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ENERGY INTENSITY IN THE LITHUANIAN MANUFACTURING SECTOR*

Gitana Dudzevičiūtė

The General Jonas Žemaitis Military Academy of Lithuania, Šilo Str.5A, LT-10322 Vilnius, Lithuania
Vilnius Gediminas Technical University, Saulėtekio Av. 11, LT-10223 Vilnius, Lithuania
E-mail: gitana.dudzeviciute@vgtu.lt

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Abstract. There is major concern with Lithuania's industrial development because its manufacturing structure is increasingly dependent on the consumption of energy. In spite of the Lithuanian energy intensity decrease more than 35 percent in the last decade, the energy required to produce a unit of output in Lithuania twice exceeds the average of the European Union countries.

This paper investigates the energy intensity from a production theoretic framework and uses annual data of 1998-2011 to measure energy intensity in the Lithuanian manufacturing sector. The investigation compares energy intensity in manufacturing across different activities, based on several models. The results of the research show considerable variation in energy intensity across the activities. Based on energy intensity ratio, the Lithuanian manufacturing activities are classified into three categories, such as high energy- intensive, moderate energy-intensive and low energy- intensive. The research reveals a strong and negative interrelationship between intensity of energy consumption and manufacturing production. Over a period of 1998-2011, the contribution of high energy-intensive industries to total manufacturing value added was increasing and amounted to 30 percent at the end of 2011. Finally, the research provides insights, that restructuring of the activities from energy intensive industries towards more technologically advanced ones might potentially lead to higher energy efficiency and it could be one of the most important routes to sustainable development.

Keywords: energy intensity, energy efficiency, manufacturing sector, industry

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1. Introduction

Energy, as a product of economic activities, comprises goods and services related to heat, fuel, and power. "As any other commodity, energy is the result of production, such as extraction from mineral resources or transformation of materials and substances into a new product, which can be exchanged on the market or serve as input for production of other goods and services or be used for final consumption" (Upadhyaya 2010, 2 p.). In the economic studies (Mukherjee 2008, Industrial Development report 2011), energy intensity ratio of the manufacturing process is described as the amount of energy used to produce one unit of economic activity, for example, tonnes of oil equivalent per $1000 in manufacturing value added (in constant prices). It is the inverse of energy efficiency, i.e. declining energy intensity over time is interpreted as improving energy efficiency.

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At industry sector level, energy intensity in the European Union recorded a decrease of more than 10 % between 2000 and 2011 (Eurostat database).The most significant decreases (over 30 %) were registered in Slovakia, Lithuania, Bulgaria and Romania. In spite of this decrease, the energy intensity in all four countries remained high. In Lithuania, the energy required to produce a unit of output twice exceeds the average of the European Union and it is three times above average of the countries with the lowest energy intensity (Denmark, Ireland and United Kingdom) (Eurostat database). In the case of Lithuania, high energy intensity might impact on international competitiveness of the country and pose constrains for sustainable development. Growing demand for energy raise doubts whether a secure energy supply will be satisfied in the future and whether Lithuania will be able to remain competitive in the international markets (Travkina & Tvaronavičienė 2011; Smaliukienė *et al.* 2012; Dudzevičiūtė 2012, Lankauskienė & Tvaronavičienė 2012; Dudzevičiūtė 2013; Vosylius *et al.*2013).

Manufacturing accounts above 25 % of total energy consumption in the world and energy has been the major concern for sustainable development, environmental protection and a decent standard of living (Upadhyaya 2010). According to UNIDO Report 2011, increased industrial energy efficiency is one of the most important routes to sustainable development, particularly in developing countries. Industry remains among the most energy-intensive sectors. It contributes to global GDP less than to global share of energy consumption.

Lithuanian manufacturing contribution to total value added increased from 17 % in 1990 to 21 % in 2011 (UN Statistics data) and have remained relatively significant in comparison with advanced economies of the Scandinavian countries with average contribution of 13 % in 2011. During the same period of time the Lithuanian energy consumption in manufacturing decreased about 70 %, but energy intensity ratio remained above average in comparison with many the European countries. On average over a period of 1990-2011, low-income developing economies had the highest energy intensity and developed economies had the lowest one (UN Statistics data). Industrial energy intensity declines due to contribution of structural changes and as a result of technological changes. In high income economies, the structural effect is more visible than the technological one (Industrial Development Report 2011).

This research attempts to provide more reliable estimates of the Lithuanian manufacturing energy intensity from a production theoretic framework and uses annual data of 1998-2011.

