Energy productivity during the years of Doi Moi

By

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Abstract

Economic reform during the last two decades in Vietnam has required a large energy demand. Using the input-output (IO) tables of 1989 and 1996, which are key years of Doi Moi (Reform), this work reveals the changes in energy intensities in all economic sectors and identifies sectors that are directly and indirectly responsible for the changes in the energy requirements. Furthermore, the agriculture effects on energy consumption among the various sectors are discussed. The valuable contribution of fertilizer production for sustaining the agriculture sector is clarified.

Introduction

IO table, which displays the exchanges of goods and services among the economic sectors, will be used to analyze the nature of energy consumption in Vietnam. Using this method, the total energy required to deliver a product to the final consumer, including both the energy directly consumed in the production process and the energy indirectly embodied in that industry's input, can be estimated. In the mid-1970s, the common method for analyzing the changes in energy utilization using IO tables is structural decomposition analysis (SDA). In some SDA, the direct and indirect effects of changes in embodied energy intensity can be measured (Rose A. and Casler S., 1996). The direct changes of energy input only explain part of the relationship between energy use and product output since indirect effects also contribute to changes in total energy use.

After adopting Doi Moi policy in 1986, Vietnam's chief goal became "Modernization and Industrialization" and its economy has been gradually shifting from an agricultural to an industrial based economy, which has caused a large increase in energy requirements. The energy flow in Vietnam in 1996 was analyzed by the authors in two previous works. In one of them (Nguyen T.A.T. and Ishihara K.N., 2003), manufacturing sector represented the major energy consumer and energy efficiency of cement production was mainly discussed. In the other (Nguyen T.A.T. and Ishihara K.N., 2004), the hidden energy flow from supply and demand sides was analyzed and fertilizer was

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presented as a key sector in order to raise the energy productivity in food processing sectors.

The purpose of this work is to determine the changes in energy intensity for each economic sector using SDA and identify the sectors that are directly or indirectly responsible for the change during the years of Doi Moi. Furthermore, given the importance of agricultural production, there is a particular interest in evaluating the effects of agriculture on the consumed energy among the economic sectors. The significance of the agriculture is substantial since this sector generates economic activities in other sectors through its demand for intermediate goods and services and by supplying intermediate inputs to the food processing industries.

Basis for SDA

It is reported that the energy required to deliver a product to final demand can be estimated using IO table (Bullard C. and Herendeen R., 1975, Miller R. and Blair P., 1985). IO tables are usually in monetary units, but for the energy sectors analyses, physical units rather than monetary units are preferred. Hence, we, first, modified the technical coefficient matrix, A, to hybrid-unit one, A^* (hereafter, superscription* denotes hybrid unit), by assuming that the amount of goods transferred is proportional to their monetary value. Then the matrix of embodied energy intensity, ε, can be obtained by extracting energy rows from the *hybrid-unit Leontief inverse*.

$$\varepsilon = (I - A^*)^{-1} \tag{1}$$

where e is defined as a *product matrix* of type $m \times n$ and m of n sectors are assumed energy sectors. This matrix consists of zeroes and ones with the ones denoting energy sectors.

Embodied energy consumption of any sector j is obtained by multiplying embodied energy intensity of that sector ε_j by the corresponding value of final demand, y_j^*.

$$x_e^* = \varepsilon \hat{y}^* \tag{2}$$

where ^ denotes a diagonalized matrix.

The SDA can be performed to separately measure the change of embodied energy intensity caused by direct use of energy (directly related to the energy sectors) and by indirect use (associated with the consumption of energy in the non-energy sectors) between two years (Millan A. J. and Millan S. J., 2002). The direct changes of energy input only explain a part of the relationship between energy use and product output since indirect effects also contribute to changes in embodied energy use. Based on Eq.(1), the relationship between years is:

$$\varepsilon_1 - \varepsilon_1 A_1^* = \varepsilon_0 - \varepsilon_0 A_0^* \tag{3}$$

where ε_0 and ε_1 represent embodied energy intensity in the based and terminal year, respectively.

