JARQ 47 (3), 307 – 317 (2013) http://www.jircas.affrc.go.jp

Economic Ripple Effects of Bioethanol Production in ASEAN Countries: Application of Inter-regional Input-Output Analysis

Yoji KUNIMITSU[1]*, Kei TAKAHASHI[2], Takaaki FURUBAYASHI[3] and Toshihiko NAKATA[3]

[1] National Institute for Rural Engineering, National Agriculture and Food Research Organization (NARO) (Tsukuba, Ibaraki 305-8609, Japan)
[2] Environment and Energy Division, Mitsubishi UFJ Research and Consulting (Minato, Tokyo 105-8501, Japan)
[3] Management of Science and Technology Department, University of Tohoku (Sendai, Miyagi 980-8579, Japan)

Abstract

Bioethanol has great potential to reduce greenhouse gas emissions, improve energy security, and help revitalize agriculture. Accordingly, an E10 policy that substitutes bioethanol for 10% of all gasoline consumed will be globally popular. The present study aims to analyze the economic effects of bioethanol production for an E10 policy in nine ASEAN countries (except Brunei), with efforts to minimize CO_2 emissions. We consider two self-sufficient bioethanol production policies, i.e. self-sufficiency within each country and that within the ASEAN region under the scheme of a production quota. The optimization model, based on Takahashi et al.[20], and the inter-regional Input-Output Table, as estimated from the GTAP-7 (Global Trade Analysis Project, ver. 7) database, are used for consistent policy evaluation. The results demonstrated initially that the E10 policy under the scheme of a regional production quota elicited about 20% more environmental and economic effects than self-sufficient production within each country. Second, Singapore, Japan, China and the USA increased their production through bioethanol plant construction and annual production, even though this study assumed they did not increase bioethanol production. Approximately half the total induced production emerged in these countries. Third, induced production in agriculture accounted for half the total induced production. Based on these merits, several policy implications relating to the E10 policy with policy coordination are discussed.

Discipline: Agricultural economics
Additional key words: Annual bioethanol production, GTAP-7 database, Induced production, Investment in bioethanol production plants

Introduction

ASEAN countries have been experiencing rapid economic growth since the 1990's, and gasoline consumption in these countries is increasing rapidly. Because of a rise in oil prices, bioethanol is attracting great interest as an alternative vehicle fuel from people and businesses. Since an excessive dependence on the fossil fuels may increase geopolitical risk, a shift to bioethanol from fossil oil can improve national energy security. Along with bioethanol production, increased agricultural production as a demand for material is useful in revitalizing rural areas. Furthermore, as a form of carbon-neutral energy, bioethanol is expected to ease global warming and hence has multiple benefits for society. Considering these merits, many bioethanol production plants have already been launched, and the number of commercial production plants is now growing in ASEAN countries.

ASEAN countries are located in a tropical or sub-tropical zone and have high photosynthetic efficiency, low-cost agricultural production, and the ability to increase per-unit agricultural production, hence superiority in bioethanol production (NEDO[9]). Some countries have already expressed great interest in the production and use of bioethanol. For example, Thailand has already adopted an E10 policy that substitutes bioethanol for 10% of all gasoline consumed, while Vietnam and the Philippines show future usage plans

*Corresponding author: e-mail ykuni@affrc.go.jp
Received 1 July 2011; accepted 4 January 2013.

for bioethanol in the form of a renewable energy policy. If ASEAN countries adopt E10 policy, it may spawn great projects like the Green New Deal, which may, in turn, stimulate economies that suffered from serious global recession following the Lehman Shock. Of course, there is also the potential for bioethanol production from edible parts of agricultural crops to increase competition with food consumption. Birur et al.[1] analyzed the influence of bioethanol production on the food market using a computable general equilibrium model and showed how bioethanol production pressured the food market through land reallocation. Considering the limited use of edible parts, it is important to know the economic impacts of E10 policy on ASEAN countries.

Previous studies evaluated the environmental aspects of bioethanol produced from edible parts of agricultural products, such as sugar cane, maize and cassava. Using the life-cycle assessment (LCA) method, the net greenhouse gas (GHG) emissions from bioethanol production were quantified (Silaertruksa and Gheewala[19], Nguyen, Gheewala and Garivait[10], Papong and Malakul[15], Ou et al.[14], Saga et al.[18] and Koga[6]). Many results indicated that replacing gasoline with bioethanol could reduce total GHG emissions. However, the degree of reduction varies depending on the countries and materials used in bioethanol production (von Blottniz and Curran[22]).

The economic impacts of bioethanol production were also measured; mainly in the USA, Brazil, Japan and the EU. Urbanchuk[21] analyzed the macro-economic effects of bioethanol production by the input-output (I/O) model and showed that bioethanol production induced $32.5 billion of added value and created 110,000 employees in the USA in 2006. Polagye et al.[17] demonstrated the profit from a bioethanol production factory in the USA. Hayashi[4] analyzed Japanese bioethanol production by I/O analysis and pointed out that the economic benefit of bioethanol production could be positive if the fossil oil price increased in line with recent trends. Kunimitsu and Ueda[7] also measured the economic effects of biomass energy production in Thailand by I/O analysis. However, few studies evaluated the macro-economic impacts and ripple effects of bioethanol production in ASEAN countries.