The paper is organized as follows. Section 2 gives a short summary of the relevant empirical literature on energy intensity issues and research methodology. The investigations of different researchers are summarized and the main insights are provided. Section 3 analyses the Lithuanian energy intensity across different industrial activities and classifies them by energy intensity level. Section 4 concludes summarizing the main trends observed.

2. Empirical studies' review and research methodology

An overview of empirical studies has showed that the assessment of energy intensity and its trends is a research topic that continuously attracts researchers from different countries. The interest of energy consumption and economic growth grew in the seventies, and the relevance of this topic is taking on an even greater meaning nowadays due to the scarcity of energetic resources and growing their prices. All economic sectors and activities depend on energetic resources and strongly affected by them (Munim *et al.* 2010, Smaliukienė *et al.* 2012, Tang & Tan 2012; Dudzevičiūtė 2013).

Many researchers agree that the interaction between energy intensity and economic growth depends on the country's level of development, economic state, technology that is used (Akinlo 2009, Li 2010, Amador 2011, Zheng *et al.* 2011, Bojnec & Papler 2011, Sadorsky 2012). Some studies Grebliauskas & Ramanauskas 2007; Zheng *et al.* 2011, Amador 2011, Sadorsky 2012) reveal that in medium and high-tech countries economic growth and energy intensity interact closely, while in low-tech countries this relationship is not significant. Energy intensive sectors, such as chemical and petrochemical, steel and iron accounted for even about 70 % of the European Union's total industrial energy consumption.

Three approaches are mainly prevailing in the scientific literature regarding energy consumption or intensity and economic growth issue. These approaches are as follows: 1) growth (Ho *et al.* 2007; Chontan-

awat *et al.* 2008; Ozturk 2010; Lee *et al.* 2011; Georgantopoulos 2012; Apergis *et al.* 2012); 2) feedback approach (Ozturk 2010; Lee *et al.* 2011; Apergis *et al.* 2012); 3) neutral interrelationship (Payne 2009; Chen *et al.* 2012).

The growth approach describes that energy consumption is an essential component in economic growth. The presence of unidirectional causality from energy consumption to economic growth means that the economy is energy dependent (Apergisu&Danuletiu 2012; Dudzevičiūtė 2013).

Feedback approach supports bidirectional causality between energy consumption and economic growth, while neutral approach shows the absence of causality. Neutral causality means that energy conservation policy will not have a significant impact on economic growth (Apergisu &Danuletiu 2012; Dudzevičiūtė 2013).

The researchers have concluded that there are interdependency of energy consumption or intensity and economic growth, but the practices of different countries lead to different results regarding the presence of causality.

In the Lithuanian context, however, there is the shortage of detailed research on energy intensity in manufacturing sector. Notable studies of the Lithuanian scientists include more general investigations at macroeconomics level. Bobinaitė *et al*. (2011) assessed the causality relationship between renewable energy consumption and economic growth in Lithuania; Smaliukienė *et al*. (2012) investigated interrelationship between energy consumption and the Lithuanian economic growth; Konstantinavičiūtė *et al*. (2010) examined the dynamic of energy demand; Dudzevičiūtė (2013) did research on economic structural changes and energy consumption.

The research was guided by the measurement of energy intensity from a production theoretic framework applied in Mukherjee' s (2008) and s Upadhyaya's (2010) surveys and uses data involving energy consumption and output by the Lithuanian manufacturing sub-sectors. The comparative statistical analysis of the energy intensity of different industrial activities was applied in order to devide observed activities into high energy intensive, moderate energy intensive and low energy intensive ones. The author refer to Upadhyaya's (2010) and UNIDO's methodology on energy intensity considered in Industrial Development Report 2011 (UNIDO 2011).

Energy intensity indicator is based on the relation of energy input and output. It is one of the major indicators of energy efficiency, which is calculated as follows:

$$E\,\mathrm{int}_t = \frac{E_t}{Y_t} \quad (1)$$

where: E int $_t$- energy intensity ratio; E_t- total consumption of energy by manufacturing sector for t year; Y_t- output of manufacturing or manufacturing value added (MVA) for t year.

Energy intensity decreases in two cases: 1) when less energy is used to produce the same amount of production or 2) when production increases per unit of energy used.