When $\Delta\varepsilon = \varepsilon_1 - \varepsilon_0$ and $\Delta A^* = A_1^* - A_0^*$ then:

$$\Delta\varepsilon = \varepsilon_1 A_1^* - \varepsilon_0 A_0^* \tag{4}$$

$$2\Delta\varepsilon(1 - \frac{A_1^* + A_0^*}{2} = (\varepsilon_1 + \varepsilon_0)\,\Delta A^* \tag{5}$$

When $\bar{\varepsilon} = \frac{\varepsilon_1 + \varepsilon_0}{2}$ and $\bar{A}^* = \frac{A_1^* + A_0^*}{2}$ then:

$$\Delta\varepsilon = \bar{\varepsilon}\Delta A^*(1 - \bar{A}^*)^{-1} \tag{6}$$

The A matrix can be separated into 2 matrices: $A = A_e + A_n$ where matrix A_e consists of the energy rows and the remaining rows with zeroes and matrix A_n consists of the non-energy rows and the energy rows with zeroes. Consequently:

$$\Delta A^* = \Delta A_e^* + \Delta A_n^* \tag{7}$$

The changes of direct energy requirements of sector i are accounted for column i in matrix ΔA_e^* that has only non-zero entries in the energy rows. Column i of the matrix ΔA_n^* measures the change of non-energy inputs, which are goods and services sold to sector i. Since energy is required to produce all non-energy inputs, the changes of non-energy inputs indirectly affect the embodied energy intensity of sector i.
Substituting Eq. (7) in the expression (6), then:

$$\Delta\varepsilon = \bar{\varepsilon}\Delta A_e^* (I - \bar{A}^*)^{-1} + \bar{\varepsilon}\Delta A_n^* (I - \bar{A}^*)^{-1} \tag{8}$$

Eq. (7) consists of the change $\bar{\varepsilon}\Delta A_e^* (I - \bar{A}^*)^{-1}$ caused by changing energy inputs and the change $\bar{\varepsilon}\Delta A_n^* (I - \bar{A}^*)^{-1}$ caused by changing non-energy inputs.

Results

In this work, the 1989 and 1996 IO tables (General Statistical Office, 1992 and 1999) are used as the basis for calculations. In order to interpret the results, 46 sectors are aggregated for 1989 and 1996 IO tables. These sectors are classified following the Vietnamese Classification of Economic Activities issued by the Government as Decree 75/CP on 30th October 1993. It is noted that the competitive IO tables are used, where the vector of final demand is reduced by the amount of imports.

The following adjustments were made in order to fit our purpose.

- In this study, three sectors, coal, petroleum refineries, and electricity, are considered as energy sectors. Coal is obviously a primary energy source. Refined petroleum is treated as an energy source because this energy is completely imported. Electricity is also treated as an energy source, therefore, the electricity sector is not considered as an energy consumer but energy producer. Crude oil is produced but completely exported, therefore this energy is not taken into account as an energy source.
- To reflect above conditions, when we convert to energy unit in technical coefficient matrix, the following adjustments are performed. In the case of electricity sector, the value of heat equivalence is calculated based on the primary energy

Table I. Price and heat equivalence of energy sources (Ministry of Science Technology and Environment, 2001)

Energy type	1989	1996	Unit
Heat equivalence of energy sources:			
Coal	0.566	0.566	toe/t
Refined petroleum	1.030	1.030	toe/t
Electricity*	0.233	0.159	toe/MWh
Energy price (at 1994 constant price):			
Coal	168		VND/kg
Refined petroleum	3,000		VND/kg
Electricity	450		VND/kwh

* The heat values are taken from the results of hydroelectricity and electricity produced from fossil fuel used in reference year.

(fossil fuel and hydro source) using the efficiency of thermal power plants, as shown in Table I. The coefficient of coal use and petroleum use in electricity production, $A^*_{coal,electricity}$, and $A^*_{petroleum,electricity}$, are put to zero. The coefficient of electricity use in electricity production, $A^*_{electricity,electricity}$ counts only the amount of utilities. In the case of coal sector, the coefficient of coal use in coal production, $A^*_{coal,coal}$, is assumed to be zero.

- When domestic energy consumption is calculated, the amount of energy exports, q^*_e, is subtracted from the total primary energy consumption, x^*_e

IO tables are normally based on the current producer prices. To make two tables comparable, excluding the impact of the price factor, the technical coefficient matrices, gross output and final demand vectors must be adjusted to a constant price. In this study, due to the availability of data, the set of prices in 1989 and 1996 were constructed for 1994.

$$A = P^{-1}A_C P \tag{9}$$

$$X = P^{-1}X_C \tag{10}$$

$$Y = P^{-1}Y_C \tag{11}$$

where P is the diagonal matrix of price indices (1994 = 1) which is the ratio of the current price to the constant price; A_C, X_C, Y_C, are the technical coefficient matrix, gross output vector and final demand vector at current price, respectively.

