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An econometric analysis of energy input in the agricultural sector and its impact on co_2 emissions: a case of Indonesia

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Abstract. This study analyzes the impact of the energy input on the total production in the agricultural sector in Indonesia by using an econometric approach. Unlike in other studies, the total production in this study was measured in monetary unit (i.e., value added). The results show that if the energy input in the agricultural sector was increased by 1%, the agricultural productivity (the value added) would increase by 0.45%. This study also examines the factors which affect the total CO_2 emissions due to the energy use in the sector by applying the extended Kaya model during 1990-2005. The results show that the value added was found to increase the total CO_2 emissions during the periods of 1990-1995, 1996-2000, and 2001-2005. The energy intensity effect also contributed towards increasing CO_2 emissions at each period except at the period of 2001 – 2005, while the contribution of the energy mix effect to the total CO_2 emissions was neglible at all periods.

1. Introduction

In many countries, the role of agricultural sector is very important for their economic development since the share of the agricultural production to the total national output (gross domestic product) is very significant. For example, in South-East Asia countries, such as Myanmar, Lao PDR, Cambodia, Vietnam, Indonesia and Thailand, the shares of their agriculture sector to GDP in 2007 were 49.9%, 44.8%, 31.9%, 21.10%, 13.4% and 11.4% respectively [1]. There are many factors which affect the agricultural productivity, one of them is the energy input in the agricultural sector. Policy makers wish to know by how much the agricultural productivity would increase if the energy consumption in the agricultural sector is increased. Furthermore, it is of interest also for policy makers to examine the impact of the energy use on CO_2 emissions because of the growing concern for a global climate change. Econometrics method has been used extensively in analyzing the cause-effect problems in many areas, for example the implication of energy consumption on the agricultural production. There are only a few studies examining the impacts of the energy consumption on the agricultural production, however, most of the studies treated the dependent variable in index unit (see e.g., [2]) or in physical unit (see e.g., [3]). [4] represented the dependent variable (i.e., agricultural productivity) in their model in monetary unit, however it was in terms of the value of the agricultural production. To the knowledge of the author, so far, there is no study uses the value added (i.e., monetary unit) as the dependent variable in the econometric analysis to analyze the impacts of energy consumption on the agricultural production, particularly in the Indonesian agricultural sector. The use of value added as the dependent variable is very important because the value added is mostly used in measuring the national output (GDP) since it avoids the statistical problem of double counting [5]. Decomposition analysis has been used very frequently to examine the factors which affect the CO emissions (see e.g., [6]) as well as the CO_2 emissions changes (see e.g., [7]) due to the energy consumption, however, mostly their analysis are in the non-agricultural sector. [8] analyzed the factors which affect the changes in CO_2 emissions due to energy consumption in the agricultural sector, however, they did not decompose factors which affect the agricultural sector CO_2 emissions. Furthermore, their decomposition analysis was not base on Logarithmic Mean Divisia Index (LMDI) approach as recommended by [7]. LMDI has been used extensively recently because this method has several desirable advantages including time dependence, ability to handle zero values and consistency in aggregation. To the best of the author's knowledge, there is no decomposition study analyzes the CO_2 emissions and the CO_2 emissions changes by using Index Decomposition Analysis (IDA) based on Logarithmic Mean Divisia Index (LMDI) approach as recommended by [7] in the agricultural sector, particularly in Indonesia. This paper analyzes the impact of the energy input in the agricultural sector in Indonesia on the agricultural production by applying the econometric method and including the value added as the dependent variable during the period 1990-2005. This study also examines the impact of the energy consumption of the sector on CO_2 emissions and examines the factors which affect the CO_2 emissions and the CO_2 emissions changes during the period by adopting the IDA technique using additive LMDI method.

2. Method

2.1. Econometric Model Development

Basically, the relationship between output and input is well known with the production function. There are various models of the production function, and the best known is the Cobb-Douglass (C-D) production function. The Cobb-Douglass production function is a linear regression model (i.e., linear in the parameters), and can be written as follows:

$$\ln Y_t = \ln \beta_0 + \sum_{k=1} \beta_k \ln(X_{kt}) + \mu_t \quad (1)$$

where μ, known as the disturbance- or error-term, and it is a random (stochastic) variable that has well-defined probabilistic properties, i.e., zero mean and constant variance σ^2 (i.e., it is *white noise stochastic error term*). The disturbance term μ in this model may well represent all those factors that affect the dependent variable *Y* but are not taken into account explicitly. *t* denote the t^{th} observation while *k* denotes the k^{th} independent variable *X*. Since the model is already correctly specified, a time trend variable is not needed to be included in the empirical model [9]. So, the econometric model to analyze the energy input in the Indonesian agriculture is presented as follows:

$$\ln V_t = \ln \beta_0 + \beta_1 \ln E_t + \mu_t \quad (2)$$

In this study, EViews program software [10] was used to estimate the coefficients in the model.

