Sources of Energy Intensity Change of Thailand's Steel Industry in the Decade of Global Turbulent Time

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Abstract

The study aims at finding the energy intensity and the sources of the changes of the energy intensity of the steel and steel products industry in Thailand using the firm level data collected from the surveys and interviews of steel firms in 2005 and 2012. The study finds that the energy intensity of the industry during the decade of domestic and global economic turbulent time in the 2000s fluctuated. The intensity declined immediately after recovering from the 1997 financial and currency crises but moved in an inverted U-shaped curve when the industry went through the various changes of production structure during 2003 to 2010. The decomposition analysis based on the logarithmic mean Divisia index method finds that the source of the changes of the energy intensity of the industry was dominated by the structural change effect. The fluctuation of the energy intensity was found despite a persistent decline, albeit relatively small, in the energy intensity of individual subsectors. This calls for the need to strengthen the effect of subsector energy intensity changes to help reduce the energy intensity of the industry in the long term. The study results imply four policy measures the government should use to induce steel firms to reduce their energy intensity and thus use the energy in the most efficient way.

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บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์ที่จะวัดระดับความเข้มข้นการใช้พลังงานและระบุแหล่งที่มาของการเปลี่ยนแปลงความเข้มข้นการใช้พลังงานในอุตสาหกรรมเหล็กและผลิตภัณฑ์เหล็กของไทยโดยอาศัยการรวบรวมข้อมูลจากการออกแบบสอบถามและการสัมภาษณ์ผู้ประกอบการในอุตสาหกรรมฯ จากการสำรวจในปี 2548 และปี 2555 ผลจากการศึกษาพบว่า ในช่วงทศวรรษแห่งไม่แน่นอนของภาวะเศรษฐกิจทั้งภายในและภายนอกประเทศ ค่าความเข้มข้นการใช้พลังงานของอุตสาหกรรมเหล็กและผลิตภัณฑ์เหล็กมีค่าที่แกว่งขึ้นลง เห็นได้จากค่าความเข้มข้นการใช้พลังงานที่ลดลงภายหลังจากที่เศรษฐกิจเริ่มฟื้นตัวจากวิกฤตการณ์ทางการเงินและวิกฤตการณ์ทางอัตราแลกเปลี่ยนในปี 2540 จากนั้นก็มีการเคลื่อนไหวในรูปแบบตัวยูกลับหัว ต่อมาในช่วงเวลาที่อุตสาหกรรมฯ ก้าวเข้าสู่ช่วงเวลาแห่งการเปลี่ยนแปลงโครงสร้างการผลิตภายในอุตสาหกรรมในปี 2548 ถึงปี 2553 ผลจากการวิเคราะห์การเปลี่ยนแปลงความเข้มข้นการใช้พลังงานด้วยวิธี logarithmic mean Divisia index พบว่า สาเหตุสำคัญที่ทำให้เกิดการเปลี่ยนแปลงค่าความเข้มข้นการใช้พลังงานมีผลมาจากการเปลี่ยนแปลงโครงสร้างการผลิตเป็นสำคัญ สำหรับความเข้มข้นการใช้พลังงานของแต่ละกลุ่มอุตสาหกรรมย่อยนั้นเป็นส่วนที่ช่วยให้ความเข้มข้นการใช้พลังงานของอุตสาหกรรมลดลงทุกปี แต่ก็มีขนาดที่น้อยกว่าผลการเปลี่ยนแปลงจากการเปลี่ยนแปลงโครงสร้างการผลิต จึงทำให้ความเข้มข้นการใช้พลังงานในภาพรวมมีค่าแกว่งขึ้นลง การศึกษานี้มีข้อสรุปคือ ควรจะมีการส่งเสริมให้ผลของการเปลี่ยนแปลงความเข้มข้นการใช้พลังงานในแต่ละกลุ่มอุตสาหกรรมย่อยให้อยู่ในระดับที่สูงเพียงพอที่จะนำไปสู่การลดลงของความเข้มข้นการใช้พลังงานของอุตสาหกรรมในระยะยาว ผลจากศึกษานำไปสู่ข้อเสนอแนะเชิงนโยบาย 4 มาตรการที่สามารถนำไปใช้ในการส่งเสริมให้อุตสาหกรรมเหล็กและผลิตภัณฑ์เหล็กมีความเข้มข้นการใช้พลังงานลดลงและมีการใช้พลังงานในวิถีทางที่มีประสิทธิภาพต่อไป

1. Introduction

In the decade after the new millennium the world economy was undergoing a turbulent time resulting in wild fluctuations in individual economies. The rise of energy prices throughout the decade further complicated the economic conditions. It raised concerns over issues of price stability and external imbalances of developing countries particularly in the oil-importing ones. Will the soaring energy prices coupled with rising energy consumption lead to an increased inflation during the economic upturns and turn the external sector into a deficit during the global economic downturns? These concerns imply the need to save energy. If successful, the effort of energy saving could not only satisfy economic stability but also reduce production costs which could in turn enhance international competitiveness. Eventually, the external sector balance could be restored and living standards improved. In addition, the life quality could be upgraded as the CO_2 emission is reduced and the environment is saved from the global warming effect.

To save energy all industries particularly the ones which consume more energy than others should improve the efficiency of their energy use. A simple measurement of energy efficiency which is commonly used is energy intensity. An industry with high energy intensity reflects its high energy consumption per unit of production but it does not necessarily mean a lack of energy efficiency. Rather, it is the change in energy intensity which could suggest energy wastage. In Thailand among all industries the steel and steel products industry has the highest energy intensity, second only to the nonmetallic mineral industry. Therefore, the ability to improve the energy efficiency of the steel and steel products industry should contribute significantly to energy-saving of the overall industrial sector and in turn the whole economy of Thailand. Our study intends to measure the energy intensity of Thailand's steel industry by individual subsector during the decade of the 2000s, followed by the changes of energy intensity. Finally, we will analyze the sources of the energy intensity changes using the decomposition method. The data for the study are at the firm level and collected from our firm surveys and interviews conducted in two phases, first in 2005 and the recent one in 2012. The study results are expected to imply policies and measures which could be used for reducing energy intensity and improving the efficiency of energy consumption of the steel and steel products industry in Thailand.

The organization of the paper is as follows. Section 2 discusses the growth of Thailand's steel and steel products industry in the world market. This section includes the topics of the steel industry in the process of Thailand's industrialization, growth of the steel industry, and production and trade of the industry in the world market. Section 3 presents and discusses structural change, energy consumption, and the computed energy intensity of Thailand's steel industry. Section 4 highlights the analysis of the changes of energy intensity using the decomposition method. The section first introduces the method which is used in our study, followed by a discussion on the computed results. Finally Section 5 concludes our findings and draws policy implications from our study.

2. Growth of Thailand's Steel Industry in the World Market

2.1 The Steel Industry in the Process of Thailand's Industrialization

Production in the steel and steel products industry of Thailand began to grow in the early 1960s at about the time when the country started to industrialize. Since it is an import-substituting industry which caters its production for the domestic market, its growth is closely related to the growth of the domestic economy and the process of Thailand's industrialization. Thailand began to industrialize in the 1960s with the share of manufacturing production in GDP increased from less than 10 % of GDP to 30 % in the following two decades. In the 1970s the manufacturing sector continued from the previous decade to grow at the average rate of 9.5 % a year. However, the growth was the most rapid in the

1980s with the share of the sector in GDP increased to 30 %, and since then the country has been entitled to become a newly-industrialized economy. Unfortunately, the economy suffered from the financial and currency crises in 1997 and the average growth rate slowed down to 6.2 % a year in the 1990s. Thanks to the country's relatively strong economic fundamentals the economy was able to recover from the crises in just a few years.

