Energy Efficiency Tracking in Thai Manufacturing Sector by Decomposition Technique

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Abstract. This paper presents an analysis of energy saving and changes in energy intensities in Thai manufacturing sector by Logarithmic Mean Divisia Index decomposition technique. This method includes three effects consists of the energy intensity effect, the structural effect and the effect of the economic growth on the energy consumption in Thailand by using the 25-year annual data from 1990 to 2014, carried out in four phases; (i) before National Energy Conservation law, (ii) during the effect of the law, (iii) Transition period of the law from first to second version, and (iv) during the effect of the law (No.2). We found that the most effective intensity effect is in the third phase due to the effect of the implementation of new energy efficient equipment from the second phase by enforcement of the law, especially in non-metallic sector, while the first phase illustrates the lowest intensity effect due to the energy conservation law had not been occurred. However, due to the highest economic growth of the country and change from agricultural to industrial development direction, the first phase presents the most effective structural effect, then this effect continuously decreased by time. We also conclude that the energy conservation law have direct effect to energy efficiency of the country however, strictly individual regulation which have target to enforce to energy intensive industries is still required for sustainable energy efficiency improvement.

1 Introduction

The final energy consumption in Thailand increases continuously during the past 25 year. The economic growth rate in the period 1990-2014 averaged at 4.36 percent. In period 1990 - 1997 was 4.71 percent. In period 1997 - 2007 was 3.71 percent. In period 2007 - 2010 was 2.33 percent and the last period 2010 - 2014 economic growth increased average at 2.95 percent [1]. The growth of manufacturing sector has grown rapidly and continuously, so in energy planning essential to learn more effect and factors that affect to energy use in this sector.

This paper studies on the comparative analysis of factors influencing energy intensity changes. The analyse is also includes the energy saving in Thai manufacturing sector by using the decomposition techniques, which is the powerful tool for indicate the energy performance in manufacturing energy demand analysis [2],[3].

2 Methodology

The methodology consists of two topics, as follows;

2.1 Economic and energy aggregation.

During the last 25 years, Thailand's economic growth increase continuously while manufacturing sector has the highest share of the country. Share of the manufacturing sector GDP in total GDP increased from 25.41 % in the year 1990 to 28.49 % in the year 2014 and share of final energy consumption of the manufacturing sector in total final energy consumption increased from 27.94 % in the year 1990 to 36.76 % in the year 2014 , as presented in Fig. 1.

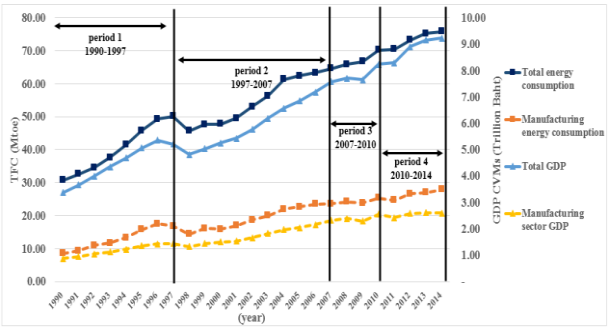

Figure 1. GDP and final energy consumption. Period: 1990-2014.

Fig. 1. The manufacturing sector and all economic sector of final energy consumption which has the same trend as the GDP growth of the country.

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By considering the energy and economic significant impact, the twentyfive-year period of this study was divided into four period; i.e. (i) The first sub-period is from 1990 to 1997 which presents the high economic progress of the country before The National Energy Conservation law A.D.1992 and the time before the 1997 economic crises, (ii) The second, from 1997 to 2007, during the effect of the law and the period of economic slowdown after the crises. (iii) The third transition period of the law from 2007 to 2010 from first to second version and the global economic slowdown , and (iv) The last from 2010 to 2014, during the effect of the law (No.2) and the political crisis in the Thai economy.

2.2 Decomposition technique

To analyze technique, the amount of energy consumption data set is required to study the multiplicative decomposition analysis by Logarithmic Mean Divisia Index method I (LMDI I) [4], [5] for estimate an index value.

The main equation of this method shows in equation (1). Assume that all variables are in time series dataset and given as of time t applying the theory of instantaneous growth rate.

$$D_{tot} = D_{act} \times D_{str} \times D_{int} \quad (1)$$

where D_{tot} is the total effect, D_{act} is the activity effect, D_{str} is the structural effect and D_{int} is the intensity effect.

The activity effect considers changes in the scale of economic activity or in the level of output of the entire economy, under the assumption that an increase in the level of this output in volves an increase in energy consumption. At the aggregated and sectoral level usually measured by monetary indicators is Gross Domestic Product (GDP) or value-added[6].