2.2. CO_2 Emission Calculation

The CO_2 emissions of energy type *i* (C_i) is estimated as follows [11]:

$$C_i = E_i \times F_i \tag{3}$$

F_i is calculated as follows:

$$F_i = \frac{CC_i \times OR_i \times 44/12}{EC_i} \tag{4}$$

where E_i is energy input type *i*, F_i is CO_2 emission factor of energy type *i*, CC_i is carbon content of energy type *i* (%), OR_i is oxidation rate of energy type *i* (%), and EC_i is energy content per unit of energy type *i*.

2.3. Factor decomposition methodology

The drivers of the CO_2 emissions are analyzed by using an extended Kaya identity (Kaya, 1990) as outlined by Equation 5 as follows:

$$C = \sum_i C_i = \sum_i \frac{C_i}{E_i} \times \frac{E_i}{V} \times V \tag{5}$$

where C is the total CO_2 emissions from the agricultural sector, C_i is the CO_2 emissions of energy type *i*, C_i/E_i is the energy mix (defined as the CO_2 emissions per unit of energy type *i*), E_i/V is the energy intensity (defined as the energy type *i* required per unit of value added), and V is the value added (value added is at 2000 Rp. constant prices). If C_{em} is the energy mix by all types of energy (hereafter called as the energy mix effect), C_{ei} is the energy intensity by all types of energy (here after called as the energy intensity effect), and C_{va} is the value added effect, hence, the total CO_2 emissions by all types of energy from the agricultural sector is now the product of the three factors (effects), i.e.:

$$C = C_{em} \times C_{ei} \times C_{va} \tag{6}$$

It is of interest also to examine the changes in the CO_2 emissions due to the changes of the three factors mentioned above based on the sum rather than the product of the factors. This problem can be handled by using the complete additive LMDI decomposition without any residual as proposed by [7]. Hence, the factors which affect the changes in total CO_2 emissions between year *t* and *(t+1)* is the sum of the changes of the three factors and can be written as follows:

$$\Delta C = C(t+1) - C(t) = \Delta C_{em} + \Delta C_{ei} + \Delta C_{va} \tag{7}$$

where ΔC_{em} is the change in CO_2 emissions due to the change of the energy mix effect, ΔC_{ei} is the change in CO_2 emissions due to the change of the energy intensity effect, and ΔC_{va} is the change in CO_2 emissions due to the change of the value added effect in the agricultural sector. Following LMDI method ([7], [8]), each decomposition factors in equation (7) can be calculated as follows: $\Delta C_{em} = \sum_i L(C_i^{t+1}, C_i^t) \ln\left(\frac{C_{em}^{t+1}}{C_{em}^t}\right)$; $\Delta C_{ei} = \sum_i L(C_i^{t+1}, C_i^t) \ln\left(\frac{C_{ei}^{t+1}}{C_{ei}^t}\right)$, and $\Delta C_{va} = \sum_i L(C_i^{t+1}, C_i^t) \ln\left(\frac{C_{va}^{t+1}}{C_{va}^t}\right)$; where $L\left(C_i^{t+1}, C_i^t\right) = \left(C_i^{t+1} - C_i^t\right) / \left(\ln C_i^{t+1} - \ln C_i^t\right)$ for $C_i^{t+1} \neq C_i^t$ and $L\left(C_i^{t+1}, C_i^t\right) = C_i^{t+1}$ for $C_i^{t+1} = C_i^t$. $L\left(C_i^{t+1}, C_i^t\right)$ is called the logarithmic mean function.

3. Results and Discussion

3.1. Econometric Analysis of Energy Consumption

The results of the econometric model are reported in Table 1. Table 1 shows that the coefficient of the energy input is statistically significant at level of significance α =1%. The sign of this coefficient is expected, i.e., positive, which means if the energy input increased, the agricultural productivity would increase as well. The *F* statistic is also significant at level of significance *α* = 1%. This indicates that the value of R^2 = 61.1% is acceptable. This value shows that around 61.1% of the agricultural productivity was explained by the energy input of the Indonesian agricultural sector. Since time series data were used in this study, so it is of interest to check whether autocorrelation appears in the model. The value of the Durbin-Watson statistic shown in the result (i.e., $d = 1.703$) indicates that there is no autocorrelation appear in the model. This is because $d > d_U$. Please note that the *1%* critical values for Durbin-Watson test when number of observation *(n) = 16*, and number of independent variable *(k) = 1* are $d_L = 0.844$ and $d_U = 1.086$. Since the model is a double log model, so the coefficient of the independent variable also shows the elasticity. As shown in Table 1, the coefficient for the energy input is 0.45 which indicates that if the energy input in the agricultural sector in Indonesia was increased by 1%, the agricultural productivity (i.e., the value added) would increase by 0.45%. This elasticity is higher than the study of [2] in the case of the Turkish agricultural sector, i.e., 0.17.