Despite the relatively rapid recovery the growth of the manufacturing sector after the crisis could not match the growth rate in the decade before 1997. Furthermore, the growth rates in the decade after the full recovery in 2000 fluctuated. The growth of sector in the initial period after recovery between 2000 and 2007 rose from the previous decade to 6.3 % a year. Soon after that the growth was declined to 1.2 % a year from 2007 to 2011, resulting in the average growth for the whole decade of the 2000s to be reduced to 4.5 %. The moderate and fluctuating growth during 2000 to 2011 was due largely to the turbulent global economy and unstable domestic politics.

During 2000 to 2007 the global economy was highly favorable to Thailand's international trade and investment. The manufacturing exports were able to grow at 12 % a year and foreign direct investment increased steadily at 19 %, leading the sector to grow at 6.3 % a year. The economic conditions changed from 2007 to 2011 as both the domestic and the world economic conditions declined. On the domestic front the increasingly unresolved political conflicts which began in the mid-2000s was escalated to cause political instability in the late 2000s. In the meantime most industrial countries suffered from a financial crisis that turned their economies into a deepened and prolonged recession. Both incidents had severely affected Thailand's export growth and the whole economy. Consequently, the manufacturing growth declined to the average annual growth rate of merely 2.1 % and the share of the manufacturing sector stagnated at 30 % of GDP.

Within the manufacturing sector each and every industry was affected by the fluctuations of the world and the domestic economies, albeit at different levels and for different impact factors. The export-oriented industries suffered from the instability of the world economy and foreign exchange rates. On the other hand, the import-substituting industries such as the steel and steel products industry was affected by the fluctuation of the domestic economy and rising competition from imported goods during the global recession in the late 2000's. Below will discuss the growth of the steel and steel products industry by separating the discussion into different subperiods. They range from prior to the 1997 crises, the subperiod after the 1999 recovery to 2007, and the time under the effect of the great recession in the OECD during 2008 to 2011.

2.2 Growth of Thailand's steel industry

The steel and steel products industry of Thailand began to grow under the import substitution policy in the 1960s. Major steel products such as hot-dip galvanized iron and wire rods began production in the early 1960s. In 1967 the GS Steel Company started the production of steel bars with electric arc furnace (EAF). In the following decade of the 1970s there was an increased production of additional products namely steel bars and cold-rolled section. In the first half of the 1980s the production of hot-rolled section followed. However, it was during the boom time of the manufacturing sector in the late 1980s that production of the steel industry became more sophisticated with expanded production of hot-rolled and cold-rolled coils. They were intermediate products used for the production of final products in the various other industries. During the period the steel industry followed the booming domestic economy and rapid industrialization to grow at 12 % a year.

The steel industry attempted a leapfrogging development after Thailand started to liberalize its international financial market in 1990. Large producers in the steel industry found the opportunity to fulfill the ambition of quickly turning the industry to be an integrated one with production ranging from

upstream to downstream goods. They borrowed heavily from abroad to reap the benefit of low foreign interest rates and the country's essentially fixed exchange rates to invest in highly capital-intensive integrated steel mill projects. In hindsight the industry was overinvested and it became one of the sectors which suffered the most damage from the financial and currency crises of 1997. Some large firms were afflicted by high indebtedness and had to resort to consolidation, or else going bankrupt, after the fixed exchange rate system collapsed and the foreign capital was drying up in 1997. However, the industry recovered slowly during 1998 to 1999. In fact, it was not until 2000 when it started to grow favorably again.

Table 1 shows the growth rate of production, imports, and demand, including the import penetration ratio (indicating the amount of the steel imports over consumption) of the steel and steel products industry of Thailand separated by three subperiods during 1999 to 2010. They are the first subperiod of 1999 to 2005 immediately after the 1997 financial crisis, the second subperiod of 2005 – 2008 when the domestic economy started to grow slowly, and the last subperiod of 2008 to 2010 when the economy grew the slowest in the aftermath of the OECD financial crisis. In the initial subperiod from 2000 to 2005, shortly after recovering from the crisis, Thailand's steel and steel products industry grew at a very high rate of 18 % a year due to steady growth of the domestic market particularly in the construction and downstream export-oriented industries. In the second subperiod, from 2005 to 2008, as the domestic economy started to slow down and the political conflicts were looming the industry's growth slowed down to 7 % a year. Finally, during 2008 to 2011 when the domestic political problems persisted and the financial crisis in the industrial countries spread across the world the industry shrank at 1 % a year. Apparently, in the last decade although the steel industry relied heavily on the domestic market, its growth was affected by not only the growth of the domestic economy but also the world economic conditions. This is because the market of the industry has lately been shifting from the domestic construction sector to export-oriented industries such as automobile parts, electrical appliances, and food products. Hence, factors which affect Thailand's export sector became indirectly affecting the steel industry growth.

Table 1: Growth of Production, Imports and Demand, and the Imports Penetration Ratio of the Steel Industry in Thailand by Subperiod, 1999 to 2010

Subperiod	Growth Rate (%)			Import-Penetration Ratio
	Production	Import	Demand	
1999-2005	17.7	8.1	7.3	48.6
2005-2008	-6.9	9.4	9.4	52.5
2008-2010	-0.9	-0.5	-18.1	56.2

Source: Institute of Steel Industry of Thailand

Furthermore, since the economy was increasingly open to world trade the steel industry was directly affected by the tide of imports which occasionally flowed into the country, particularly when there was a glut of the steel products in the world market. When the world economy was in the period of prolonged slowdown in the late 2000s excess supply of steel and steel products from abroad spilled to the domestic market and consequently put pressure on the industry to compete painfully with the

imports. In fact, from Table 1 the import penetration ratio increased steadily during the rate 2000s. During the earlier period of 1999 to 2005 the import of steel and steel products grew at 8.1 % a year, much slower than the domestic production which grows at 17.7 %. At the time the import penetration ratio was about 48.6 %. From 2005 to 2008 the imports rose to 9.4 % a year as domestic production declined at 6.9 % and as a result the import penetration ratio increased to 52.5 %. Subsequently, during the turbulent years from 2008 to 2011 the domestic production declined further at 0.9 % a year but the imports declined a slow rate of 0.5 % resulting in the import penetration ratio continuing rising to 56.2 %.

Evidently, although the import- substituting steel and steel products industry in Thailand did rely mostly on the growth of the domestic economy the growth of the industry could not be insulated from the fluctuating world economic conditions. During 1999 to 2005 the steel and steel products industry performed very well thanks to the expanded domestic economy combined with the rapid growth of the demand from the export-oriented industries such as automobile parts, electrical appliances, and canned foods. These latter industries were supported by the favorable world economy. For the rest of the decade after 2005 both the domestic and the global economies turned highly unstable and the steel industry was alternatively adversely affected by both the declined domestic demand and the increased competition from imported goods. The imports came from major steel producers in the world market attempting to release their excess supply to the rest of the world including Thailand. Below will assess the position of Thailand's steel industry in the world market to understand how its growth could easily be hindered by world competition.

2.3 Production and Trade of Thailand's Steel Industry in the World Market

Thailand is a small steel producing country in the world market with demand and production expanding fast during the period after fully recovering from the 1997 financial and currency crises in the first half of the 2000s. In the late 2000s both demand and production growth began to slow down due to unstable domestic and global economies. Presently the industry is still in its import-substitution stage with domestic production struggling to compete with the imports.

Table 2 shows the shares of production, consumption, imports, and exports of the steel and steel products of major steel producing and trading countries in the world market for the decade of the 2000's. Throughout the decade of the 2000s the production of the steel and steel products of Thailand remained accounted for less than 1% of total world production. The major steel producers in the world were China (33% of total world steel output), the EU (13%), Japan (9%), the US (8%), followed by major emerging economies namely, Russia (6%), South Korea (4%), and India (4%).