The present study aims to analyze the environmental and economic effects of bioethanol production under E10 policy in nine ASEAN countries (except Brunei, where economies are small), and discuss the implications of the bioethanol policy. The features of this study are as follows. First, the study considers two self-sufficient bioethanol production policies, i.e. self-sufficiency within each country and that within the ASEAN region by using production quota to minimize regional CO_2 emissions. Second, the optimization model developed by Takahashi et al.[20] is combined with the I/O model to optimize CO_2 emissions and production within ASEAN countries and consistently measure the economic effects. Third, induced production as a ripple effect is evaluated by the I/O model, which endogenizes labor income and consumption, with the inter-regional I/O table estimated from the GTAP-7 (Global Trade Analysis Project, ver. 7, Purdue University) database for ASEAN and neighboring countries such as China, Taiwan, Japan, Korea and the USA.

The next section shows the methods used to estimate annual production under E10 policy and its costs, including construction. In addition, the methods used to estimate the inter-regional I/O Table and induced production are explained. In section 3, the performance of the estimated I/O Table is compared with the Asian International I/O Table published by the IDE-JETRO (Institute of Developing Economies—Japanese External Trade Organization). Next, the CO_2 emission reduction effects and the ripple effects of construction investment and annual production are evaluated with regard to the two self-sufficient policies. The final section provides policy implications based on the evidence to conclude this study.

Methodology

1. Bioethanol production and costs

To reduce the environmental burden and satisfy bioethanol demands for E10 policy, we considered two self-sufficient production policies.

Case 1 (self-sufficiency within each country): each country produces bioethanol to meet its internal demand subject to constraints of materials and CO_2 emissions and,

Case 2 (self-sufficiency within the ASEAN region under the production quota scheme): ASEAN countries produce bioethanol to meet the regional demands of E10 policy with restrictions on materials and allot their bioethanol production to countries where production is most environmentally effective to minimize regional CO_2 emissions.

Takahashi et al.[20] proposed a means of optimizing bioethanol production of the target area to minimize CO_2 emissions under constraint of materials. Their model is shown as:

$$\min. \quad \sum_j \left(g^{const}{}_{ij} + g^{feed}{}_{ij} + g^{om}{}_{ij}\right) x_{ij} \qquad (1) \text{ and}$$

$$s.t. \quad x_{ij} \le \alpha\, a_{ij}\, \eta_j\,, \quad \sum_j x_{ij} \ge b_i \qquad (2),$$

where suffixes i and j are countries which produce bioethanol and the kinds of material used for annual production, respectively. The superscripts *const*, *feed*, and *om* respectively show the construction process of the production plant, the material processing, and the operation-and-maintenance process. g is GHG emission per production [t-CO_2/L], x is the amount of bioethanol production [L], α is the upper limit ratio of the material increased in future and used for bioethanol production as compared to the present production level, η is the conversion coefficient that shows bioethanol production per unit of crops [L/t], a is the total amount of material crops as the basis of the change [t], and b is the consumption amount of bioethanol [t]. Detailed data for the above model are based on Takahashi et al.[20], although Vietnam is added from the same statistical source. The value of b is set as 10% of gasoline consumption in each country. To avoid using only specific crops and consider the limited speed of technology diffusion, the value of α is set as 0.1 for each material crop subjectively, after considering the potential increased in the unit harvest of each crop[i].

The total costs for plant construction (C^{const}), materials (C^{feed}), and operation-and- maintenance (C^{om}) in each country are

$$C^{const}{}_i = c^{const} \cdot LF_i \cdot \sum_j x_{ij} \quad (3),$$

$$C^{feed}{}_{ij} = p_{ij} \cdot x_{ij} / \eta_j \quad (4) \text{ and}$$

$$C^{om}{}_i = c^{om}{}_i \cdot \sum_j x_{ij} \quad (5),$$

where p is the crop price [\$/t], c^{const} and c^{om} are, respectively, annual unit construction cost for capital [\$/L], and the unit operation-and-maintenance costs for production [\$/L]. LF is the location factor of the plant, which is the ratio of the average construction cost for a chemical plant in each country to that in Japan (Japan Machinery Center for Trade and Investment, *Report on PCI/LF*). The values of c^{const} are estimated from the research data of Japanese bioethanol production plants in the town of Shimizu, Hokkaido. Other unit costs by input sectors are based on the expense rates shown in the reports of F.O. Licht GmbH and Agra CEAS Consulting[3].

The price of bioethanol is assumed to be the same as that of gasoline, because bioethanol is supposed to compete with gasoline in the market. The difference between the selling price and unit cost is assumed to be covered by government subsidies if the total unit cost exceeds the selling price. If the selling price exceeds the cost, the gap is assumed to be government surplus or tax revenue.

2. Inter-regional I/O analysis

Inter-regional I/O analysis is used for measuring ripple effects, assuming the price is less flexible in the real market. Nakamura[8] analyzed the linkage structure of Asian countries with the Asian International I/O Table (IDE-JETRO). This table appears credible and is based on field surveys. However, the reference year is 2000 and excludes Cambodia, Laos, Myanmar and Vietnam, where biomass resources are rich. To consider the above countries, we estimated the inter-regional I/O table using the GTAP-7 database.

Estimations are based on the methods of Davis and Caldeira[2] and Peters and Hertwich[16] (Appendix). Sectors for intermediate inputs are 23, kinds of added values are four, and final demands are six respectively. The target countries are 14: nine ASEAN countries and China, Taiwan, Japan, Korea, and the USA; the non-ASEAN countries included have strong economic relations with ASEAN countries. The estimated table is a hybrid type, i.e. non-rival assumptions for trade commodities within the region and rival consumption for goods imported from outside the region.