Table 1: Estimated coefficients and their statistics of the econometric model†

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant	8.802089	0.741769	11.86635*	0.0000
Energy input	0.450144	0.096001	4.688970*	0.0003
R-squared	0.610965	F-statistic		21.98644@
Adjusted R-squared	0.583176	Prob(F-statistic)		0.000348
Durbin-Watson stat	1.703183	Number of observation		16

†The results were estimated by using EViews software package [10].
*These indicate that the coefficients are significant at level of significance α = 1%.
@This indicates that the model with R^2 = 0.611 is significant at level of significance α = 1%.

3.2.Decomposition Analysis of CO_2 Emissions

The evolution of CO_2 emissions from the agricultural sector during 1990-2005 is shown in Figure 1 along with the energy mix effect (C_{em}), the energy intensity effect (C_{ei}), and the value added effect (C_{va}). The agricultural sector CO_2 emissions in 2005 were 1.9 times higher than that in 1980. During the Indonesian economic crisis of 1997-1998, the CO_2 emissions from the agricutural sector hardly changed. The AAGR of the agricultural sector CO_2 emissions in Indonesia during 1990-2005 was 4.5%. Table 2 shows the contribution of each factor to the agricultural sector CO_2 emissions between 1990 and 1995, 1996 and 2000, and 2001 and 2005 in an index form. Since this is a multiplicative decomposition, the product of the indices of all effects is equal to the index of actual CO_2 emissions. As shown in Table 2, the CO_2 emissions due to the value added effect (i.e., C_{va}) was found to contribute positively (i.e., the C_{va} index was higher than unity) to the growth of CO_2 emissions at each period. This reflects the growth of energy input in the agricultural sector associating with the rising value added of the sector. The C_{va} was the main factor behind the increase in CO_2 emissions at each period, except at the period of 1996 and 2000. This is because in 1997 (i.e., in the period of 1996 and 2000), Indonesia was severely affected by the economic crisis. The C_{ei} (i.e., the emission due to the energy intensity effect) was found to contribute towards increasing CO_2 emissions at each period except at the period of 2001 – 2005. The C_{ei} (i.e., the emission due to the energy intensity effect) was the predominant factor behind the growth in CO_2 emissions during the period 1996 – 2000. In this study, there was no significant change in the total CO_2 emissions due to the C_{em} (i.e., the emission due to the energy mix effect) at all periods.

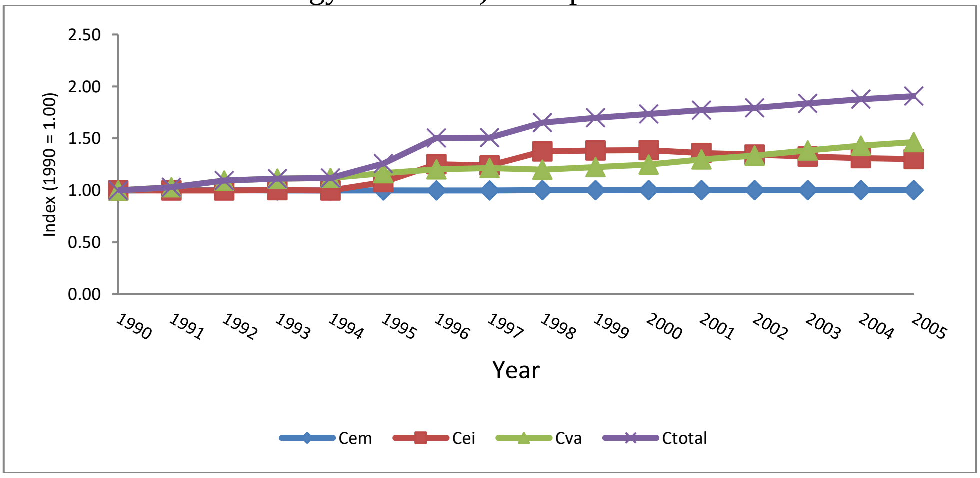

Figure 1: Factors contributing to CO_2 emissions from agricultural sector during 1990-2005