China was the largest producer and consumer of steel and steel products, but the EU had the largest volume of trade. The spectacular growth of China from the 1990s had resulted in the rapid increase in steel demand. Meanwhile, its large deposit of coal input made it possible for China to become the major producer in the world. However, due to the country's size and the rapid growth its production was unable to cover the demand and the imports had to increase from the 1990s to the early 2000's. Astonishingly, the country's trade pattern had changed since the mid-2000s. Its steel industry had developed so fast that it turned to export a large amount of steel products to the world market. By the late 2000s China was about to catch up with the EU and Japan to become another major exporter of steel products in the world.

Table 2: Share of Production, Consumption, and Trade of the Steel and Steel Products Industry of Major Countries in the World Market in the Decade of the 2000s

	Production	Consumption	Imports	Exports
World	100.00	100.00	100.00	100.00
The EU	13.85	13.52	31.12	32.05
North America	10.54	12.96	12.31	5.58
The US	7.79	9.42	7.60	2.40
CIS Republic	9.54	4.35	2.94	16.56
Russia	5.65	3.13	1.24	7.76
Ukraine	3.18	0.60	0.35	7.33
Latin America	3.78	3.25	2.15	3.90
Brazil	2.69	1.90	0.50	2.92
Asia	53.94	54.77	29.66	29.26
Japan	9.54	6.72	1.14	9.41
China	33.02	32.83	6.90	8.37
India	3.99	4.13	1.42	1.51
South Korea	4.27	4.42	5.51	4.68
Indonesia	0.29	0.69	1.40	0.31
Malaysia	0.47	0.72	1.36	0.74
Thailand	0.36	1.20	2.88	0.55
Others	8.36	11.14	21.83	12.67

Source: World Steel Association (2011)

The EU has long been the largest exporter and importer of steel and steel products because they were both the major world producer and consumer of the products. The US was a major steel consuming country but the domestic production remained short of the demand. Actually, its domestic production had faced competition from many foreign producers and the imports had increased so much that the government had to occasionally resort to the various protective measures to prevent the domestic industry from being outcompeted by the imports. In contrast, Japan had steadily expanded its production in the 1970s and increased its exports to the US and other countries. Until the recent years it

had become the largest exporter of the products, second only to the EU. Generally, the steel exports from Japan were competitive both in terms of prices and quality, and its exports had always been greater than the imports despite its great domestic demand. However, since the mid-2000s the country had increasingly faced competition from China which was able to export lower quality products at very competitive prices. Indeed, in the recent years its exports to some countries such as Thailand have increasingly been replaced by the exports from China.

Following the EU, Japan, and China other top exports in the world market were Russia, Ukraine, and South Korea. Russia and Ukraine produced a large amount of iron and steel which were used as inputs for the production of steel products but the demand has mostly been less than the supply. So, there was much surplus for these countries to export to the rest of the world. Since the late 2000's they had exported an increasing amount of the middle-stream production of slab and billet to Thailand replacing the country's domestic production. Another major steel trading country is South Korea. The country, without any raw material for iron and steel production, started its integrated steel mill projects in the late 1970s and presently at the stage where domestic production increased as fast as the demand. The industry was able to produce for export but the imports were also very high. In fact, besides being a top world exporter in the late 2000s it had followed the EU to become the second largest importer of the steel and steel products in the world market. Thailand has always been inspired by the South Korean success to develop a more vertically integrated steel industry. To achieve this target, the industry has to firstly learn how to improve its efficiency and productivity to increase its international competitiveness.

Presently, both production and exports of the steel products were still minor in the world market (about 0.5 % in the world total) but the import share in the overall world imports was over six times larger and it continued to increase. The domestic industry realized its needs to greatly enhance its productively or reducing production costs to stay competitive in the domestic and the world markets. Since the industry is highly capital-intensive and uses a large amount of energy in the production process the ability to reduce energy costs in the current era of escalating energy prices should be one of the crucial strategies it could implement to increase its international competitiveness. Next we will discuss the energy consumption and intensity of the industry. Furthermore, we will find the source of the change of energy intensity in order to determine factors which can help the industry to increase its energy efficiency and the international competitiveness.

3. Structural Change, Energy Consumption, and Energy Intensity in Thailand's Steel Industry

The production structure of Thailand's steel industry has not yet been fully integrated in all lines of products which should range from upstream to downstream. Essentially, the structure is skewed towards the production of downstream products while the production of middle-stream products were growing for while during 2003 to 2008 before losing to the competition of the imported products after the global recession beginning 2008. Currently, the industry still relies on the imports of upstream and some middle-stream products as inputs for the production of its downstream output. Table 3 shows the structure of steel production during 1999 to 2010. Among the 15 subsectors (groups of steel and steel products) the ones with the highest share of production were hot-rolled coil without electric arc furnace (EAF), cold-rolled coil, hot-rolled coil with EAF, hot-dip galvanized iron, electric resistance welding pipes, steel bars with EAF, wire and rod with and without EAF, tin plates and tin fire, and cold-rolled section. The rest were products with low production share.

Table 3: Structural Change of Production Structure of the Steel Industry in Thailand, during 1999-2010

unit : %

	1999-2002	2003-2007	2008-2010
Steel Bar, with EAF	6.8	6.1	5.1
Steel Bar, without EAF	4.4	4.0	3.3
Wired Rod, with EAF	0.0	3.2	4.4
Wired Rod, without EAF	4.0	2.1	1.1
Hot-rolled Section, with EAF	8.0	4.0	1.7
Hot-rolled Section, without EAF	0.6	0.7	0.4
Hot-rolled Coil, with EAF	0.0	18.3	14.8
Hot-rolled Coil, without EAF	30.0	20.2	22.8
Cold-rolled Coil	12.6	19.4	19.1
Hot-Dip Galvanized Iron	7.8	6.3	6.5
Electro Galvanized Plates	4.9	3.0	1.9
Tin Plates, Tin Free	12.0	7.0	4.8
Cold-rolled Section	0.7	1.5	3.2
Electric Resistance Welding Pipes	5.8	3.3	10.0
Galvanized Steel Pipes	2.3	1.0	0.8
Total	100.0	100.0	100.0

Source: Authors' survey data

Most of the above products belong to downstream industries with some were at the middle-stream level. In the early 2000s the Thai steel industry focused its production on downstream products by importing upstream and some of the middle stream products to be used as inputs for the production of semi-finished and finished steel products. The imported raw materials included stab, billet, and bloom, and most of the final finished steel products were hot and cold-rolled coils, steel bars, and hot-rolled section. Note that the only middle-stream products produced at the period were steel bars with EAF. From 2003 to 2007 production in the middle-stream industry increased. Steel scraps were imported to manufacture slab and billet (using EAF) to produce raw materials for use in the final production of wires and rods, hot-rolled section, and hot-rolled coils. As a result of the above changes, when comparing the production shares of different products between the subperiod of 1999 to 2002 and the subperiod of 2003 to 2007 we witness a change of the production structure. There was an increase in the production of middle-stream products (all the ones using the EAF), resulting in their share in total production to increase but the share of downstream products to decline.