The structural effect considers changes in the mix of activities. These changes have an impact on energy consumption due to each activity has different energy intensiveness : for example, energy consumption will grow if a high intensity industry such as oil extraction, increases its output share with in the economy [7].

The intensity effect considers the impact on energy consumption of changes in energy intensity. This is considered a good proxy of energy efficiency changes. Energy intensity reductions occur either because of more efficient technology or better processes, which can include substitution off actor inputs such as substitution of renewable energy for fossil fuels in the production processes [8].

The compute the method as shown in equations (2)-(6) [4], [9].

$$D_{act}=exp\sum_{i=1}^{n}\left[w_i^*\times In\left[\frac{A_{i,t}}{A_{i,0}}\right]\right] \quad (2)$$

$$D_{str}=exp\sum_{i=1}^{n}\left[w_i^*\times In\left[\frac{S_{i,t}}{S_{i,0}}\right]\right] \quad (3)$$

$$D_{int}=exp\sum_{i=1}^{n}\left[w_i^*\times In\left[\frac{I_{i,t}}{I_{i,0}}\right]\right] \quad (4)$$

$$w_i^*=\frac{L[w_{i,t},w_{i,0}]}{\sum_i^n L[w_{i,t},w_{i,0}]} \quad (5)$$

$$L[w_{i,t},w_{i,0}]=\frac{w_{i,0}-w_{i,t}}{In\left[\frac{w_{i,0}}{w_{i,t}}\right]}=\frac{\frac{E_{i,0}}{E_0}-\frac{E_{i,t}}{E_t}}{In\left[\frac{\frac{E_{i,0}}{E_0}}{\frac{E_{i,t}}{E_t}}\right]} \quad (6)$$

where w_i^* is The weight function, A is value-added in economic sub-sector, S is share of activities in economic sub-sector, I is energy use per unit of activity and i is economic sub-sector within a given sector.

3 Results and discussion

3.1 Analysis of economic

This part presents the result of the economic. We analyze share of final energy consumption, value-added [1],[10] and energy intensity of all economic sectors and the manufacturing sectors, as presented in Table 1 to 2.

Table 1. Share of final energy consumption, share of value-added and energy intensity in Thai economic sectors, Period 1990-2014.

Economic sector	1990-1997	1997-2007	2007-2010	2010-2014
Final energy consumption (%)				
Agriculture	4.2	5.0	5.1	5.2
Mining	0.1	0.2	0.2	0.2
Manufacturing	32.2	35.0	36.2	36.0
Construction	0.6	0.3	0.2	0.2
Residential	18.3	14.8	15.2	15.1
Commercial	5.1	6.4	7.5	7.8
Transport	39.5	38.2	35.7	35.6
Total	100.0	100.0	100.0	100.0
Value-added (%)				
Agriculture	8.8	8.6	7.7	7.4
Mining	2.0	2.4	2.7	2.6
Manufacturing	26.2	29.1	30.6	29.3
Construction	6.9	3.2	2.7	2.6
Commercial	53.5	53.5	53.0	55.0
Total	100.0	100.0	100.0	100.0

Economic sector	1990-1997	1997-2007	2007-2010	2010-2014
Energy intensity (ktoe/billion Baht)				
Agriculture	4.3	5.3	5.7	5.8
Mining	0.5	0.7	0.6	0.6
Manufacturing	11.1	11.0	10.2	10.2
Construction	0.8	1.0	0.6	0.6
Residential	1.6	1.4	1.3	1.3
Commercial	0.9	1.1	1.2	1.2
Transport	3.6	3.5	3.1	3.0
Total	9.0	9.1	8.6	8.3

Source: Department of Alternative Energy Development and Efficiency [10] and Office of the National Economic and Social Development Board, 2014 [1]

Table 1. shows that during 1990 to 2014, all economic sectors that consumed the largest amount of energy were transport and manufacturing sectors [11] share average at 37.3% and 34.9% respectively.The growth of energy consumption of the manufacturing sector continued to increased 3.8% whereas the growth of energy consumption of the transport sector declined to 3.9% in last period. This implies that energy consumption trend in the manufacturing sector would higher than the transport sector for the next periods, as for the energy intensity of the manufacturing and transport sector declined to 0.9% and 0.6% respectively whereas the commercial sector increased to 0.3%. It shows that the efficiency of energy use increased in the transport and manufacturing sector but declined in the commercial sector.