Since data on Myanmar was omitted from the first version of GTAP-7 due to low reliability, this study uses the input coefficients of Vietnam for Myanmar by assuming similar industrial linkage structures in both countries. The RAS method is employed to balance the inputs and outputs in the table[ii]. Okamoto and Arakawa[12] point out that induced production estimated from the I/O matrix using the input coefficients of another country is relatively reliable if the RAS method is applied, and the economic and institutional conditions resemble those of the country from which the input coefficients are borrowed.

The estimated inter-regional I/O table allows us to measure the ripple effects of investments for plant construction as well as the annual expenditures for bioethanol production. Such ripple effects are measured by induced production by the model, in which consumption and labor income are endogenous variables (Miyazawa[11], Okuyama, Sonis and Hewings[13]). The induced production (**X**) is

$$\mathbf{X} = \mathbf{B}\,\Delta\mathbf{F_X} + \mathbf{B\,C\,K\,V\,B}\,\Delta\mathbf{F_X} + \mathbf{B\,C\,K}\,\Delta F_Y \quad (6).$$

Hereafter, bold characters show the vectors and matrixes. **B** is the inverse matrix calculated by $\mathbf{B} = [\mathbf{I} - (\mathbf{I} - \mathbf{M})\mathbf{A}]^{-1}$. **I** is the identity matrix. **M** is the import coefficient matrix. **A** is

[i] The New Energy and Industrial Technology Development Organization[9] (NEDO) reported that the potential unit harvest of material crops, such as sugarcane, cassava and maize for bioethanol production, can be increased by about 50% from 2003 or 2004 to 2030 in ASEAN countries. Based on the report of the Food and Agricultural Organization (FAO), Kawashima[5] mentioned that areas to expand agricultural land in Southeast Asia corresponded to 19% of the cultivated farmland with suitable conditions for crops. Based on these forecasts, the potential exists to expand the production of material crops if demand increases.

[ii] RAS is a technique to adjust the input-output matrix to equalize the column sum and row sum of the I/O table. In this method, the economic structure is assumed to change from the base table to a target table with minimal change.

the matrix of the intermediate input coefficients. **C** is the consumption coefficient vector, which shows the consumption of each section against one unit of income increase. **K** is the multiplier related to the income increase and calculated by $\mathbf{K} = (\mathbf{I} - \mathbf{V}\ \mathbf{B}\ \mathbf{C})^{-1}$. **V** is the income coefficient vector, which shows the income increased against one production unit in each industrial sector. $\Delta\mathbf{F_X}$ is the vector that shows increases in final demand relating to the intermediate industry and includes consumption, investment, and export. ΔF_Y is the scalar of the increase in labor income. **A**, **M**, and **V** are computed from the I/O table estimated above, and **C** is calculated by multiplying the average propensity of consumption (0.762) by the share rate of consumption in each sector.

The first term on the right side of Eq. (6) is the ripple effect induced through the industry linkage among intermediate industries (backward effect). The second term is the further ripple effect induced through the following steps (forward effect). The first effect improves labor income via labor cost in each sector and then increases consumption, which becomes demand for the intermediate inputs in each sector. This process is repeated in the next stage by increasing consumption with some leakage through saving until the increased production converges with zero[iii]. The third term shows another ripple effect caused by an increase in direct labor income in final demand, which induces consumption by boosting intermediate demand (the second forward effect).

The construction investment of the plant and expenses for annual production regarding with the intermediate inputs are respectively substituted for $\Delta\mathbf{F_X}$, while the labor cost required for production as labor income is substituted for ΔF_Y. Ripple effects from other value added factors are not measured here.

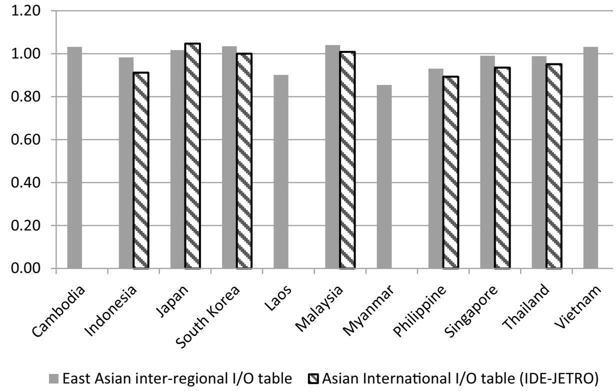

Fig. 1. Power of dispersion by countries
(Note) The height of the bar shows the average value of coefficients for 23 industries in each country (14 countries).

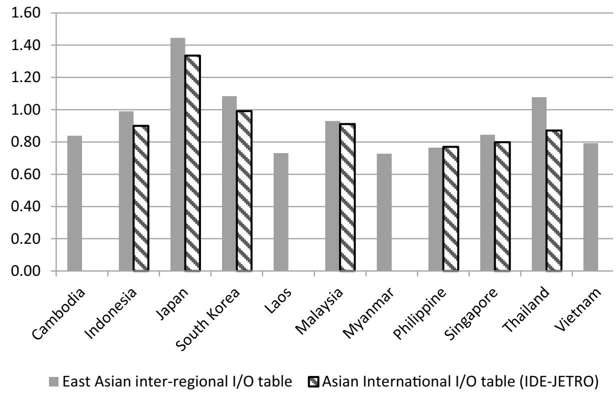

Fig. 2. Production inducement coefficients by countries
(Note)Same as Figure 2.