The price index for each category was estimated based on sectoral data of GDP and output values in Yearbooks. The energy unit is toe (tons of oil equivalence) and the currency unit is VND (Vietnamese Dong). Conversion factors are shown in Table I.

Economic scene and industrial structure

Between 1989 and 1996, the Vietnamese economy has been gradually moving from a centrally-planned to a market economy. The structure of gross output (GO) for the 17 sectors, which was aggregated from a detailed description of the 46 sectors, in 1989

Table II. Gross output (GO) of 17 sectors in 1989 and 1996

Economic sectors	1989 (at 1994–price)		1996 (at 1994–price)	
	billion VND	*%*	*billion VND*	*%*
Agriculture, forestry and fishing	78777	32.7%	115422	20.8%
Mining (exception of coal)	1856	0.8%	16480	3.0%
Manufacturing	84355	35.0%	226300	40.8%
▪ Food processing	*18137*	*7.5%*	*64469*	*11.6%*
▪ Textile and leather	*10649*	*4.4%*	*26289*	*4.7%*
▪ Pulp paper and wood products	*5181*	*2.1%*	*15388*	*2.8%*
▪ Chemical products	*12501*	*5.2%*	*28531*	*5.1%*
▪ Petroleum refineries and coal	*7045*	*2.9%*	*13734*	*2.5%*
▪ Glass, clay and stone products	*6554*	*2.7%*	*17507*	*3.2%*
▪ Iron and steel	*2842*	*1.2%*	*3324*	*0.6%*
▪ Non–ferrous metals	*2313*	*1.0%*	*9585*	*1.7%*
▪ Machinery and equipments	*16852*	*7.0%*	*38056*	*6.9%*
▪ Other industries	*2282*	*0.9%*	*9417*	*1.7%*
Construction	12023	5.0%	49628	9.0%
Electricity, gas and heat supply	3184	1.3%	10393	1.9%
Trade and services	23196	9.6%	46068	8.3%
Transportation	5343	2.2%	18048	3.3%
Others	32504	13.5%	71746	12.9%
Total	241239	100%	554084	100%

and 1996 are shown in Table II. The share in GO of agriculture dropped from 32.7% in 1989 to 20.8% in 1996. The following industries drastically increased their shares in GO, in descending order: food processing (from 7.5% in 1989 to 11.6% in 1996), mining (from 0.8% in 1989 to 3.0% in 1996), and construction (from 5.0% in 1989 to 9.0% in 1996). Service activities (including transportation) have been maintained a ratio of 25% for both years.

Parallel to raising final demand, the calculated energy consumption in Vietnam was approximately 13.2 Mtoe in 1996, which is nearly twice as much as in 1989 (6.7 Mtoe) as shown in Table III and Fig. I. However, due to the small scale of the economy, the level of energy use is still very low. In 1996, the energy consumption per capita of Vietnam was only 0.452 toe based on author's estimation (or 0.432 toe based on The World Bank, 2004). As shown in Table IV, with the exception of Myanmar, energy consumption per capita of Vietnam was lowest among the one of East Asia and Pacific countries.

In term of sectoral energy consumption, the embodied energy consumption in petroleum refineries and coal is the largest because these sectors are the energy producers and the huge final demand of coal exists. That in construction is the second largest and drastically increased because of the large final demand from the operating urban infrastructure in Vietnam. The modernization in living standards also increased the demand for the sectors which produce end-use products, such as food processing, textile and leather, pulp paper and wood products. Due to the huge contribution to total gross out-

Table III. Embodied energy consumption of 17 sectors in 1989 and 1996

Sector	1989	1996
Agriculture, forestry and fishing	517	755
Mining (exception of coal)	151	310
Manufacturing	3218	7584
▪ Food processing	*771*	*1057*
▪ Textile and leather	*237*	*549*
▪ Pulp paper and wood products	*60*	*278*
▪ Chemical products	*68*	*117*
▪ Petroleum refineries and coal*	*1285*	*5058*
▪ Glass, clay and stone products	*403*	*248*
▪ Iron and steel	*50*	*1*
▪ Non–ferrous metals	*12*	*8*
▪ Machinery and equipments	*286*	*149*
▪ Other industries	*46*	*118*
Construction	1252	2203
Electricity, gas and heat supply	159	492
Trade and services	525	588
Transportation	286	302
Others	625	957
Total	6732	13191