Table 4: Structural Change of Energy Consumption of the Steel Industry in Thailand, during 1999-2010

unit : %

	1999-2002	2003-2007	2008-2010
Steel Bar, with EAF	18.2	12.9	11.3
Steel Bar, without EAF	4.7	3.2	2.8
Wired Rod, with EAF	0.0	6.1	9.9
Wired Rod, without EAF	6.9	2.7	1.4
Hot-rolled Section, with EAF	22.5	8.4	3.9
Hot-rolled Section, without EAF	0.9	0.7	0.4
Hot-rolled Coil, with EAF	0.0	33.5	32.0
Hot-rolled Coil, without EAF	30.2	17.8	22.5
Cold-rolled Coil	9.0	9.9	12.0
Hot-Dip Galvanized Iron	2.4	2.0	1.5
Electro Galvanized Plates	1.0	0.7	0.6
Tin Plates, Tin Free	2.5	1.2	0.8
Cold-rolled Section	0.0	0.0	0.1
Electric Resistance Welding Pipes	0.3	0.2	0.4
Galvanized Steel Pipes	1.5	0.6	0.4
Total	100.0	100.0	100.0

Source: Authors' survey data

Nevertheless, the development from downstream to middle-stream production changed after 2007. During 2008 to 2010 the production of middle-stream products (those using EAF) declined as their imports increased instead. During the period the world economy plunged and the growth of manufacturing production in both developed countries and the emerging economies greatly slowed down. The above conditions reduced the supply of steel scraps and as a result their prices soared. Consequently it became more costly to import steel scraps to use as raw material for producing the middle-stream products domestically than import the products directly. Actually, in the late 2000s when the prices of the steel scraps increased much more rapidly than the prices of billet, slab, and bloom Thailand's imports of these middle-stream products from Russia and Ukraine had increased, but the domestic production of these products declined dramatically.

Therefore, during the period of 2008 to 2010 the structural change was reversed from the previous period. The middle-stream production share was reduced but that of the downstream products was increased instead. After all, it has not been easy for the country to initiate a sustainable integrated steel production structure. The shares of most middle-stream products with EAF increased during 2003 to 2007 but declined during 2008 to 2010. The above structural changes during 1999 to 2010 had produced an impact on the energy consumption of the steel industry.

Regarding the energy consumption of the steel industry for the overall period of 1999 to 2010 the products with the largest energy consumption were as follows: hot-rolled coils with EAF, hot-rolled coils without EAF, wires and rods with EAF, cold-rolled coils, steel bars with EAF, hot-rolled section with EAF, steel bars without EAF, hot-dip galvanized iron, tin plates and tin free, and wires and rods without EAF. When comparing the above group of products with the one with the highest production shares we found earlier, products in the two groups were not totally the same. This implies that there were some products which consume a larger amount energy per output than others. We call the energy consumption per output energy intensity and its reciprocal measures the efficiency of energy use. Normally, the middle-stream products which are highly capital-intensive consume greater amount of energy per unit of production than the downstream products. We will discover later that the structural changes which came from the alternation between the production of middle-stream and downstream steel products had a crucial impact on the energy intensity of the overall steel industry.

The measurement of energy intensity of the steel industry of Thailand during 1999 to 2010 by 15 subsectors is shown in Table 5. By comparing the energy intensity of different subsectors throughout the period we find the subsectors with consistently high energy intensity were steel bars with EAF, hot-rolled section with EAF, wires and rods with EAF, and hot-rolled coils with EAF. They were all middle-stream steel products used as raw materials for the production of downstream steel products. The subsectors with medium energy intensity were wires and rods without EAF, hot-rolled section without EAF, cold-rolled coils, and galvanized steel pipes. There was mostly major downstream production with high production shares. Other than the above subsectors the rest were downstream steel products with very low energy intensity and they were hot-dip galvanized iron, electro galvanized plates, ten plates and tin free, cold-rolled section, and electro resistance welding pipes. All of them had very low production shares as well.

From Table 5 it is noted that for the subsectors which produced the same types of steel products the ones with the EAF had a much higher energy intensity than the ones without the furnaces. This is because in the process of smelting and mixing steel liquid in the furnaces to produce the middle-stream products of slab and billet, there was a heating requirement which needed a lot of energy with high temperature. Therefore, it is inevitable that the middle-stream subsectors which produced raw materials for all the downstream subsectors had a much higher energy intensity than others. Among the downstream subsectors the ones which produced wires and rods, hot-rolled section, hot-rolled coils, and steel bars had the energy intensity higher than the rest. In addition, because different subsectors had different levels of energy intensity the change in production structure of the industry over time would lead to a change in the energy intensity of the overall industry.

When tracing the movement of the energy intensity overtime Figure 1 shows that the energy intensity of the overall steel industry in Thailand fluctuated over the decade of 1999 to 2010. It declined during the years after 1997 crises between 1999 and 2002; increased in 2003 and maintained the stable but high level to 2007; and eventually from 2008 to 2010 the energy intensity declined. If focusing on the period after the industry increased the middle-stream production from 2003 to 2010 the energy intensity of the industry looked like an inverted U-shaped curve. This is thanks to the fact that the effort to deepen the production structure to become more vertically integrated initiated in 2003 faced a setback after the global recession in 2008. As a result, the production structural change during 2003 to 2007 was not sustainable. Actually, it was reversed during 2008 to 2010, resulting in altering the trend of the energy intensity of the industry as well. The next section will analyze the source of the changes of the energy intensity of the steel industry in order to isolate the structural change effect from other

effects using the decomposition method. The computed results would be beneficial for identifying channels and policies for further improving the energy efficiency

Table 5: Energy Intensity of the Steel Industry in Thailand by subsector, 1999-2010

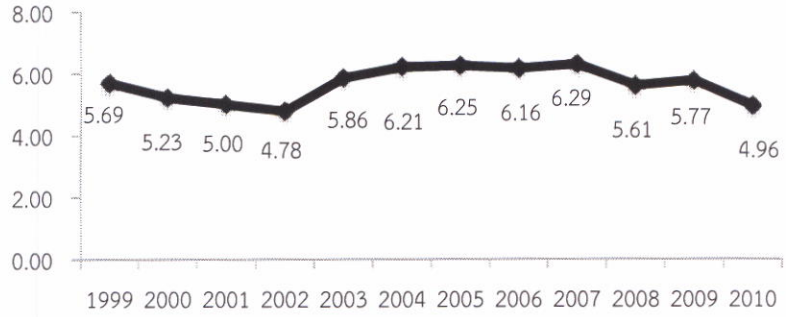
Unit: KTOE per Billion Baht

	1999	2000	2001	2002	2003	2004
Steel Bar, with EAF	14.69	13.88	14.75	12.17	14.16	11.70
Steel Bar, without EAF	5.86	6.00	5.56	4.78	4.88	4.89
Wired Rod, with EAF					11.54	10.57
Wired Rod, without EAF	11.03	8.10	8.28	8.02	7.86	8.23
Hot-rolled Section, with EAF	14.80	15.91	14.66	12.67	12.62	13.38
Hot-rolled Section, without EAF			7.27	6.51	6.24	6.39
Hot-rolled Coil, with EAF					12.77	11.72
Hot-rolled Coil, without EAF	5.44	5.35	5.05	5.03	5.11	5.40
Cold-rolled Coil	4.91	3.55	3.42	3.32	2.89	2.88
Hot-Dip Galvanized Iron		1.53	1.54	1.50	1.60	1.58
Electro Galvanized Plates	1.13	0.91	1.02	1.19	1.20	1.13
Tin Plates, Tin Free	1.05	1.19	1.10	1.14	1.05	1.11
Cold-rolled Section	0.02	0.01	0.01	0.01	0.01	0.01
Electric Resistance Welding Pipes	0.24	0.23	0.24	0.25	0.27	0.28
Galvanized Steel Pipes	3.02	3.40	3.53	3.73	4.22	5.00
Total Industry	5.69	5.23	5.00	4.78	5.86	6.21