Results

1. Performance of the estimated inter-regional I/O table

The performance of the estimated I/O table was compared with the Asian International I/O Table published by IDE-JETRO. The countries and year of the Asian International I/O Table are different from the estimated inter-regional I/O table, so the two tables do not completely correspond with each other. The power of dispersion (POD) and production inducement coefficients (PIC) calculated from the inverse matrix in Eq. (6) were compared to determine the comprehensive effects of industrial linkage. The POD shows strength in backward linkage, while the PIC shows strength in the forward linkage of industries.

The PODs in both tables were almost the same in all countries (Fig. 1). In addition, the PICs of the two tables corresponded well except for Thailand (Fig. 2). Thailand has strong relations with Cambodia, Laos, Myanmar, and Vietnam, which were not included in the IDE-JETRO table, so the estimated table captured reflection effects from the added countries and could cause a slight difference between the PICs.

We also compared these coefficients in each industry, the results of which were not presented here, however, due to space. The PODs and PICs of the estimated inter-regional I/O table resembled those of the comparative table in most

[iii] The ultimate ripple effects calculated by the second term may not be realized in a year in a real economy. Some previous studies considered only the income inducement effect in the first step. However, this study considered all effects, including future effects, because it aims to evaluate the impacts during operating periods for 15 years. As shown in the case of Vietnam, 75 to 85% of the total income inducement effect comes from the first step, meaning the evaluation employed here shows substantially different values from that using only the first step.

Table 1. Increased rate of material crops for bioethanol production in each country

[rate]

Countries	rice	maize	sugarcane	cassava	sweet potato
Case 1 (Selfsufficiency within each country)					
Cambodia			0.10	0.03	
Indonesia	0.03		0.10	0.10	
Laos			0.10	0.01	
Malaysia	0.10	0.10	0.10	0.10	0.10
Myanmar			0.05		
Philippines			0.09		
Singapore					
Thailand			0.10	0.01	
Vietnam			0.10	0.07	
Case 2 (Production quota within ASEAN region)					
Cambodia	0.05	0.10	0.10	0.10	0.10
Indonesia			0.10		
Laos	0.10	0.10	0.10	0.10	0.10
Malaysia			0.10		
Myanmar	0.10	0.10	0.10	0.10	0.02
Philippines			0.10		
Singapore					
Thailand			0.10		
Vietnam			0.10		

(Note) Values in this table were calculated by (the amount of material crop increase) / (present crop production). Since α is set as 0.1, the maximum value in this table cannot exceed 0.1.

Table 2. Quantity of bioethanol produced and replaced with gasoline

Countries	Prod. of bioethanol million L	Cons. of bioethanol (a) million L	Cons. of gasoline (b) million L	Bioethanol /Gasoline (a)/(b)	Reduction of CO2 by the change 1000 ton
Case 1 (Selfsufficiency within each country)					
Cambodia	21	21	205	0.10	7
Indonesia	1,851	1,851	18,507	0.10	487
Laos	3	3	33	0.10	3
Malaysia	210	210	10,845	0.02	70
Myanmar	51	51	508	0.10	61
Philippines	355	355	3,548	0.10	427
Singapore	0	0	1,093	0.00	0
Thailand	697	697	6,972	0.10	723
Vietnam	402	402	4,020	0.10	305
Total	3,589	3,589	45,732	0.08	2,083
Case 2 (Production quota within ASEAN region)					
Cambodia	376	21	205	1.83	-441
Indonesia	38	1,851	18,507	0.00	2,821
Laos	260	3	33	7.79	-320
Malaysia	13	1,085	10,845	0.00	1,656
Myanmar	2,633	51	508	5.18	-3,154
Philippines	412	355	3,548	0.12	408
Singapore	0	109	1,093	0.00	167
Thailand	623	697	6,972	0.09	856
Vietnam	219	402	4,020	0.05	541
Total	4,573	4,573	45,732	0.10	2,535

Table 3. Production, costs and needed investment by scenarios and countries

[$ million]

Countries	Production costs						Surplus minus Subsidy	Total sales	Inv. for plant construct.
	Total	Material	Service etc.	Labor	Capital	Trans-port			
Case 1 (Selfsufficiency within each country)									
Cambodia	7	4	0	0	3		3	11	31
Indonesia	1,282	996	11	19	257		-562	721	2,666
Laos	6	5	0	0	0		-4	2	5
Malaysia	138	104	1	2	31		-63	75	322
Myanmar	14	6	0	1	7		12	26	76
Philippines	295	242	2	4	47		-72	222	489
Singapore	0	0	0	0	0		0	0	0
Thailand	332	221	4	7	100		105	437	1,040
Vietnam	171	107	2	4	58		49	220	599
Total	2,245	1,684	21	37	503		-532	1,714	5,228
Case 2 (Production quota within ASEAN region)									
Cambodia	183	123	2	4	54	0	10	194	561
Indonesia	36	16	0	0	5	14	-21	15	55
Laos	137	95	2	3	37	0	-3	134	387
Malaysia	15	6	0	0	2	7	-11	5	20
Myanmar	1,431	1,010	15	27	378	0	-76	1,355	3,926
Philippines	313	251	2	4	55	0	-54	258	568
Singapore	1	0	0	0	0	1	-1	0	0
Thailand	292	192	4	6	89	0	99	391	929
Vietnam	104	67	1	2	31	1	16	120	326
Total	2,511	1,761	26	47	652	24	-40	2,471	6,772

(Note)

1. Total sales = gasoline price × production quantity of bioethanol, and Surplus - subsidies = total sales – total production costs.
2. Material cost is the production cost of crops and cost of service etc. including costs of chemical products, repair and retail services.
3. Investment in plant construction was calculated by the annual capital cost (Japan) × Location factor.
4. In both cases, Singapore did not produce bioethanol, but increased the material production used elsewhere.

industries, meaning there is probably no serious problem in using this estimated table for the simulation.