Having manufacturing sub-sectors data, the energy intensity described in formula (1) can be decomposed in order to measure *energy intensity at sectoral level* and structural change on overall energy intensity. The formula (1) is expanded as follows:

$$E\,\mathrm{int}_t = \frac{E_t}{Y_t} = \sum E\,\mathrm{int}_{i,t} S_{i,t} \quad (2)$$

where: E int $_t$- energy intensity for total manufacturing for year t; E int $_{i,t}$- energy intensity for i manufacturing subsector for year t; $S_{i,t}$- share of i sub-sector in total MVA..

$$S_{i,t} = \frac{Y_{i,t}}{Y_t} \quad (3)$$

where: $S_{i,t}$- share of i sub-sector in total MVA; $Y_{i,t}$- MVA for i subsector for t year; Y_t- total MVA for t year.

Further, manufacturing sub-sectors were arranged by rank score in order to identify highest to lowest energy intensive manufacturing activities. Obtained results were compared to the *mean energy intensity ratio* calculated as follows:

$$\overline{E} = \frac{\sum E\,\mathrm{int}_t}{n} \quad (4)$$

where: $\overline{E}$ -mean energy intensity ratio; E int $_t$- energy intensity for total manufacturing for year t; n-number of observations.

In the scientific works (Sheehan, Sun 2007; Yao, Luo 2012; Bobinaitė *et al.*2011; Steinbuks 2012) energy use elasticity is analyzed with different respects. Referring to the proposed methodology of these authors, energy elasticity with respect of manufacturing

production is calculated as follows:

$$E = \frac{\Delta Q_E \%}{\Delta P_M \%} \quad (5)$$

where: E- energy elasticity with respect of manufacturing production; ΔQ_E- percentage change in energy consumption; ; ΔP_M- percentage change in manufacturing production.

These above described indicators are easy to calculate, they are informative for interpretation of their impact on economic development. However, they give only general information and do not reveal the reasons for energy efficiency.

3. The Lithuanian manufacturing dependence on energy consumption

3.1. Manufacturing sector's trends and energy intensity

Two approaches are employed in this research. First, annual data analysis of the Lithuanian manufacturing sector is carried out in the period of 1998-2011. The aim of this exercise is to analyze the relationship among manufacturing sector's trends, energy consumption and energy intensity. Second, the energy intensity at the sub-sectors level is decomposed into activities and three categories based on energy consumption intensity are distinguished as follows: 1) high energy intensity, 2) moderate energy intensity and low energy intensity. The twelve subsectors are defined for each analysis, i.e. 1) food, beverages, and tobacco; 2) textile and leather; 3) wood and wood products; 4) paper and print; 5) chemical and chemical products; 6) rubber and plastics; 7) non-metallic mineral products; 8) basic metal; 9) fabricated metal products; 10) machinery and equipment; 11) transport and equipment; 12) furniture and other.

Figure 1 reveals the relationships among the Lithuanian manufacturing production development, energy consumption and energy intensity as well. Over a period of 1998-2011, the Lithuanian manufacturing production has increased twice from LTL 17.7 million to LTL 34.5 million while energy consumption has decreased by 5 % from 39505 TJ to 37715 TJ. These changes have impacted on energy intensity ratio, which has dropped from 2.3 to 1.1 J per LTL 1000.