	2005	2006	2007	2008	2009	2010
Steel Bar, with EAF	13.03	12.72	13.49	12.68	13.03	10.74
Steel Bar, without EAF	4.63	5.08	5.10	4.60	4.75	4.37
Wired Rod, with EAF	12.91	11.79	12.40	11.86	12.61	11.87
Wired Rod, without EAF	7.28	7.16	7.73	6.06	7.33	7.07
Hot-rolled Section, with EAF	11.84	11.64	12.58	12.64	12.67	12.41
Hot-rolled Section, without EAF	5.65	5.55	6.00	4.70	5.69	5.49
Hot-rolled Coil, with EAF	10.97	11.22	10.62	10.78	13.08	12.32
Hot-rolled Coil, without EAF	5.51	5.52	5.67	5.59	5.47	5.08
Cold-rolled Coil	3.31	3.26	3.17	3.30	3.58	3.40
Hot-Dip Galvanized Iron	1.99	2.36	2.15	1.87	1.50	0.76
Electro Galvanized Plates	1.84	1.84	1.82	1.74	1.71	1.39
Tin Plates, Tin Free	1.18	1.11	1.06	1.04	0.90	0.88
Cold-rolled Section	0.21	0.24	0.17	0.15	0.21	0.22
Electric Resistance Welding Pipes	0.27	0.33	0.35	0.15	0.19	0.23
Galvanized Steel Pipes	2.48	2.64	2.72	2.20	3.59	2.99
Total Industry	6.25	6.16	6.29	5.61	5.77	4.96

Source: Authors' computation.

Figure 1: Energy Intensity of the Steel Industry in Thailand, 1999-2010.



Source: Authors' computation

4. Sources of Energy Intensity Changes of the Steel Industry in Thailand

The production of the aggregate steel industry in Thailand consists of output of individual subsectors. The changes of energy intensity of the aggregate industry can be decomposed to be from two sources namely, the structural change effect and the subsector energy intensity change effect. The changes of energy intensity of the aggregate industry due to the structural effect comes from the change in the production shares of different subsectors in overall industry production. Whenever there is a change of the production structure from the subsectors with low energy intensity to the ones with high energy intensity, the energy intensity of the overall steel industry will increase. In contrast, whenever the structural change is such that the production shares of the low energy intensity subsectors increase while the decrease of the production shares of the subsectors with high energy intensity decrease, the energy intensity of the overall industry will on the contrary, decline. We call the effect of the changes of production composition of the steel industry on the energy intensity of the overall industry the structural change effect.

Another source of the change in energy intensity of the steel industry is called the subsector energy intensity change effect. Here the change of the aggregate energy intensity is from the changes of the energy intensity of individual subsectors. For example, if over time most subsectors experience a decrease in the energy intensity, the energy intensity of the aggregate steel industry will also decrease. In this case, all subsectors regardless of having high or low energy intensity could all contribute to the decline in the energy intensity of the aggregate industry provided that each subsector puts an effort to reduce its energy intensity.

There are two approaches one can use to decompose the change in the energy intensity of the steel industry namely, the multiplicative and the additive approaches. Next we will present the methods that will be used to decompose the changes of energy intensity of the steel industry, followed by showing and discussing our computed results of the structural change effect and the subsector energy intensity change effect.

4.1 The decomposition method of energy intensity changes

There are two approaches we can use to decompose the change in the energy intensity of the steel industry namely, the multiplicative and the additive approaches.

The multiplicative approach: $D_{tot} = \frac{i_t}{I_0} = D_{str} D_{int}$

The additive approach: $\Delta I_{tot} = I_t - I_0 = \Delta I_{str} + \Delta I_{int}$

In all the approaches we need to compute $D_{str}, D_{int}, \Delta I_{srt}$ and ΔI_{int} by using different methods below.

(1) Laspeyres Index Method
(2) Arithemetic Mean Division
(3) Log Mean Divisia Index

We will next present each of the approaches used for determining the sources of the change of the energy intensity in more detail, followed by showing different methods one can use to compute all the terms in each approach.

4.1.1 Approaches to decompose energy intensity changes

Let us suppose that the aggregate energy consumption of the steel industry is the sum of consumption of n different subsectors. Define the following variables for time t measured by year. Energy consumption is measured in ktoe and the steel production is evaluated at constant prices.

Let E_i = Total energy consumption the steel industry

E_{it} = Energy consumption in the i-th subsector

Y_t = Total steel production

Y_{it} = Steel production in the i-th subsector

S_{it} = Production share of the i-th subsector = Y_{it} / Y_t

I_t = Aggregate energy intensity = E_t / Y_t

I_{it} = Energy intensity of the i-th subsector = E_{it} / Y_{it}

Next we write the aggregate energy intensity of the steel industry in terms of production share and subsector energy intensity in the following form:

$$I_t = \sum_i S_{it} I_{it}$$

Suppose the aggregate energy intensity changes from I_0 at time 0 to I_t at time T, we can write the changes in the energy intensity in two forms namely multiplicative form (D_{tot}) and additive form (ΔI_{tot}) where

$$D_{tot} = \frac{I_t}{I_0} \text{ and } \Delta I_{tot} = I_t - I_0$$

Based on the multiplicative form; if D_{tot} = 1, it means there is no change in the aggregate energy intensity over time. If D_{tot} > 1, the energy intensity of year T is greater than the reference Year 0. If D_{tot} < 1, the energy intensity in Year T is reduced from Year 0.

Alternatively, if we express the changes in the aggregate energy intensity in the additive form and ΔI_{tot} = 0, it would mean there is no change in the energy intensity. If ΔI_{tot} > 0, it means there is an increase in the energy intensity overtime. If ΔI_{tot} < 0, the energy intensity decreases form year 0 to T.

Now we are ready to decompose the changes in the energy intensity to be from two sources namely, structural change effect and subsector intensity changes effect. If we write the aggregate energy

intensity changes in the multiplication form, then D_{tot} will be able to be decomposed in the following form:

$$D_{tot} = D_{str} D_{int}$$

where D_{str} represents the structural change effect and D_{int} denotes the changes of the energy intensity at the subsector level.

If we express the aggregate energy intensity changes in the additive form, then ΔI_{tot} will be able to be decomposed in the following form:

$$\Delta I_{tot} = \Delta I_{str} + \Delta I_{int}$$

where ΔI_{str} and ΔI_{str} denote the structural change effect and the changes of the energy intensity at the subsector level respectively.

4.1.2 Methods for computing the changes in the energy intensity

Terms in each of the approaches for finding the sources of the changes in the energy intensity of the steel industry can be computed by choosing each of the following methods.

(1) Laspeyres index method

The Laspeyres index method isolates the impact of variable through letting the specific variable change while holding the other variables at their respective base year values. Under the multiplicative decomposition, we can write

$$D_{str} = \frac{\sum_i S_{it} I_{it}}{\sum_i S_{i0} I_{i0}}$$

$$D_{int} = \frac{\sum_i S_{i0} I_{it}}{\sum_i S_{i0} I_{i0}}$$

and

$$D_{rsd} = \frac{D_{tot}}{D_{str} D_{int}}$$

where D_{rsd} denotes to residual term.

Under the additive decomposition we can write

$$\Delta I_{str} = \sum_i S_{it} I_{i0} - \sum_i S_{i0} I_{i0} = \sum_i (S_{it} - S_{i0}) I_{i0}$$

$$\Delta I_{int} = \sum_i S_{i0} I_{it} - \sum_i S_{i0} I_{i0} = \sum_i (I_{it} - I_{i0}) S_{i0}$$

and

$$\Delta I_{rsd} = \Delta I_{tot} - \Delta I_{srt} - \Delta I_{int}$$

where ΔI_{rsd} denotes the residual term.