**Note: including final demand*

Figure I. Embodied energy consumption of 17 sectors in 1989 and 1996

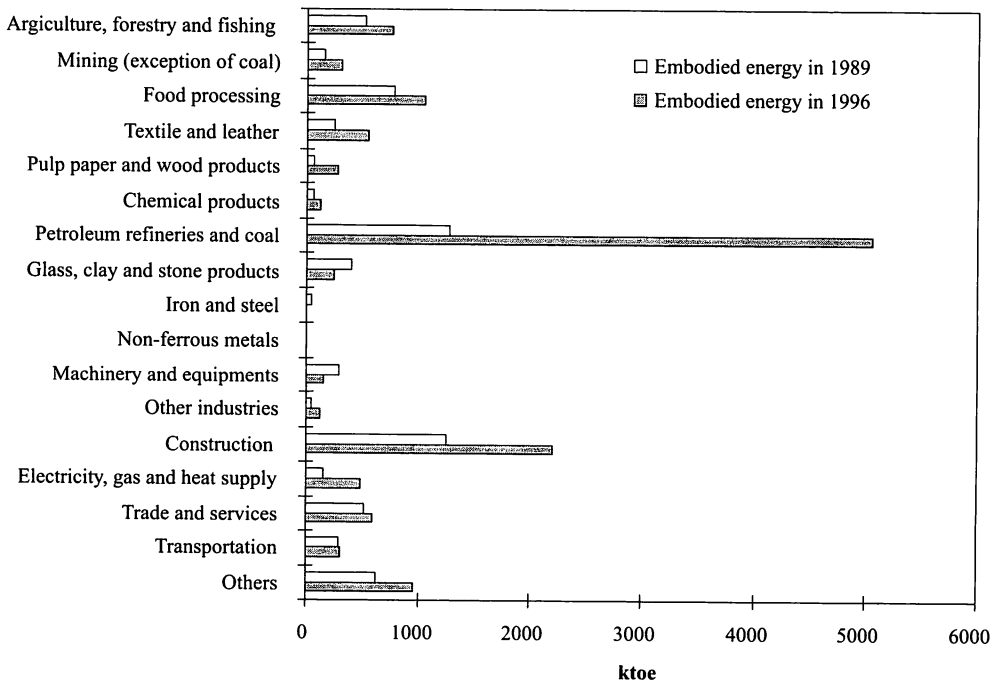


Table IV. Energy indices of East Asia and Pacific countries (The World Bank, 2004)

Country	Energy use (kgoe per capita)	
	1989	1996
Australia	5070	5512
Brunei	5160	6563
China	737	915
Hong Kong, China	1947	2113
Indonesia	494	651
Japan	3377	4045
Korea, Dem. Rep.	1739	891
Korea, Rep.	1892	3581
Malaysia	1153	1873
Myanmar	274	263
New Zealand	3910	4409
Philippines	456	514
Singapore	3358	6010
Thailand	695	1167
Vietnam	366	431

put, the agriculture sector also consumed a considerable amount of energy, 5.5% and 3.5% of the total in 1989, 1996, respectively.

Since, in this study, energy price in each economic sector in 1989 and 1996 is not available, the calculations were done under the assumption that the amount of goods transferred is proportional to their monetary value in every sector. We are able to make a comparison between the estimated coal, petroleum, electricity consumption by all sectors using IO table and corresponding data in the yearly energy balance tables (Ministry of Science Technology and Environment, 2001). The estimated energy consumption by sectoral groups, such as manufacturing, construction, transportation is also compared with the corresponding statistics (Institute of Energy, 2002). As the results, it is confirmed that all the values which we used in this work are reasonable.

Changes in energy intensities

In this section, the inter-linkage changes in the embodied energy intensity are examined using SDA. Tables V and VI illustrate the changes in energy inputs and the changes in non-energy inputs, respectively, in each sector affected the embodied intensities of coal, petroleum and electricity use in the productive system in the period 1989 -1996. Embodied coal intensity has been decreased in almost all economic sectors, and this change mainly caused by reducing energy inputs, indicated by negative values in column "coal" of Table V. On the contrary, embodied petroleum and electricity intensity have been increased in almost all economic sectors, but this change mainly caused by changing non-energy inputs, indicated by positive values in columns "petroleum" and "electricity" of Table VI. Embodied energy intensity dominantly has been reduced