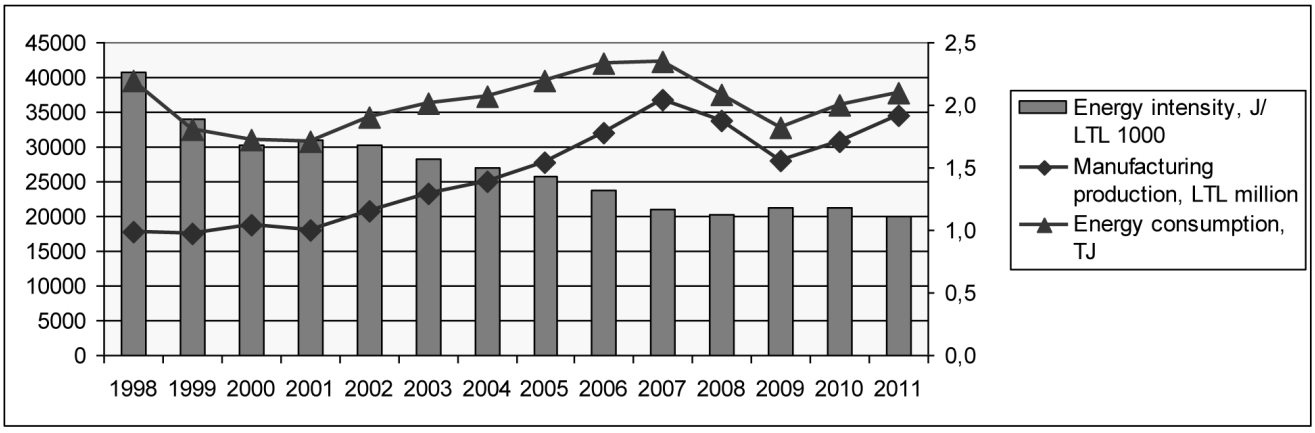

Fig. 1. The Lithuanian manufacturing production and energy trends in 1998-2011

Source: author's calculations based on the Lithuanian Statistics department data

The analysis has shown moderate and positive interrelationship with correlation coefficient of 0.6 between manufacturing production and energy consumption and a very strong and negative relationship (correlation is 0.9) between manufacturing production and energy intensity (Fig. 1). As manufacturing production is increasing, energy intensity is decreasing over the same period of time. The significance of the correlation coefficient is proved by the help of Student's criteria t. In this case $t_{st} > t_{cr}$ (7,16>2,18), it means that significant relationship is confirmed.

The examination of the long- run (1998-2011) energy use percentage change and manufacturing production change has described that the Lithuanian industry is inelastic of energy consumption. Over 2000-2011, the average elasticity coefficient has made 0.6. It means that the Lithuanian manufacturing was improving its energy efficiency over time. Table 1 describes percentage change in manufacturing production and energy consumption. In general,

energy consumption grew at a much lower rate than manufacturing production, excluding 1999 and 2008.

Table 1. The changes in manufacturing production and energy consumption

Year	Changes, %	
	Manufacturing production	Energy consumption
1999	-1,3	-17,5
2000	7,2	-4,8
2001	-3,4	-0,6
2002	14,3	11,4
2003	12,5	5,4
2004	7,6	2,9
2005	11,3	5,9
2006	15,3	6,4
2007	14,3	0,7
2008	-7,9	-11,2
2009	-17,0	-12,6
2010	9,4	9,5
2011	12,4	5,0

Source: author's calculations based on the Lithuanian Statistics department data

The analysis of separate years has revealed that in 1999 and 2008 the energy use in the Lithuanian manufacturing was elastic of production (Fig. 2).

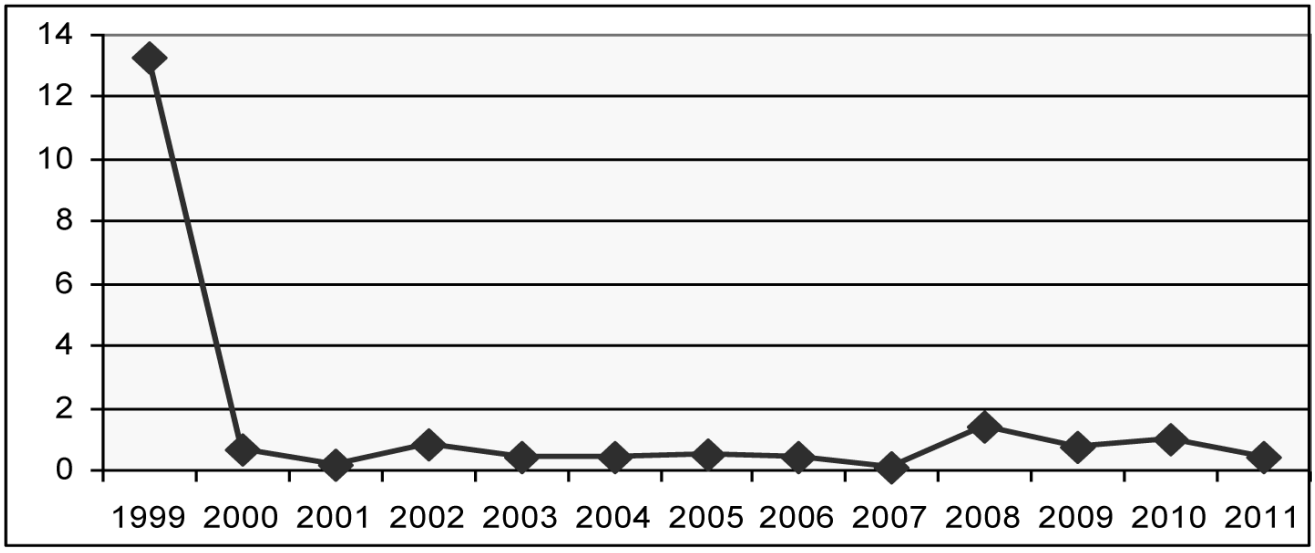

Fig. 2. Energy elasticity with respect of production in the Lithuanian manufacturing sector