(2) Arithmetic mean Divisia index method

According to Ang (2000), if we apply the theorem of instantaneous growth rate to the equation: $I_t = \sum_i S_{it} I_{it}$ we obtain

$$\frac{d\ln(I_t)}{dt} = \sum_i \omega_i \left(\frac{d\ln(S_{it})}{dt} + \frac{d\ln(I_{it})}{dt} \right)$$

where $\omega_i = E_{it} / E_t$ is the sector share of energy consumption and is known as the weight for subsector i in the summation. Integration over time from 0 to T and rearranging the terms gives:

$$\ln \frac{I_t}{I_0} = \int_0^T \sum_i \omega_i \frac{d\ln(S_{it})}{dt} + \int_0^T \sum_i \omega_i \frac{d\ln(I_{it})}{dt}$$

Exponentiating the above equation can be expressed in the multiplicative form $D_{tot} = D_{str} D_{int}$ where:

$$D_{str} = \exp\left(\int_0^T \sum_i \omega_i \frac{d\ln(S_{it})}{dt} \right)$$

$$D_{int} = \exp\left(\int_0^T \sum_i \omega_i \frac{d\ln(I_{it})}{dt} \right)$$

Since only discrete data are available in our empirical studies, the weight function will be approximated by the arithmetic mean of the weights for year 0 and year T.

$$D_{str} = \exp\left(\sum_i \frac{(\omega_{it} + \omega_{i0})}{2} \ln \frac{S_{it}}{S_{i0}} \right)$$

$$D_{int} = \exp\left(\sum_i \frac{(\omega_{it} + \omega_{i0})}{2} \ln \frac{I_{it}}{I_{i0}} \right)$$

As a result of this approximation, the product of the above equations is not equal to D_{tot} and we may write $D_{tot} = D_{str} D_{int} D_{rsd}$. The additive Divisia index can be derived in the same manner. The formulae are:

$$\Delta I_{str} = \sum_i \frac{\left(\frac{E_{it}}{Y_t} + \frac{E_{i0}}{Y_0} \right)}{2} \ln \frac{S_{it}}{S_{i0}}$$

$$\Delta I_{int} = \sum_i \frac{\left(\frac{E_{it}}{Y_t} + \frac{E_{i0}}{Y_0} \right)}{2} \ln \frac{I_{it}}{I_{i0}}$$

(3) Logarithmic Mean Divisia Index Method

Ang and Choi (1997) propose a refined Divisia index method using a logarithmic mean weight function to discretize the integral Divisia index to give an ideal index. Thus, D_{str}, D_{int}, ΔI_{srt} and ΔI_{int} can be respectively transformed into the following forms.

$$D_{str} = \exp\left(\sum_i \frac{L(\omega_{it}, \omega i0)}{\sum_i L(\omega_{it}, \omega_{i0})} \ln\frac{S_{it}}{S_{i0}}\right) = \exp\left(\sum_i \frac{L(\frac{E_{it}}{E_t}, \frac{E_{i0}}{E_0})}{\sum_i L(\frac{E_{it}}{E_t}, \frac{E_{i0}}{E_0})} \ln\left(\frac{S_{it}}{S_{i0}}\right)\right)$$

$$D_{int} = \exp\left(\sum_i \frac{L(\omega_{it}, \omega i0)}{\sum_i L(\omega_{it}, \omega_{i0})} \ln\frac{I_{it}}{I_{i0}}\right) = \exp\left(\sum_i \frac{L(\frac{E_{it}}{E_t}, \frac{E_{i0}}{E_0})}{\sum_i L(\frac{E_{it}}{E_t}, \frac{E_{i0}}{E_0})} \ln\left(\frac{I_{it}}{I_{i0}}\right)\right)$$

The above formulas give perfect decomposition and their additive version which also leads to perfect decomposition can be written in the following form:

$$\Delta I_{str} = \sum_i L\left(\frac{E_{it}}{Y_t}, \frac{E_{it}}{Y_t}\right) \ln\frac{S_{it}}{S_{i0}}$$

$$\Delta I_{str} = \sum_i L\left(\frac{E_{it}}{Y_t}, \frac{E_{it}}{Y_t}\right) \ln\frac{S_{it}}{S_{i0}}$$

As to the zero-value problem in the data, Ang and Choi (1997) and Ang et.al.(xxxx) show that the problem can be overcome by replacing zero values with a small positive number. Converging results are obtained as the positive number approaches zero.

Ang (2000) shows that the Laspeyres index method does not have the zero-value problem but it has the serious drawback of leaving a large residual after decomposition. In early studies, the practice was to lump it together with one of the estimated impacts, or to treat it separately as interaction among the main effects. However, very often the residual is so large that the decomposition analysis may become meaningless. For instance, in the case for Japan in Park et.al. (1987), the residual we found to be 1322% of the change in total energy consumption between 1980 and 1988. Sun (1998) recently proposed a method which is a refinement of the Laspeyres method. We shall refer to it as the refined Laspeyres index method. In this method the interactions (residual) are distributed equally among the main effects based on the "jointly created and equally distributed principle". We take the case of aggregate energy intensity to illustrate such an approach. Based on the notations defined earlier, the total change in aggregate energy intensity can be written as:

$$\Delta I_{tot} = \sum_i S_{it} I_{it} - \sum_i S_{i0} I_{i0} = \sum_i (S_{it} - S_{i0}) I_{t0} - \sum_i (I_{it} - I_{i0}) S_{t0} + \sum_i (S_{it} - S_{i0})(I_{it} - I_{i0})$$

where the first two terms on the right-hand side of the equation are respectively ΔI_{str} and ΔI_{int}. The third term, which is the interaction term, is the residual. When the variations in

variables S_i and I_i are large, the residual (interaction) is large. By splitting it equally between the two main effects, the formulae become:

$$\Delta I_{str} = \sum_i (S_{it} - S_{i0}) I_{i0} + \frac{1}{2} \sum_i (S_{it} - S_{i0})(I_{it} - I_{i0})$$

$$\Delta I_{int} = \sum_i (I_{it} - I_{i0}) S_{i0} + \frac{1}{2} \sum_i (S_{it} - S_{i0})(I_{it} - I_{i0})$$

We have tried all of the above decomposition approaches and methods to determine the sources of the changes of the energy intensity of the steel industry. The data are at firm level and obtained from the surveys and interviews of firms in 15 subsectors producing steel and steel products. Output of the surveyed firms represented about 75 % of the total production value of the industry. Our computation shows that the log mean Divisia index is the most appropriate method that should be used in all of the approaches in our study. The computed results are reported and analyzed below.

4.2 Analysis of Sources of Energy Intensity Changes from Computed Results

Tables 6 and 7 and Figures 2 and 3 show the sources of annual changes of the energy intensity of the steel industry of Thailand during 1999 to 2010 using 1999 as the base year. The computation by using the log-mean multiplicative method (shown in Table 6 and Figure 2) shows the results consistent with the ones using the log mean additive method (shown in Table 7 and Figure 3). During 2000 to 2002 after Thailand recovered from the 1997 financial and currency crises the energy intensity of the steel industry declined yearly when compared to the base year of 1999. However, during 2003 to 2007 when the domestic economy followed the global economy to accelerate the energy intensity increased. Eventually, when the global economy was suffering from a great slowdown from 2008 to 2010 and inevitably affected the domestic economy the energy intensity turned to a fluctuation, that is, declining in 2008, rising in 2008, and greatly reducing in 2010.