2. Bioethanol production and production costs

Table 1 shows the amount of production and the increase rate of material crops. In case 1, maize, cassava, and sugarcane were mainly used. Malaysia's upper production limit was far less than the demand designated by the E10 policy and Singapore could not achieve the E10 policy, but other countries produced all bioethanol domestically demanded. Myanmar and the Philippines did not reach the upper limit of materials, even after producing bioethanol for the E10 policy. As shown by the surge in sugarcane and cassava, these crops were used in the early stages due to low CO_2 emission rates and high conversion efficiency. In contrast, rice tended to be not used. In Case 2, bioethanol production was concentrated in countries where sugarcane could be increased within the material constraints.

Table 2 shows the production and consumption amounts of bioethanol, and the reduction of CO_2 emissions by replacing gasoline with bioethanol for motor vehicles. The total reduction in CO_2 emissions was 22% superior than Case 1, even though Cambodia, Laos and Malaysia, where bioethanol production exceeded consumption, saw increased CO_2 emissions.

Table 3 shows the production, costs, and required investment in plant construction, the values of which were input into Eq. (6). The values in the surplus-minus-subsidy column show the gaps when bioethanol was sold in the market. In Case 1, Indonesia, Laos, Malaysia and the Philippines need government subsidies due to high production costs and a relatively low selling price which is equivalent to the gasoline price converted by the energy difference. In contrast, there were large economic surpluses in Thailand and Vietnam. In Case 2, the negative values became small and total surplus minus subsidies decreased to less than 1/10. In this case, the selling price was set at the same level as Case 1 to clarify the difference, so most of the negative values originated from a deficit in domestic production. Overall, the rate of total sales divided by total costs in the case of production quota (0.98) exceeded domestic production (0.76), showing that the production quota can increase economic efficiency in bioethanol production.

The investment costs exceeded those of annual production, but only marginally. Such a small difference between construction costs and annual expenditures was due to the low portion of capital costs in bioethanol production. Actually, 70% of the annual production costs consist of material costs, and the capital costs are relatively low, which is a characteristic of bioethanol production from edible farm products.

3. Results of ripple effects measured by induced production

Induced production from investment in plant construction is shown in Table 4. In Case 1, an investment of $5.2 billion generated production of $15.0 billion (the multiplier value is 2.9). In Case 2, total investment was $6.8 billion, and induced production was $18.2 billion. The multiplier (2.7) was lower than in Case 1, because the production level decreased in Case 2 in Indonesia and Malaysia, where industrial linkage was more complex and import rates were lower. Interestingly, only half of all induced production emerged in the home country where initial investment was input, and the remainder went to other countries within the region via inter-industrial linkage.

Induced production in Singapore was modest in spite of the short distance of trade from other countries within the region. Singapore's manufacturing sector is weak compared to China's. Japan, China, and the USA received great benefits from bioethanol production even though our simulation assumed these countries did not increase bioethanol production. This is because these countries export machinery used for chemical plants in ASEAN countries.

Table 5 shows induced production caused by annual expenditures for bioethanol production after plant construction. Induced production mainly emerged in domestic economies, and the domestic production rate exceeded 0.5. In both cases, total induced production was about twice as high as the input value from annual production. This multiplier was lower than construction investment because the sector related to this activity was mainly agriculture, which has a simpler industrial linkage structure than the manufacturing sector. Owing to a reduction in the negative value of surplus minus subsidies in Case 2, total output per total input exceeded that of Case 1, while total ripple effects in Case 2 exceeded Case 1 by about 21%. In particular, Cambodia, Laos and Myanmar could increase the total ripple effects in Case 2.

Table 6 shows induced production from plant construction and annual production by industries. The ripple effects of plant construction appeared mostly in the second and third industries, whereas the effects of annual production dominated in the first industry. More than half of all induced production took place in the agricultural sector,

Tale 4. Ripple effects of plant construction investment

[$ million, ratio]

Countries	Inv. for plant const.	Induced Prod.	multiplier
Case 1 (Selfsufficiency within each country)			
Cambodia	31	34	1.11
Indonesia	2,666	4,312	1.62
Laos	5	10	2.01
Malaysia	322	465	1.44
Myanmar	76	75	0.99
Philippines	489	548	1.12
Singapore	0	361	
Thailand	1,040	1,357	1.31
Vietnam	599	690	1.15
China		1,443	
Japan		2,531	
Korea		499	
USA		2,645	
Total	5,228	14,970	2.86
Rate of domestic prod.		0.52	
Case 2 (Production quota within ASEAN region)			
Cambodia	561	628	1.12
Indonesia	55	266	4.84
Laos	387	485	1.25
Malaysia	20	323	16.10
Myanmar	3,926	3,868	0.99
Philippines	568	613	1.08
Singapore	0	530	
Thailand	929	2,009	2.16
Vietnam	326	434	1.33
China		3,152	
Japan		2,526	
Korea		724	
USA		2,687	
Total	6,772	18,245	2.69
Rate of domestic prod.		0.50	

(Note) 1. Induced production was calculated by inputting the investment value converted from the original investment value shares in the inter-regional I/O table.

though its share rate was lower than the input share in agriculture. Accordingly, bioethanol production can stimulate not only agriculture but also other industries via industrial linkage.