Table 2 Indices of CO_2 emission at selected periods and contributing factors

Period	CO_2 emission index (C_{total})	Decomposition of factors		
		C_{em}	C_{ei}	C_{va}
1990 and 1995*	1.2563	0.9993	1.0779	1.1664
1996 and 2000**	1.1536	1.0031	1.1087	1.0373
2001 and 2005***	1.0766	0.9994	0.9557	1.1272

*1990 values = 1.0000; **1996 values = 1.0000; ***2001 values = 1.0000

3.3. Decomposition Analysis of the Changes in CO_2 Emissions

Figure 2 shows the changes in CO_2 emissions in three periods, i.e., 1990-1995, 1995-2000, and 2000-2005. The total changes in CO_2 emissions was found the highest during the period 1995-2000 (i.e., 321 kt) and then followed by the total changes in CO_2 emissions during 1990-1995 and 2000-2005, i.e., 172 kt and 115 kt respectively.

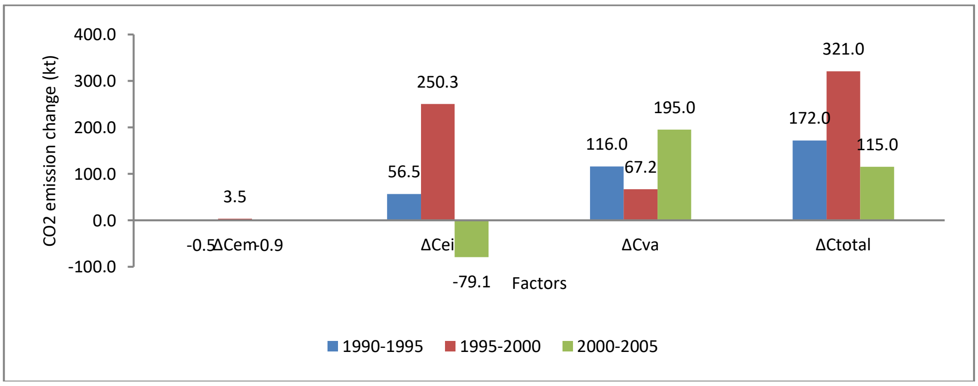

Figure 2: Factors contributing to CO_2 emissions changes at selected periods

The change in the value added effect (ΔC_{va}) during each period would affect positively towards increasing CO_2 emissions in all periods. The shares of the ΔC_{va} to the total changes in CO_2 emissions during the periods 1990-1995, 1995-2000, and 2000-2005 were 67.5%, 20.9%, and 169.6% respectively. The shares of the ΔC_{ei} during the period 1990-1995 and 1995-2000 were 32.9% and 78% respectively. Unlike the periods of 1990-1995 and 1995-2000, the ΔC_{ei} during 2000-2005 acted negatively toward increasing total CO_2 emissions changes or, in other words, the change in the energy intensity effect contributed towards increasing CO_2 emissions. So, in the period of 2000-2005, the ΔC_{va} was counteracted by the ΔC_{ei} that made the total changes in CO_2 emissions during 2005-2005 was the least among the three periods. The shares of the ΔC_{em} to the total changes in CO_2 emissions during the three periods were relatively small (i.e., less than 1.1%).

4. Conclusion

This paper presents the econometric analysis of energy consumption in the agricultural sector in Indonesia. In the econometric model, value added as the dependent variable was included in the model while as the independent variable, energy consumption is used in the agricultural sector. The results show that there is a positive relationship between energy consumption and value added, or this indicates that if the energy consumption increased, the value added would increase as well. From the elasticity (i.e., the coefficient of the independent variable "energy input"), it can be seen that if the energy consumption in the agricultural sector was increased by 1%, the value added would increase by 0.45%. The energy input in the agricultural sector would cause CO_2 emissions. The factors which affect the total CO_2 emissions during 1990-2005 were the value added effect (C_{va}), the energy intensity effect (C_{ei}), and the energy mix effect (C_{em}). In this study, the product of these effects is equal to the total CO_2 emissions. The CO_2 emissions due to the value added effect contributed towards increasing CO_2 emissions during 1990-1995, 1996-2000, and 2001-2005 and this effect was the main factor behind the growth of CO_2 emissions at each period except at the period of 1996-2000. The CO_2 emissions due to the energy intensity effect was found to contribute towards increasing CO_2 emissions at each period except at the period of 2001 – 2005. Unlike the C_{va} and the C_{ei}, the C_{em} was not found to affect the total CO_2 emissions significantly at all periods.

5. References

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