Regarding in the growth rates of GDP, Chained Volume Measures (CVM) of agriculture and construction sector continued to declined 1.4% and 4.3% respectively whereas manufacturing and commercial sector continued to increased due to the export growth and increased direct foreign investment particularly in the fabricated metal sub-sector in the second period during the effect of the law (No.2) from 1997 to 2007.

Table 2. shows that during 1990 to 2014, the manufacturing sector which consumed the largest amount of energy ware food and beverages and non-metallic sub-sector share average at 32.8% and 28.8% respectively. In term of growth, energy consumption of labour-intensive production of textiles continued to decline to 4.9% whereas the food and beverages sub-sector declined to 4.1% in the first period due to the effect of economic slowdown in the after the crises but increased to 5.4% under of the law (No.2) A.D.2007.

The highest energy intensity were non-metallic sub-sector average 63.9 ktoe per billion Baht, followed by basic metal sub-sector average 25.8 ktoe per billion Baht and the lowest energy intensity were fabricated metal sub-sector average at 2.6 ktoe per billion Baht while the energy intensity of less energy-intensive industries were chemical and textiles sector, the high energy intensive industries were food and beverages, paper, non-metallic and basic metal sub-sector, showed a rapid rise in energy intensity throughout the period.

Regarding to the growth rates of GDP of textiles and food and beverages sub-sector had declined to 9.7% and 4.3% respectively whereas the fabricated metal and chemical sub-sector were as high as 10% and 3% respectively. The decline growth of the labour-intensive industries was the result of rising competition from the emergence of many low-wage countries such as China, India, and Vietnam, in the world market [9].

Moreover, the result show that the manufacturing sector use less energy has become more value-added was fabricated metal sub-sector, in the other hand high energy has become less value-added was non-metallic sub-sector. However, In the last period, energy efficiency of non-metallic still higher than fabricated metal sub-sector and effect to conducive to declining energy intensity of manufacturing sector.

3.2 Analysis of decomposition method.

This part presents the results of the multiplicative decomposition analysis by Logarithmic Mean Divisia Index method 1. We analyzed the change of energy consumption of all economic sector and manufacturing sector. The result are presented by graphical instruments, as presented in below.

Table 3 and Fig. 2 shows the increase in activity effect in all periods while the structural effect declined during 2007-2010 to 0.1 and increased to 1.45 during 2010-2014 due to the manufacturing sector changed. For intensity effect, it continue to decline to 0.09 by manufacturing sector change in the first and the second period during 1990-2007 and commercial sector change in the third and the last period during 2007-2014.

As presented in Table 3, the energy consumption has significantly changed during 2010-2014 which is during the law No. 2. In addition, the structural changes impact to energy consumption change more than intensity effect due to the manufacturing sector is also key part.

Table 2. Share of final energy consumption, share of value-added and energy intensity of manufacturing sector, Period 1990-2014.

Manufacturing	1990-1997	1997-2007	2007-2010	2010-2014
Final energy consumption (%)				
Food and beverages	34.1	30.0	31.5	35.4
Textiles	8.0	5.8	4.0	3.1
Wood and furmiture	0.8	0.8	0.9	1.2
Paper	4.0	4.2	6.6	6.0
Chemical	9.4	12.0	9.4	9.2
Non-Metallic	28.7	29.1	31.1	26.2
Basic metal	4.1	4.7	4.6	5.7
Fabricated metal	3.6	6.2	6.2	6.6
Others	7.4	7.2	5.8	6.7
Total	100.0	100.0	100.0	100.0
Value-added (%)				
Food and beverages	25.3	22.5	20.1	21.0

Manufacturing	1990-1997	1997-2007	2007-2010	2010-2014
Textiles	18.9	14.7	11.3	9.2
Wood and furnituer	2.1	1.1	1.0	1.1
Paper	3.0	3.3	2.8	2.6
Chemical	13.7	18.0	16.3	16.7
Non-Metallic	5.8	4.9	4.3	4.4
Basic metal	1.7	2.4	2.1	1.8
Fabricated metal	16.4	20.8	28.1	26.5
Others	13.1	12.5	14.1	16.6
Total	100.0	100.0	100.0	100.0
Energy intensity (ktoe/billion Baht)				
Food and beverages	14.8	14.6	15.9	17.4
Textiles	4.6	4.3	3.5	3.4
Wood and furnituer	4.1	8.1	9.0	10.9
Paper	14.8	14.1	23.7	23.5
Chemical	7.6	7.3	5.8	5.7
Non-Metallic	54.6	65.6	74.1	61.1
Basic metal	26.6	21.9	22.6	32.0
Fabricated metal	2.4	3.2	2.2	2.6
Others	6.2	6.3	4.1	4.1
Total	11.0	11.0	10.1	10.3

Source : Department of Alternative Energy Development and Efficiency [10] and Office of the National Economic and Social Development Board, 2014 [1]

Table 3. Change in energy consumption in Thailand *(*all economic sectors*)*, Period 1990-2014.