Policy implications and concluding remarks

This study analyzed the economic effects of bioethanol production for E10 policy in ASEAN countries where gasoline consumption has been increasing under rapid economic growth. Two self-sufficient bioethanol production policies were considered, i.e. self-sufficiency within each country and self-sufficiency within the ASEAN region under the production quota scheme. The amount of bioethanol production was estimated by the optimization model to minimize CO_2 emissions and induced production was measured

Table 5. Ripple effects of annual expenditures for bioethanol production

[$ million, ratio]

Countries	Input		Output				
	Inter-mediate inputs	cosumption increased by labor income	Induced prod. by intermed.	multi-plier	Induced prod. by labor income	Surplus-Subsidy	Total
Case 1 (Selfsufficiency within each country)							
Cambodia	4	0	4	0.97	0	3	7
Indonesia	1,006	11	1207	1.20	14	-562	659
Laos	5	0	5	1.00	0	-4	1
Malaysia	105	0	127	1.21	1	-63	65
Myanmar	6	0	7	1.11	0	12	19
Philippines	244	3	270	1.11	3	-72	201
Singapore	0	0	17		0	0	17
Thailand	225	4	268	1.19	4	105	377
Vietnam	109	1	117	1.07	1	49	167
China			152		0		152
Japan			395		2		397
Korea			51		0		51
USA			779		6		785
Total	1,705	19	3,399	1.99	31	-532	2,898
Rate of domestic prod.			0.59				0.52
Case 2 (Production quota within ASEAN region)							
Cambodia	125	2	162	1.29	3	10	175
Indonesia	30	0	47	1.57	0	-21	26
Laos	97	1	104	1.07	1	-3	102
Malaysia	13	0	21	1.60	0	-11	10
Myanmar	1,026	17	1059	1.03	27	-76	1,010
Philippines	254	3	282	1.11	3	-54	231
Singapore	1	0	11	11.00	1	-1	11
Thailand	196	4	251	1.28	10	99	360
Vietnam	70	0	75	1.07	0	16	91
China			150		4		154
Japan			420		6		426
Korea			47		0		47
USA			858		11		869
Total	1,811	27	3,487	1.93	66	-40	3,513
Rate of domestic prod.			0.58				0.57

(Note) 1. Intermediate inputs consist of material costs, other service costs and transportation costs. Consumption increased by labor income is set by (the share of consumption for each good) × average propensity of total consumption× increased labor income.

from the plant construction process and production process by using a newly estimated inter-regional I/O table. The results suggest the following policy implications:

First, the E10 policy brought about environmental and economic effects, and the scheme of the production quota produced more in both effects than the individual policy. The rates of increase in the production quota scheme were about 20% in terms of both environmental and economic effects as compared to the self-sufficiency within each country, which means the production quota among ASEAN countries is environmentally and economically more effective than self-sufficient production within each country. Although the negative values in surplus minus subsidies decreased in the production quota scheme, some countries still need subsidies for bioethanol production. To realize the production quota within ASEAN countries and fill the gap between oil prices and bioethanol production costs, policy coordination among countries is crucial. For such coordination, it is important to show economic ripple effects in addition to environmental merit to policy decision makers.

Second, Singapore, Japan, China, and the USA can also induce their production by plant construction and annual production, even though they are assumed not to increase bioethanol production in this study. Approximately half the total induced production emerged in these neighboring countries. Because of such leakage through industrial linkage, the rate at which ASEAN countries can obtain the benefit was relatively low, hence these neighboring coun-

Table 6. Ripple effects by industrial sectors

[$ million]

Destination \ Origin	Plant construction investment: Input	Share	Induced pord.	Share	Annual expenditures (except for capital costs): Input	Share	Induced pord.	Share
Case 1 (Selfsufficiency within each country)								
Agriculture	33	0.01	161	0.01	1,686	0.97	1,730	0.50
Mining	0	0.00	374	0.02	0	0.00	16	0.00
Manufacture	1,965	0.38	6,181	0.41	19	0.01	390	0.11
Public service	2,999	0.57	5,829	0.39	9	0.01	936	0.27
Other service etc.	231	0.04	2,425	0.16	19	0.01	357	0.10
Total	5,228	1.00	14,970	1.00	1,733	1.00	3,429	1.00
Case 2 (Production quota within ASEAN region)								
Agriculture	208	0.03	428	0.02	1,764	0.96	1,762	0.51
Mining	0	0.00	419	0.02	0	0.00	12	0.00
Manufacture	2,873	0.42	8,511	0.47	32	0.02	315	0.09
Public service	3,401	0.50	6,548	0.36	11	0.01	1,027	0.29
Other service etc.	290	0.04	2,339	0.13	40	0.02	371	0.11
Total	6,772	1.00	18,245	1.00	1,846	1.00	3,487	1.00

tries should provide a capital fund for investment to ASEAN countries and take the initiatives for policy coordination. In addition, these countries should help and develop bioethanol production technology to achieve E10 policy with low production costs.