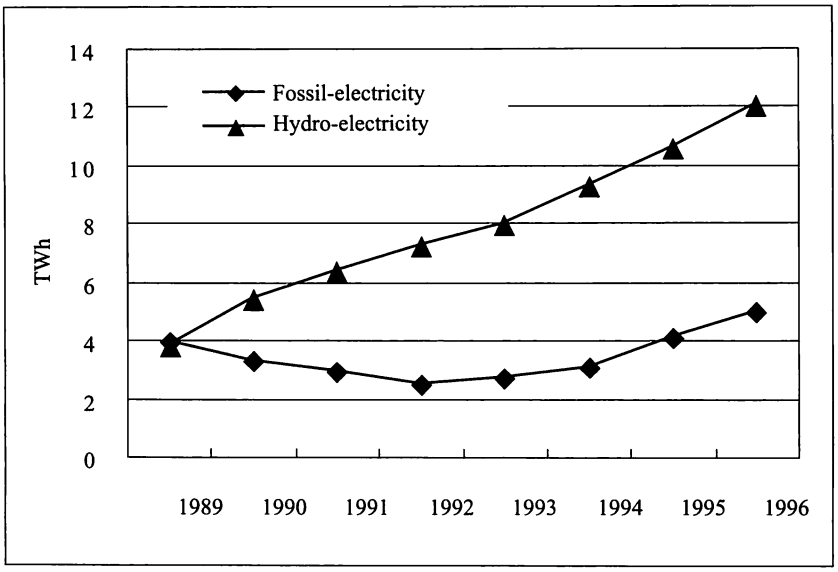
Table V. Changes in energy intensities (toe/10^6 VND) caused by direct effects (changes of energy inputs) $\bar{\varepsilon}\Delta\bar{A}^{*}_{e}(I-\bar{A}^{*})^{-1}$ in period 1989 – 1996

Changes in	Coal	Petroleum	Electricity	Total
Agriculture	0.004	–0.001	–0.001	0.002
Forestry	–0.002	–0.007	–0.001	–0.010
Fishing	–0.012	–0.035	0.000	–0.047
Coal	–0.007	–0.003	–0.003	–0.013
Mineral mining	–0.009	–0.043	0.008	–0.044
Other mining	–0.019	–0.045	–0.005	–0.069
Other food stuff	–0.056	–0.004	–0.001	–0.061
Vegetable, fruit canning	–0.046	–0.001	–0.006	–0.054
Alcoholic, other beverages	–0.049	–0.002	0.002	–0.049
Sugar	–0.022	–0.007	0.003	–0.025
Tea, coffee processing	0.039	0.000	0.002	0.041
Tobacco, cigarettes	–0.003	–0.001	0.002	–0.002
Aquatic products	–0.021	–0.025	0.003	–0.043
Milling and grain products	–0.045	–0.007	–0.007	–0.059
Ceramics, glass, porcelain	–0.080	–0.013	0.003	–0.090
Paper, paper products	–0.013	0.001	0.010	–0.002
Wood processing, wood products	–0.015	0.000	0.003	–0.012
Cement	–0.101	–0.013	–0.002	–0.116
Bricks, tiles	–0.035	–0.018	0.010	–0.043
Other construction materials	–0.272	–0.014	0.005	–0.280
Chemical products	0.009	–0.001	–0.006	0.002
Fertilizer, insecticide	0.031	–0.001	0.000	0.030
Pharmaceuticals	–0.003	0.000	0.000	–0.003
Rubber, rubber products	–0.040	–0.005	–0.011	–0.056
Soap and cleaning materials	–0.014	–0.004	–0.002	–0.020
Plastic, plastic products	–0.001	0.000	0.003	0.002
Other chemical products	–0.001	0.000	0.010	0.009
Equipment, machinery, other metallic products	–0.017	–0.001	–0.002	–0.021
Electrical and electronic products	–0.002	0.000	–0.001	–0.003
Manufacture of non–ferrous metals	–0.006	0.000	0.006	0.001
Manufacture of ferrous metals	–0.058	–0.003	–0.005	–0.065
Manufacture of textiles	–0.021	0.002	0.008	–0.011
Carpets and rugs	–0.009	0.014	0.004	0.009
Leather, foot wear, bleaching, dyeing of fabrics	–0.012	0.000	0.002	–0.010
Other industry	–0.012	–0.003	–0.006	–0.021
Other materials	–0.005	0.005	0.005	0.006
Petroleum, natural gas	0.000	0.001	0.000	0.001
Electricity	–0.005	–0.001	0.000	–0.006
Water	–0.004	0.003	–0.024	–0.026
Construction	–0.059	–0.006	0.001	–0.064
Trade	–0.007	0.000	0.001	–0.006
Personal repairs	–0.019	0.006	0.000	–0.013
Restaurants	–0.025	0.002	0.012	–0.011
Transportation	–0.010	–0.029	–0.001	–0.039
Communication	–0.002	–0.005	0.000	–0.008
Others	–0.010	0.002	0.002	–0.006