Source: author's calculations based on the Lithuanian Statistics department data

The elasticity of energy use with respect of production varied from 13.2 in 1999 to 1.4 in 2008. Many factors impacted on it, but the most influential ones could be named as economical crisis in Russia in the middle of 1998 and financial and economical crisis all over the world in 2008. It showed the Lithuanian manufacturing sensitivity and dependence on trading partners and situation in the world economy.

Detailed analysis is needed at manufacturing sector level to identify the most energy-intensive activities as well as the lowest ones. Next part of the investigation is devoted for this issue.

3.2. Analysis of energy intensity at manufacturing sector's level

Average manufacturing energy intensity fell in all activities over 1998-2011. Non-metallic minerals and basic metals sub-sectors reported the most significant improvement of energy efficiency from 1998 to 2011 (Table 2). Energy intensity ratio was reduced by 6.1 and 4.0 J/ LTL1000 respectively.

Table 2. Energy intensity (J / LTL 1000) of manufacturing activities

Manufacturing sub-sectors	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Food and tobacco	1,24	1,18	1,07	0,99	1,07	0,98	0,90	0,85	0,78	0,74	0,69	0,70	0,76	0,75
Textiles and leather	1,48	1,24	1,01	1,01	1,00	1,08	1,02	0,99	0,93	0,78	0,57	0,78	0,64	0,49
Wood and wood products	3,21	1,72	1,28	2,02	2,43	2,30	2,39	2,15	1,98	1,99	2,08	1,79	1,88	1,46
Paper and print	2,87	2,53	3,10	3,15	1,89	1,63	1,13	1,26	1,03	1,03	0,97	1,63	2,01	1,35
Chemical and chemical products	4,36	3,11	2,84	2,91	2,66	2,86	3,15	3,03	2,83	1,98	2,36	2,56	2,39	2,45
Rubber and plastics	1,11	0,92	0,57	0,60	0,51	0,32	0,44	0,45	0,39	0,44	0,46	0,58	0,45	0,46
Non-metallic minerals	11,69	10,73	9,90	10,89	9,23	7,20	6,60	5,70	5,12	5,09	5,17	6,10	5,78	5,56
Basic metals	4,60	2,18	1,38	1,58	1,07	1,42	2,34	2,10	2,14	1,82	0,68	0,58	0,70	0,61
Fabricated metal products	1,70	2,86	0,71	0,93	0,91	0,57	0,62	0,52	0,41	0,22	0,29	0,35	0,39	0,33
Machinery and equipment (instruments)	1,66	1,32	2,07	1,89	1,67	1,42	1,37	1,15	0,60	0,37	0,34	0,27	0,27	0,24
Transport and equipment	1,55	0,93	0,75	1,04	1,02	0,61	0,44	0,43	0,41	0,34	0,26	0,45	0,34	0,21
Furniture and other	0,80	0,63	0,67	0,95	0,86	0,97	0,79	0,70	0,56	0,44	0,32	0,29	0,29	0,33
Total	**2,26**	**1,89**	**1,68**	**1,73**	**1,68**	**1,58**	**1,51**	**1,43**	**1,32**	**1,17**	**1,12**	**1,18**	**1,18**	**1,11**

Source: author's calculations based on the Lithuanian Statistics department data

Manufacturing sub-sectors were arranged by rank score in order to identify highest to lowest energy intensive activities. Obtained results from every subsector were compared to the *mean energy intensity ratio* of total manufacturing sector. After comparison of the results, manufacturing activities were grouped into three categories of energy intensity (Table 3).

As analysis shows, that five manufacturing sub-sectors (wood and wood products, paper and print, chemical and chemical products, non-metallic minerals and basic metals) belong to high energy- intensive group, three industries (food and tobacco, textiles and leather, machinery and equipments) belong to moderate energy intensive group and four industries- to low energy-intensive group.