Third, annual bioethanol production increases agricultural production, benefiting the agricultural sector with more than half all induced production. Interestingly, the initial share rate of increased final demand in agriculture was about 90%, whereas the share rate of induced production in this sector was low and that in other industries became high.

However, bioethanol production from edible farm products may affect the food market. People will not accept the conversion of food to bioethanol when market food prices rise. Nevertheless, when food prices decline, bioethanol production can be an alternative income source for farmers. To achieve a balance, economic evaluation can play an important role. Without concrete evidence, discussions will never converge. Reflecting such purpose, the method employed here is useful for developing policies related to bioethanol production.

Several issues remain unresolved. The upper limit of material increase was set subjectively, but a more objective method based on field surveys is urgently needed. To avoid competition in the food market, the evaluation of cellulosic ethanol produced from wood or rice straw (second-generation bioethanol production) are issues that must be urgently resolved. In addition, the influences of bioethanol production from edible crops on the food market should be analyzed and evaluated. The computable general equilibrium model can be applied to this issue. The inter-regional I/O data estimated here can also be used for this analysis.

Appendix

The inter-regional I/O table used in this paper was estimated from the GTAP-7 database according to the following procedure:

(i) Domestic intermediate input, x, is ① in Fig. A-1 (hereafter the circled number shows the part in Fig. A-1):

$$x(i_k, j_k) = x'_k(i, j) + \{1 - rw_k(i)\} \cdot mx'_k(i, j) \qquad \text{(a1)}.$$

Here, x' is the domestic intermediate input of the GTAP-7 data (hereafter, variable with apostrophe originates in the GTAP-7) and mx' represents the imports of intermediate inputs from the rest of the world (ROW). The suffixes i and j show industry, while k and l show country ($i, j = 1,2,\cdots 23$, $k, l = 1,2,\cdots 14$), so i_k means the i-th industry in the k-th country. rw is the rate of import from other countries within the region as follows:

$$rw_l(i) = 1 - mo'_l(i) / M'_l(i) \qquad \text{(a2)}.$$

Here, mo'_l is the import of the l-th country from ROW, and M'_l is the total import.

(ii) Intermediate inputs of the l-th country from the i-th country within the region are (②):

$$x(i_k, j_l) = rr_l(i) \cdot rw_l(i_k) \cdot mx'_l(i, j), (k \neq l) \qquad \text{(a3)}.$$

The share of import by country within the region, rr, is:

$$rr_l(i_k) = m'_{k,l}(i) / \sum_k m'_{k,l}(i) \qquad \text{(a4)}.$$

Here, $m'_{k,l}(i)$ is the l-th country's import from the i-th industry in the k-th country. rw and rr for the output industries

Sectors	Cambodia Paddy	....	k-th country j- th industry	....	l-th country j-th industry	....	Vietnam Service	Cambodia Cons., Inv.	....	l-th country Cons., Inv.	....	discre-pancy	Export	Import	Total X_H
Cambodia Paddy	①							④							
:															
k-th country i-th industry			$x(i_k, j_k)$		②				④	⑤					
k-th country i_k+1-th industry				①											
:												⑧	⑦	⑥	
l-th country j-th industry		②			①					④					
:								⑤							
Vietnam Service							①								
Value added			③												
Total X_V															

Fig. A-1. Structure of the estimated inter-regional I/O table

(horizontal sectors) are assumed to be the same as in the input industries.

(iii) The added value, v, is set by the GTAP-7 data as (③):

$$v(o, j_l) = v'_l\,(o, j) \qquad \text{(a5).}$$

Here, the suffix o is the classification of input factors, such as labor income, operating surplus, depreciation of capital and surplus minus subsidies.

(iv) Final demand, fd, is (④, ⑤):

$$fd(i_k, n_k) = fd'_k\,(i, n) + \{1 - rw_k\,(i)\} \cdot mf'_k\,(i,n) \qquad \text{(a6).}$$

Here, the suffix n shows the classification of final demand, such as household consumption, government consumption and investment. $mf'_k\,(i,n)$ is the import caused by the n-th demand for the i-th industry in the k-th country, which is also shown in the GTAP-7 database.

In terms of final demand for other countries within the region, i.e. imports caused by final demand, these are calculated as follows in the same way as Eq. (a3).

$$fd(i_k, n_l) = rr_l\,(i) \cdot rw_l\,(i_k) \cdot mf'_l\,(i, n),\ \ (k \neq l) \qquad \text{(a7).}$$

(v) Import from ROW, m, is (⑥):

$$m(i_k) = \sum_j rw_l\,(i_k) \cdot [mx'_l\,(i, j) + mf'_l\,(i,j)] \qquad \text{(a8).}$$

When we calculate $fd(i_k, n_l)$ for all countries within the region by Eq. (a7), export for the k-th country emerges in the new column. So, export to the ROW, e (⑦), can be calculated as:

$$e(i_k) = e'_k\,(i_k) - \sum_l \sum_n fd(i_k, n_l),\ \ (k \neq l) \qquad \text{(a9).}$$