Table 5 and Figure 1 show that in each year from 2000 to 2002 the energy intensity declined from the base year of 1999. It was reduced from the base year by 8.16%, 12.10%, and 15.97% respectively. The reduction was due to both the structural change effect and the subsector energy intensity change effect. Tables 6 and 7 and Figures 2 and 3 show that among the three years both effects were quite balanced specifically in 2000 and 2001, but in 2002 the subsector energy intensity change effect was much stronger than the structural change effect. Actually from Table 8 and 9 it is found that in 2000 and 2001 the structural change effect accounted for slightly under 50% of the energy intensity reduction of the industry, comparable the subsector energy intensity change effect which accounted for just slightly over 50% of the reduction. However in 2002 the contribution to the energy intensity reduction by individual subsectors which put their efforts to improve the energy efficiency was increased to 88%, leaving the structural effect to decline to only 12%. It is important to note that during 2000 to 2002 there was little change in the production structure in the steel industry but firms of individual subsectors attempted to save energy costs because the energy prices started to soar. The pressures to reduce energy costs were so strong that the efforts on the part of the individual subsectors resulted in a rise in the efficiency of energy use in the whole industry. Hence, the reduction of energy intensity from the base year during this period was owed much to the efforts of energy saving of individual producers in each subsector rather than a change in the production structure.

Table 6: Decomposition of Energy Intensity Changes of the Steel Industry in Thailand Based on the Geometric Mean Multiplicative Method

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Dtot	0.92	0.88	0.84	1.03	1.09	1.10	1.08	1.10	0.99	1.01	0.87
Dstr	0.96	0.95	0.98	1.12	1.17	1.15	1.13	1.12	1.04	1.04	0.98
Dint	0.96	0.93	0.86	0.92	0.93	0.96	0.96	0.98	0.94	0.97	0.89

Figure 2: Decomposition of Energy Intensity Changes of the Steel Industry in Thailand Based on the Geometric Mean Multiplicative Method

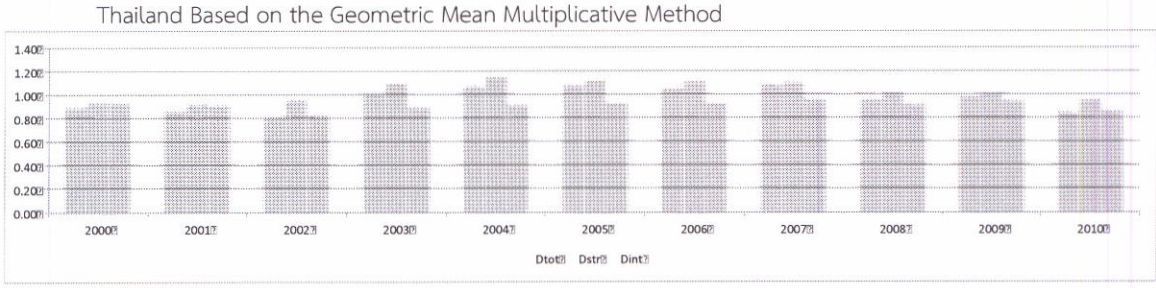


Table 7: Decomposition of Energy Intensity Changes of the Steel Industry in Thailand Based on the Geometric Mean Additive Method

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
I tot	-0.46	-0.69	-0.91	0.16	0.52	0.55	0.46	0.59	-0.09	0.08	-0.74
I str	-0.23	-0.31	-0.12	0.57	0.83	0.73	0.64	0.65	0.16	0.19	-0.22
I int	-0.23	-0.38	-0.79	-0.41	-0.32	-0.18	-0.18	-0.05	-0.25	-0.11	-0.51
I rsd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 3: Decomposition of Energy Intensity Changes of the Steel Industry in Thailand Based on the Geometric Mean Additive Method

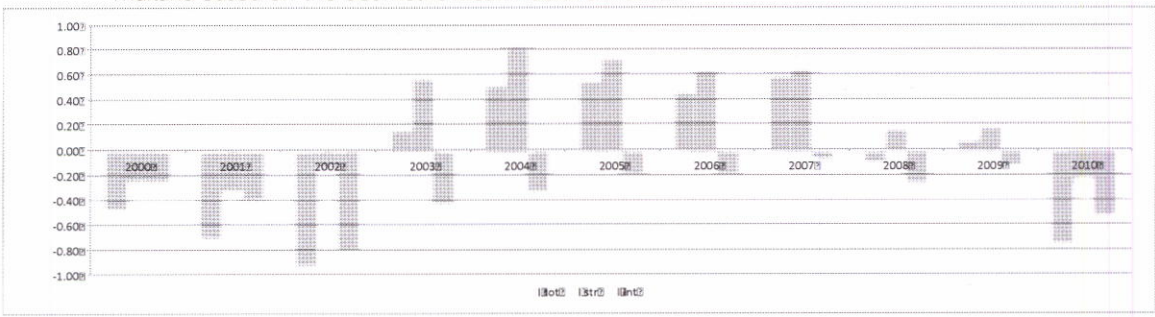


Table 8: Sources of Energy Intensity Changes of the Steel Industry in Thailand Based on the Log Mean Multiplicative Decomposition Method

	2000		2001		2002		2003	
	Proportion to Year 1999	Contribution (%)	Proportion to Year 1999	Contribution (%)	Proportion to Year 1999	Contribution (%)	Proportion to Year 1999	Contribution (%)
Dtot	0.9184	100.00	0.8790	100.00	0.8403	100.00	1.0286	100.00
Dstr	0.9594	48.78	0.9452	43.91	0.9811	11.67	1.1192	59.55
Dint	0.9573	51.22	0.9299	56.09	0.8565	88.33	0.9190	40.45

	2004		2005		2006		2007	
	Proportion to Year 1999	Contribution (%)	Proportion to Year 1999	Contribution (%)	Proportion to Year 1999	Contribution (%)	Proportion to Year 1999	Contribution (%)
Dtot	1.0912	100.00	1.0973	100.00	1.0812	100.00	1.1042	100.00
Dstr	1.1678	71.91	1.1481	77.00	1.1311	74.82	1.1227	88.17
Dint	0.9344	28.09	0.9557	23.00	0.9559	25.18	0.9835	11.83

	2008		2009		2010	
	Proportion to Year 1999	Contribution (%)	Proportion to Year 1999	Contribution (%)	Proportion to Year 1999	Contribution (%)
Dtot	0.9850	100.00	1.0132	100.00	0.8709	100.00
Dstr	1.0446	43.88	1.0397	60.88	0.9822	13.56
Dint	0.9430	56.12	0.9745	39.12	0.8866	86.44

Source: Authors' computation.

Table 9: Sources of Energy Intensity Changes of the Steel Industry in Thailand Based on the Log Mean Additive Decomposition Method

	2000		2001		2002		2003	
	Difference to Year 1999	Contribution (%)	Difference to Year 1999	Contribution (%)	Difference to Year 1999	Contribution (%)	Difference to Year 1999	Contribution (%)
I tot	-0.4644	100.00	-0.6892	100.00	-0.9092	100.00	0.1628	100.00
I str	-0.2310	49.74	-0.3094	44.89	-0.1183	13.02	0.5722	58.29
I int	-0.2334	50.26	-0.3798	55.11	-0.7909	86.98	-0.4094	41.71
I rsd	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00

	2004		2005		2006		2007	
	Difference to Year 1999	Contribution (%)	Difference to Year 1999	Contribution (%)	Difference to Year 1999	Contribution (%)	Difference to Year 1999	Contribution (%)
I tot	0.5195	100.00	0.5540	100.00	0.4623	100.00	0.5935	100.00
I str	0.8347	72.59	0.7349	80.25	0.6432	78.04	0.6484	92.20
I int	-0.3152	27.41	-0.1808	19.75	-0.1810	21.96	-0.0549	7.80
I rsd	0.0000	0.00	0.0000	0.00	0.0000	0.00	0.0000	0.00

	2008		2009		2010	
	Difference to Year 1999	Contribution (%)	Difference to Year 1999	Contribution (%)	Difference to Year 1999	Contribution (%)
I tot	-0.0853	100.00	0.0750	100.00	-0.7351	100.00
I str	0.1635	39.66	0.1853	62.69	-0.2205	29.99
I int	-0.2488	60.34	-0.1103	37.31	-0.5146	70.01
I rsd	0.0000	0.00	0.0000	0.00	0.0000	0.00

Source: Authors' computation.