Table VI. Changes in energy intensities (toe/10^6 VND) caused by indirect effects (changes of non-energy inputs) $\bar{\varepsilon}\Delta\bar{A}^{*}_{e}(I-\bar{A}^{*})^{-1}$ in period 1989–1996

Changes in	Coal	Petroleum	Electricity	Total
Agriculture	0.001	0.000	0.000	0.001
Forestry	–0.001	0.001	0.000	0.000
Fishing	–0.002	0.004	–0.001	0.001
Coal	–0.004	0.002	0.000	–0.002
Mineral mining	–0.010	0.011	0.000	0.001
Other mining	0.001	0.002	0.001	0.004
Other food stuff	–0.003	0.000	0.000	–0.003
Vegetable, fruit canning	–0.004	0.002	0.000	–0.002
Alcoholic, other beverages	–0.004	0.000	0.000	–0.004
Sugar	0.003	0.003	0.002	0.008
Tea, coffee processing	0.002	0.001	0.000	0.003
Tobacco, cigarettes	–0.005	0.000	–0.001	–0.007
Aquatic products	–0.003	–0.004	0.000	–0.006
Milling and grain products	–0.012	–0.001	–0.002	–0.015
Ceramics, glass, porcelain	–0.010	0.000	–0.001	–0.012
Paper, paper products	0.008	0.003	0.002	0.013
Wood processing, wood products	0.000	0.004	0.001	0.005
Cement	–0.014	0.003	0.000	–0.011
Bricks, tiles	–0.031	0.002	–0.002	–0.031
Other construction materials	–0.012	0.001	0.002	–0.009
Chemical products	–0.001	0.001	0.000	0.001
Fertilizer, insecticide	0.001	0.000	0.000	0.002
Pharmaceuticals	0.000	0.000	0.000	0.000
Rubber, rubber products	–0.003	–0.001	–0.002	–0.006
Soap and cleaning materials	0.000	0.000	–0.001	–0.001
Plastic, plastic products	0.001	0.001	0.001	0.004
Other chemical products	0.004	0.003	0.003	0.010
Equipment, machinery, other metallic products	–0.002	0.000	0.000	–0.002
Electrical and electronic products	0.002	0.001	0.000	0.003
Manufacture of non–ferrous metals	0.001	0.001	0.000	0.002
Manufacture of ferrous metals	–0.001	0.002	0.001	0.002
Manufacture of textiles	0.003	0.003	0.003	0.009
Carpets and rugs	–0.001	0.000	0.000	–0.001
Leather, foot wear, bleaching, dyeing of fabrics	0.001	0.001	–0.001	0.002
Other industry	–0.001	0.000	0.000	–0.001
Other materials	0.004	0.003	0.003	0.011
Petroleum, natural gas	0.000	0.000	0.000	0.000
Electricity	0.000	0.000	0.000	0.001
Water	0.004	0.003	0.004	0.011
Construction	–0.008	0.002	0.001	–0.004
Trade	–0.002	0.003	0.000	0.001
Personal repairs	0.000	0.001	0.000	0.000
Restaurants	–0.003	0.001	0.001	–0.001
Transportation	–0.001	0.001	–0.001	0.000
Communication	0.000	0.001	0.000	0.002
Others	–0.002	0.000	0.000	–0.001

Figure II. Electricity production in Vietnam during 1989–1996



for food processing; glass, clay and stone product. Leading to those changes, the direct effects, $\bar{\varepsilon}\Delta A_e^* (I - \bar{A}^*)^{-1}$, of coal use played an important role.

It was indicated in Fig.II about electricity production that due to the inauguration of the two biggest hydroelectric power stations, Tri An and Hoa Binh, the ratio of hydroelectricity production dramatically increased during the period 1989–1996. This caused the decrease in energy consumption because using hydroelectricity more efficient in conversion than thermal electricity.