(vi) Total demand (intermediate inputs + household consumption + government consumption + investment + export to the ROW - import from the ROW) equals total production. The horizontal sum should correspond to the vertical sum with regard to the same country and industry. However, x and fd in the above estimation are estimated by proportional allotment, meaning the horizontal and vertical sums may not correspond. Statistical discrepancy including tariff, H, is calculated as follows:

Vertical sum: $X_V\,(j_l) = \sum_{i,k} x(i_k, j_l) + v(j_l)$

Horizontal sum:

$X_H\,(i_k) = \sum_{j,l} x(i_k, j_l) - \sum_{n,l} fd(i_k, n_l) - e(i_k) + m(i_k)$

Statistical discrepancy and tariff (⑧):

$$H(i_k) = X_V\,(i_k) - X_H\,(i_k) \qquad \text{(a10)}$$

Acknowledgments

This study was supported by the Grant-in-Aid for Scientific Research [22530256] (Ministry of Education, Science, Sports and Culture) and the research project, “Proposal on policy coordination scheme among East Asian countries for optimal bioethanol production and utilization” (Sumitomo Foundation, the project leader Dr. Yutaka Mori, Japan International Research Center for Agricultural Science). The authors greatly appreciate their support.

References

1. Birur, K.D. et al. (2007) The Biofuels Boom: Implications for World Food Markets. Paper prepared for presentation at the Food Economy Conference, The Hague, http://www.agecon.purdue.edu/papers/.
2. Davis, S.J. & Caldeira, K. (2010) Consumption-based accounting of CO_2 emissions. *Pro. Nat. Acad. Sci.*, **107**, 5687–5692.
3. F.O. Licht GmbH & Agra CEAS Consulting (2007) Ethanol Production Costs: A Worldwide Survey. Agra Informa Ltd.,

United Kingdom, www.agra-net.com.
4. Hayashi, T. (2010) Evaluating the Economic-Environment Co-Benefit of Bio-Fuel Production: An Application of Eco-Efficiency. *J. Agric. Policy Res*., **18**, 41–57.
5. Kawashima, H. (2008) (ed.) World Food Production and Biomass Energy. The Outlook for 2050, Univ. of Tokyo Press, 2–21.
6. Koga, N. (2008) An energy balance under a conventional crop rotation system in northern Japan: Perspectives on fuel ethanol production from sugar beet. *Agric. Ecosys. Environ*., **125**, 101–110.
7. Kunimitsu, Y. & Ueda, T. (2006) Economic Evaluation on Agricultural Biomass Resource Use in Thailand-Case of Rice Husk Electricity Power Plants. *Studies in Regional Science*, **36**, 561–573.
8. Nakamura, J. (2004) International Comparison on Input Coefficients using Asian International Input-Output table. *In* International Industrial Linkage (III), eds. Nakamura & Arakawa, IDE-JETRO, 104–122.
9. New Energy and Industrial Technology Development Organization (NEDO) (2006) Investigation Report on Production and Export Potential of the Biofuel in the ASEAN Countries. No. 100010968, http://www.nedo.go.jp/library/database_index.html.
10. Nguyen, T.L.T. et al. (2007) Energy balance and GHG-abatement cost of cassava utilization for fuel ethanol in Thailand. *Energy Policy*, **35**, 4585–4596.
11. Miyazawa, K. (1975) Introduction of Input-Output analysis. NIKKEI inc., 175–184 [in Japanese].
12. Okamoto, N. & Arakawa, S. (2003) A Note of the Stability of Asian International Input-Output Tables. *In* International Industrial Linkage (II), eds. Nakamura & Arakawa, IDE-JETRO, 56–67.
13. Okuyama, Y. et al. (2010) Economic Impacts for an Unscheduled Disruptive Event: A Miyazawa Multiplier Analysis. *Understanding and Interpreting Economic Structure*, Springer, 113–143
14. Ou, X.M. et al. (2009) Energy consumption and GHG emissions of six biofuel pathways by LCA in People's Republic of China. *Applied Energy*, **86**, S197–208.
15. Papong, S. & Malakul, P. (2010) Life-cycle energy and environmental analysis of bioethanol production from cassava in Thailand. *Bioresource Technol*., **101**, S112–118.
16. Peters, G.P. & Hertwich, E.G. (2007) CO_2 Embodied in International Trade with Implications for Global Climate Policy. *Environ. Sci. Tech*., **42**, 1401–1407.
17. Polagye, B. et al. (2007) An Economic Analysis of Bioenergy Options Thinning from Overstocked Forests. *Biomass and Bioenergy*, **31**, 105–125.
18. Saga, K. et al. (2010) Net energy analysis of bioethanol production system from high-yield rice plant in Japan. *Applied Energy*, **87**, 2164–2168.
19. Silaertruksa, T. & Gheewala, S.H. (2009) Environmental sustainability assessment of bio-ethanol production in Thailand. *Energy*, **34**, 1933–1946.
20. Takahashi, K. et al. (2011) Optimization of international bioethanol supply in East Asia. *J. Jap. Inst. Energy.* **90**, 963–971.
21. Urbanchuk, J.M. (2009) 2008 Contributions of the Ethanol Industry to the Economy of the United States. RFA Reports and Studies, Renewable Fuels Association.
22. von Blottniz, H. & Curran, M.A. (2007) A review of assessments conducted on bio-ethanol as a transportation fuel from a net energy, greenhouse gas, and environmental life cycle perspective. *J. Cleaner Prod*., **5**, 607–619.