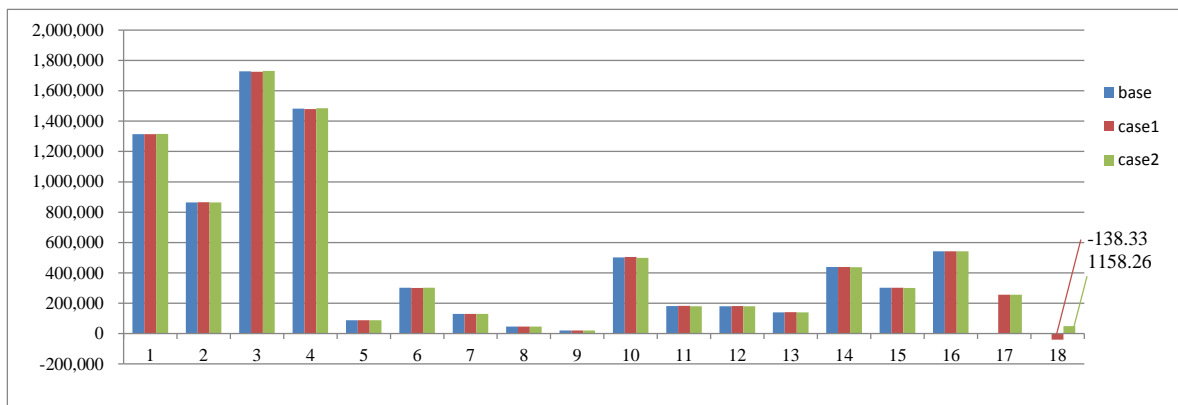
**Figure 8. Change Rates in CO<sub>2</sub> Emissions**

### (3) Other Variables

Figure 8 depicts changes in other main variables. The number of variables with large change is small in Case 1. Variables with more than 0.1% increase include current transfers from the ROW to the government (0.76%), government revenue (0.62%), government consumption (0.62%), current transfers from the government to households (0.62%) and government saving (0.62%). Variables with more than 0.1% decrease are listed as current transfers from the ROW to households (-0.53%), net indirect tax revenue (-0.40%), capital return rate (-0.29%), composite consumption price (-0.21%), household income (-0.18%), direct tax revenue (-0.18%) and household full income (-0.17%). Although there is an expansion in the government sector and household income due to the revenue of carbon credit selling of 3,293 million rupiah, the equivalent variation depicts a welfare loss of -138 million rupiah since decreases in leisure time and household saving exceed a rise in household income.

Variables with more than 0.1% increase in Case 2 are current transfers from the ROW to households (0.63%), capital return rate (0.23%), household income (0.21%), direct tax revenue (0.21%), net indirect tax revenue (0.21%), household full income (0.20%), price of household composite consumption (0.17%) and leisure time (0.14%). Conversely variables with more than 0.1% reduction are observed as current transfers from the ROW to the government (-0.61%), government revenue (-0.50%), government consumption (-0.50%), current transfers from the government to households (-0.50%), government saving (-0.50%), the total investment (-0.22%) and labor supply (-0.14%).

Since current transfers from the ROW to households rise at 3,293 million rupiah by selling the carbon credit to other regions, household income expand with growths in household consumption, leisure time and household saving showing a positive equivalent variation of 1,158 million rupiah



Note: 1: total industrial output, 2: city GDP, 3: household full income, 4: household income, 5: household consumption, 6: household leisure time: 7: household saving, 8: direct tax, 9: net indirect income, 10: government revenue, 11: government consumption, 12: government saving, 13: current transfers from government to households, 14: total investment, 15: labor supply, 16: capital supply, 17: carbon credit, 18: equivalent variation

**Figure 8. Other Variables**

### 8. Concluding Remarks

This study assumes a small scale carbon credit in Makassar City. The reason is that some variables show a little unrealistic behavior when the price of carbon credit exceeds a certain level. Hence the simulation results in this study show small changes in most variables. Large changes are found in some variables but those are small in value.

The total output and the total CO<sub>2</sub> emission decrease in Case 1, while those increase in Case 2. This is due to the different structure in demand induced by the revenue of selling carbon credit. Since regions buying the carbon

credit from Makassar City can discharge extra CO<sub>2</sub> emissions of 256,892.8t-CO<sub>2</sub>, it can be expected that more positive economic impact appears in regions with more progressive low carbon technologies than in Makassar City.

The equivalent variations in Cases 1 and 2 differ significantly since the recipients of the carbon credit revenue are different in the two cases. Case 1 depicts a negative equivalent variation with a reason that leisure time and household saving decrease although household income increases. Case 2 shows a positive equivalent variation because household consumption, leisure time and household saving expand.

Though CO<sub>2</sub> emissions increase in Makassar City in Case 2, the volume of that increase is only 15,782t-CO<sub>2</sub> being much smaller than the volume of carbon credit of 256,893t-CO<sub>2</sub>. Therefore it is preferable to construct a social system where the carbon credit revenue induces an increase in the household income.

This study captures the economic impact of the revenue by issuing the carbon credit from the commodity demand side. However a larger positive economic impact can be expected when the revenue of carbon credit is invested to low carbon technologies. This conjecture is left as a future task worth examining.

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