Period	Total Effect	Structural Effect	Intensity Effect	Activity effect
1990-1997	1.40	1.07	0.99	1.33
1997-2007	1.91	1.07	0.97	1.83
2007-2010	2.12	0.97	0.91	2.41
2010-2014	3.46	1.45	0.90	2.67

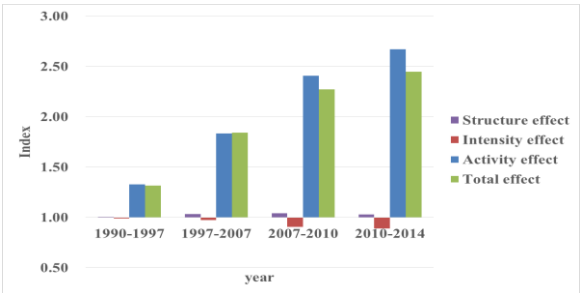

Figure 2. Results of decomposition in Thai economic sectors, Period: 1990-2014.

Table 4 and Fig. 3 show that six percent increase in the intensity effect in manufacturing sector due to the changes of energy intensity from non-metallic and basic metal sub-sector respectively. The effect of the increases of the energy intensity of individual sectors was greater than the structural change effect. The structural change did not lead to a large decline of the energy intensity in the manufacturing sector. The energy intensity increased mainly from energy intensive industries.

As a result, the energy comsumption had significantly change in manufacturing sector during the 2010-2014, which consisit of structural and intensity change by non-metallic sub-sector (cement products) and the most energy consumption due to activity increase from food and beverage sub-sector.

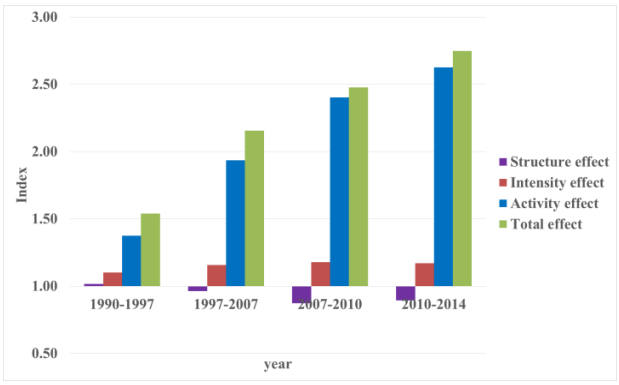

Figure 3. Results of decomposition in manufacturing sector , Period: 1990-2014.

Table 4. Analysis of change in energy consumption of manufacturing sector, Period 1990-2014.

Period	Total Effect	Structural Effect	Intensity Effect	Activitye ffect
1990-1997	1.54	1.02	1.10	1.38
1997-2007	2.16	0.96	1.16	1.94
2007-2010	2.48	0.87	1.18	2.41
2010-2014	2.75	0.89	1.17	2.63

4 Conclusions

The energy and economic significant impact, the twentyfive-year period of this study was divided into four period; i.e. (i) The first sub-period is from 1990 to 1997 which presents the high economic progress of the country before National Energy Conservation law and the time before the 1997 economic crises, (ii) The second, from 1997 to 2007, during the effect of the law and economic slowdown after the crises. (iii) The third, from 2007 to 2010, transition period of the law from first to second version and the global economic slowdown, and (iv) The last from 2010 to 2014, during the effect of the law (No.2) and the political crisis in the Thai economy. As a result in all economic sector, the energy use is the most change in the third phase, increasing the share of GDP by the transport and manufacturing sector, contribute greatly to the change of power. In addition, the structural changes impact to changing energy use more than intensity effect due to manufacturing sector is a key part. For manufacturing sector we found that the most effective intensity effect is the third phase due to the effect of the implementation of new energy efficient equipment from the second phase by enforcement of the law, while the first phase illustrates the lowest intensity effect due to the energy conservation law had not been occurred. However, due to the highest economic growth of the country and change from agricultural to industrial development direction, the first phase presents the most

effective structural effect, then this effect continuously decreased by time. We also conclude that the energy conservation law have direct effect to energy efficiency of the country though the main industry more difficult to increase energy efficiency however, strictly individual regulation which have target to enforce to energy intensive industries is still required for sustainable energy efficiency improvement.

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