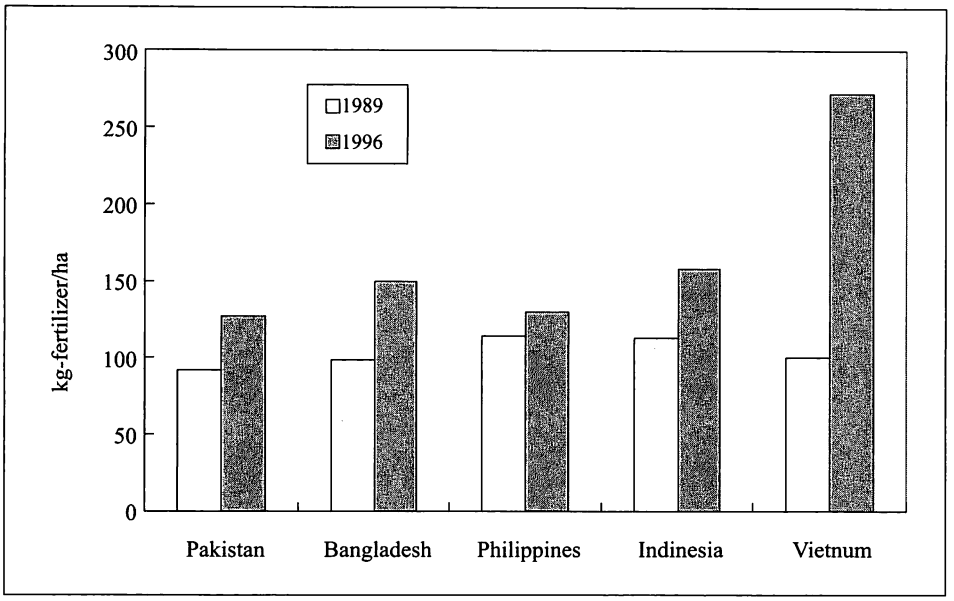
Generally, the changes in embodied energy intensity have resulted by variations in the direct energy requirements. However, parallel with the diversification of interlinkages in the current development of the Vietnamese economy, the indirect effects, $\bar{\varepsilon}\Delta A_n^* (I - \bar{A}^*)^{-1}$, are getting important.

Discussion

In the previous section, the main structure of Vietnamese energy in the years of Doi Moi has been described. It shows that the agriculture sector plays a significant role due to its' dominant contribution in the total gross output. In this section, the main factors, which affected this, are clarified in the IO structure of the Vietnamese agriculture.

It is noted that in the Table V, only the sectors, agriculture; tea, coffee processing; chemical products; and fertilizer, insecticide have the plus values in the changes in coal caused by energy inputs. While the energy intensity in fertilizer sector increases 4.5 times in this time period, since the fully production process started. As a result, the changing energy inputs caused 0.03 toe/million VND increase in embodied energy intensity of fertilizer production between 1989 and 1996. This change caused an increase

Figure III. Comparison of specific fertilizer consumption among countries (The World Bank, 2004)



in the embodied energy intensity in agriculture and then caused a chain reaction in the other sectors.

Within the agricultural components, cultivated crops and paddy rice comprised about 80% of both GDP and production value in the agricultural sector in 1996. These sub–sectors use fertilizer, pesticides, machinery, energy, and various services as inputs for their own production processes. From IO tables, fertilizer's contribution is clearly important with 24.38% and 38.37% of agriculture's inputs in 1989 and 1996, respectively. This increase is from the increase in specific fertilizer consumption during this time period.

Generally, fertilizer yields high productivity and is inexpensive. However, many farmers applied more fertilizer to their crops than the plants could absorb. As shown in Fig. III, the specific fertilizer consumption[1] (SFC) in Vietnam far exceeds that of the other countries, which have similar agricultural agropedology and climatic conditions. In 1989, SFC in Vietnam was about 100 kg/ha farmland, which is similar to the Philippines, Indonesia, Bangladesh and Pakistan. But in 1996, the reported SFC in Vietnam was 273 kg fertilizer/ha farmland, a 2.7 times increase between the two years. This brings about the serious consequence that the cultivation structure has improved, but

[1] Fertilizer consumption (100 grams per hectare of arable land) measures the quantity of plant nutrients used per unit of arable land. Fertilizer products cover nitrogenous, potash, and phosphate fertilizers (including ground rock phosphate). The time reference for fertilizer consumption is the crop year (July through June). Arable land includes land defined by the FAO as land under temporary crops (double-cropped areas are counted once), temporary meadows for mowing or for pasture, land under market or kitchen gardens, and land temporarily fallow. Land abandoned as a result of shifting cultivation is excluded.