Table 3. Manufacturing classification based on energy intensity

Energy intensity	Manufacturing activities
High energy-intensive	Wood and wood products
	Paper and print
	Chemical and chemical products
	Non-metallic minerals
	Basic metals
Moderate energy-intensive	Food and tobacco
	Textiles and leather
	Machinery and equipment
Low energy- intensive	Rubber and plastics
	Fabricated metal products
	Transport and equipment
	Furniture and others

Source: author's calculations

Over 1998-2011, total contribution of high energy-intensive industries to total manufacturing value added increased from 23.8 percent to 30.8 percent, low group's increased from 15.2 to 24.6 percent while moderate energy-intensive group reported decrease from 61.0 to 44.6 percent (Fig. 3).

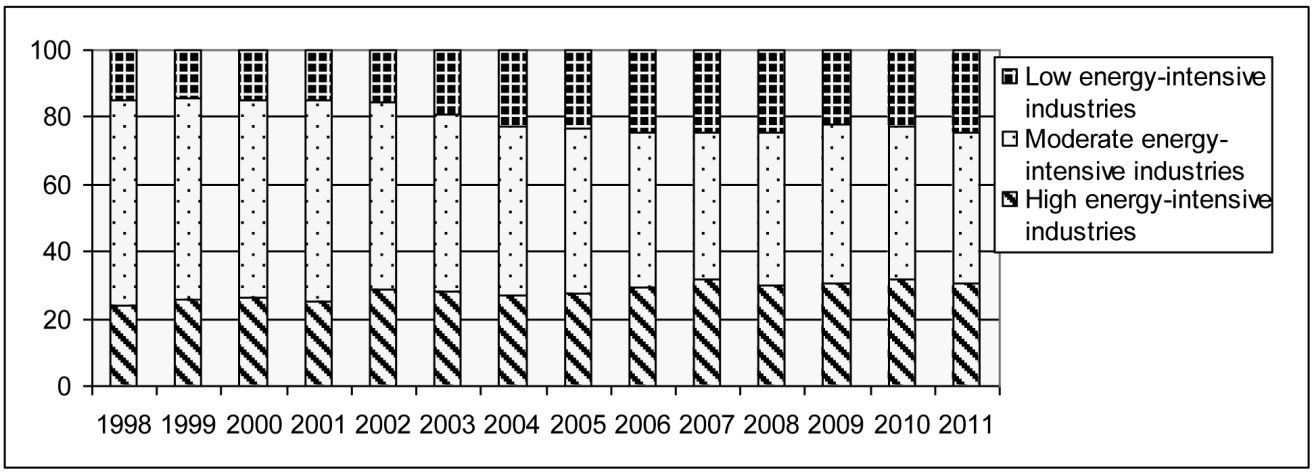

Fig. 3. Industries share (%) in total manufacturing value added by energy intensity

Source: author's calculations based on the Lithuanian Statistics department data

The intensity of energy consumption varied from 5.3 in 1998 to 2.4 J/LTL 1000 in high energy –intensive group, from 1.3 to 0.6 in moderate energy- intensive group and from 1.2 to 0.3 in low energy- intensive group.

As historical data confirmed, energy- intensive activities share in total manufacturing production was increasing over 1998-2011. Referring to this fact as well as evidence that energy-intensive branches amounted to 30 percent of total manufacturing value added, the danger for the Lithuanian competitiveness exits. The restructuring of the activities from energy intensive industries towards more technologically advanced could lead to sustain the Lithuanian manufacturing development and competition in the global context.

4. Conclusions

The research is based on the production theoretic framework and measures energy intensity in the Lithuanian manufacturing sector. The results of the research show variation in energy intensity across the manufacturing activities. The Lithuanian manufacturing activities are classified into three categories, such as high energy- intensive, moderate energy-intensive and low energy- intensive. According to energy intensity ratio, five industries belong to high energy-intensive group, three industries- to moderate energy- intensive group and four manufacturing activities- to low energy intensive group.

Over a period of 1998-2011, the contribution of high energy-intensive industries to total manufacturing value added was increasing and these activities accounted to 30 percent of total manufacturing value added. The risk for the further manufacturing development efficiency exists and high energy-intensive industries should be under special consideration in order to avoid losses in the global context.

The examination of the long- run (1998-2011) energy use percentage change and change in manufacturing production has described that the Lithuanian industry is inelastic of energy consumption. Energy consumption has grown at a much lower rate than manufacturing production, excluding 1999 and 2008. In general, it means that the Lithuanian manufacturing has improved its energy efficiency since 1999.

Lithuania's manufacturing sector with respect to energy situation involves a need to lower energy consumption and increase energy efficiency, particularly of wood and wood products, paper and print, chemical and chemical product, non- metallic minerals and basic metals.

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