Table VII. Linkage indicators of economic sectors in 1989 and 1996

Economic sectors	Backward linkages		Forward linkages	
	1989	*1996*	*1989*	*1996*
Agriculture, forestry and fishing	1.640	1.638	0.827	0.714
Mining (exception of coal)	0.480	0.664	0.651	0.578
Food processing	1.981	1.435	3.094	2.880
Textile and leather	1.049	0.808	1.181	1.273
Pulp paper and wood products	0.789	0.800	0.748	0.897
Chemical products	2.663	2.887	3.059	3.127
Petroleum refineries and coal	1.132	0.806	0.910	0.555
Glass, clay and stone products	1.022	0.786	1.524	1.477
Iron and steel	0.724	0.532	0.460	0.397
Non–ferrous metals	0.616	1.126	0.436	0.428
Machinery and equipments	1.574	1.969	1.329	1.808
Other industries	0.244	0.197	0.385	0.397
Construction	0.934	0.898	0.704	0.774
Electricity, gas and heat supply	0.202	0.734	0.230	0.234
Trade and services	0.330	0.501	0.363	0.308
Transportation	0.563	0.639	0.852	0.898
Others	1.057	0.580	0.248	0.256

improper fertilizing is affecting Vietnamese agriculture. Since there is a growing tendency of soil degradation, fertilizer is steadily used to increase the annual agricultural output to the point of abuse. This increase of fertilizer use indirectly caused the increase of coal intensity in agriculture sector as shown in Table VI.

The lack of knowledge of the Vietnamese farmers in cultivation techniques has contaminated farming land and increased the embodied energy use in their agricultural products due to very high direct energy intensity for producing fertilizer. According to the previous work (Nguyen T.A.T. and Ishihara K.N., 2003), the fertilizer sector is the 5th largest direct energy consumer in the manufacturing (next to cement, pulp and paper, brick and tiles, and textiles), with 332 ktoe consumed in 1996, occupied 8.3% of the total energy use in manufacturing and 4.2% of the total energy use in the productive system. General economic indicators (The World Bank, 2004) also reported the ratio of commercial energy use for agriculture to that for all sectors in 1995 (including indirect energy input from fertilizers) was about 15% for Vietnam, the highest compared to other Asian countries in the same year, for instance: 13.33% for China, 4.30% for India, 1.91% for Bangladesh. Next to agriculture, food processing was most influenced. This sector has increased the dependence on the supply by domestic agricultural products with 38.9% and 70.2% of intermediate inputs in 1989 and 1996, respectively. In term of linkage indicators, it is also identified in Table VII that the food processing has been deeply involved other sectors by the very high backward linkages (1.98 in 1989 and 1.44 in 1996). Therefore, saving energy in fertilizer production indirectly decreases the embodied energy intensity in other economic sectors by means of inter-

linkages.

One of the ways to enhance agricultural productivity is to apply fertilizers at a rate that equals plant uptake and improving ammonia production for all nitrogen-based fertilizers. Based on the macro-production figures (Nguyen V.B., 2001), we roughly estimate that the amount of energy required to produce the nitrogen portion of the fertilizers in Vietnam is 26,855 kcal/kg nitrogen, approximately 1.5 times higher than the world average (18,000 kcal/kg nitrogen) (Kongshaug G., 1998). To reach the world's average energy use, it is assumed that the 33.3% of coal used to produce fertilizer in Vietnam can be decreased. It means that 31.5% of the energy used in fertilizer production can be saved. The analysis of IO table indicates that this saving leads to a decrease of 3.7% of the energy cost in its own sector's intermediate expenditures, but also will cause a decrease of 10.2% and 6.4% in embodied energy intensity in agriculture and milling - grain products (food processing sector), respectively. According to the final report of the Scientific Technological project KHCN 09–08 by Ministry of Science, Technology and Environment, the fertilizer industry is one of five possible candidates that possess large energy saving potential.

It is concluded through this analysis that the improvement of energy productivity in fertilizer production and the effective use of fertilizer products in cultivation activities would play an important role in terms of raising the total energy productivity in food industries.

Conclusion

This paper analyzes the IO tables extended to account for inter-industry energy flows. During the years of Doi Moi, it is suggested that SDA is useful for analyzing the changes in energy intensity in economic sectors. The following conclusions are drawn:

- ◇ Embodied energy intensity and consumption were calculated for all economic sectors in 1989 and 1996. During the years of reform, coal intensity decreased, while electricity intensity increased for almost all sectors. The changes caused by using direct energy inputs are large and affect the changes caused by using non–energy inputs.
- ◇ Saving energy in fertilizer production is crucial for decreasing the embodied energy intensity in economic sectors, especially in agriculture. Based on the enlarged contribution of food processing inputs, the agriculture sector still constitutes the backbone of the Vietnamese economy. Further developing food processing will boost the effect of agriculture on the rest of the economy.

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