From 2003 to 2007 energy intensity of each year increased from 1999 and Figures 2 and 3 and Tables 6 and 7 show that the contribution to the energy intensity change of the structural change effect went in the opposite direction of the subsector energy intensity change effect. The former structural change effect increased the energy intensity of the industry but the latter effect led to a decline. This means that the energy intensity of the steel industry increased during the period despite the efforts of individual subsectors to reduce their energy intensity. It so happened because there was a change in the production structure during the period which led to a rise in the energy intensity. Consequently, the structural change effect was so great that it significantly dominated the subsector energy intensity change effect.

On average in each year from 2003 to 2007 the energy intensity rose 8.05% relatively to the base year and about three-quarters of the energy intensity increase was accounted for by the structural change effect (see Tables 8 and 9). The structural change effect was very strong during 2003 to 2007 because starting 2003 there was an increase in the production of middle-steam products namely, hot-rolled coils with EAF and wires and rods with EAF to partly replace the imports of billet and slab which were used as inputs for the production of the downstream products. The production of these raw material inputs needed high energy intensity and therefore, raised the energy intensity of the whole industry. As a result the rise of the energy intensity in each year from 2003 to 2007 was accounted for much by the structural change effect despite the reduction of energy intensity of individual subsectors. Evidently from the Figures 2 and 3 the reduction of energy intensity of individual sectors was too small to offset the structural change effect, which finally led to the rise of the energy intensity.

During 2008 to 2010 there was a new development regarding the change of production structure in the steel industry. Starting from 2008 the production of middle-stream subsectors or industries started to decline as low-cost imports began to flow in to replace the domestic production. The decline in the production of these subsectors was the most in 2010. This new development can be viewed as a reversed structural change of production in the industry. Instead of climbing up from downstream to the middle-stream production; it was U-turn from middle-stream to downstream. An advocate of import-substitution industrialization might find the above new development a set-back of the steel industry, but ironically, the reverse structural change had its own merit. That is, it led to a decline in the energy intensity of the steel industry because these middle-stream steel products had high energy intensity. The greater increase of their production the higher energy intensity it generated and the greater amount of energy needed to be consumed and imported from abroad. In fact, from Tables 6 and 7 and Figures 2 and 3 we find that the energy intensity of 2008 declined from the base year because there was little structural change effect that resulted from the expansion of the highly energy intensive middle-stream production. Instead, the subsector energy intensity changes effect, albeit at a relatively small energy intensity reduction, dominated the structural change effect.

In 2009 the energy intensity of the steel industry showed a small increase. This is because the reduction of energy intensity of individual subsectors was too small to offset the structural change effect. Finally, in 2010 the energy intensity declined significantly from the base year because the reverse structural change which started in 2008, had finally developed to the full effect. In this year the decline in the energy intensity was due to both the structural change and the sector energy intensity change effects. There was a significant decline in the share of production of middle-stream products used as raw materials for the production of hot-rolled coils, hot-rolled section, and steel bars. The decline the domestic production of these products was a reaction to the increased imports from Russia, Ukraine, and China. These countries diversified their export and domestic markets in response to global economic slowdown to the various emerging economies including Thailand. Note that in this period there was also

an increase in the production share of hot-rolled coils using imported raw materials, and electric resistance pipes. All these subsectors had medium to very low energy intensity. When combined with the effect of reversed structural change discussed earlier, the energy intensity of the entire steel industry was further reduced.

In summary, the energy intensity of the steel industry looked like an inverted U-shaped curve during the domestic and global turbulent times from 2003 to 2010. It decreased during 1999 to 2002, immediately after the industry recovered from the 1997 financial crisis, in response to increased capacity utilization and the rising energy prices. However, for the rest of the decade after 2003 the energy intensity fluctuated. It increased throughout the period of 2003 to 2007, but declined during 2008 to 2010. Although steel producers of individual subsectors managed to reduce the energy intensity of their firms and contributed to the reduction of the energy intensity of the industry to a certain extent, the energy intensity of the industry was mostly dominated by the structural change effect. When there was a structural change from low-energy intensive to high-energy intensive subsectors during 2003 to 2007 the energy intensity of the whole industry increased despite a reduction of energy intensity of individual subsectors. Furthermore, during 2008 to 2010 the energy intensity rose and fell following the structural change effect. Although firms in individual subsectors showed their attempt to save energy, their efforts were not significant enough to produce a strong effect. Actually, there was never once when the subsector energy intensity change effect offset the structural change effect. This implies that individual subsectors have much room for strengthening their efforts to reduce their energy intensity to counter the structural change effect which often dominated the sources of energy intensity changes. There is a need for individual producers in the steel industry to put additional and persistent efforts to save energy. The government has a role to implement price and nonprice energy policies and measures to induce them to use energy in the most efficient way.

5. Conclusion and Policy Implications

The energy intensity of the steel industry in Thailand during the decade of domestic and global economic turbulent time in the 2000s fluctuated. The intensity declined immediately after recovering from the 1997 financial crisis but rose and fell after 2003 when the industry went through the various changes of the production structure. As a result the effect of structural change of the industry is found to be the dominant factor influencing the changes of energy intensity. During 2003 to 2007 there was a major change in the production structure from an increased production share of the middle-stream products to a decreased production share of the downstream products. Since the middle-stream products had higher energy intensity than the downstream products the energy intensity of the overall steel industry increased. From 2008 to 2010 the structural change was in reverse and the energy intensity of the industry declined. The fluctuating energy intensity was found despite there was a persistent decline, albeit relatively small, in the energy intensity of individual subsectors. There seems to be a dilemma of an effort to develop the steel industry in Thailand concerning the effort to reduce energy consumption and intensity.

The structural change that transforms the industry from the one producing only downstream final products to the one with increased production of higher-stream products should be viewed as an attempt to upgrade the industry to become more vertically integrated. As a result its industrial structure becomes more deepened and the products become more diversified. However, the downside of the above industrial development is that the growth of the upstream and middle-stream steel production will produce an increased energy intensity of the aggregate steel industry simply because these products are much more energy-intensive than the downstream production. In this light the structural change

effect during 2003 to 2007 had the drawback of increased energy consumption and intensity of the industry but the reversed effect during 2008 to 2010, albeit reducing the energy intensity, raised the question on the appropriate direction of the steel industry development in Thailand.

To look forward to the long term it should not be too optimistic to hope that domestic and global economic conditions will improve resulting in a higher growth of both the economy and the steel industry in particular. Consequently more capital and technological capability will be accumulated and the industry will definitely progress to produce more diversified products including the middle-stream ones. Production of the upstream products might also be feasible in the long term. Therefore, in the future the structural change effect will be likely to continue dominating the subsector energy intensity change effect, resulting in an increased energy intensity of the aggregate industry. Then the only mean to prepare for the increased energy intensity is to strengthen the effect of subsector energy intensity changes which comes from the efforts of individual subsectors to reduce their energy intensity. The effect should be strengthened so much that it is able to dominate the structural change effect and eventually lead to a decline of energy intensity of the whole industry. This can be done provided that the government implements an appropriate energy conservation policy and steel producers are given sufficient incentives to reduce their energy use. Producers of steel products of all grades and levels should be induced to seek new production process and technology to save energy costs. The appropriate government policies implied by our study are the following:

1. Promotion of economic growth together with stability: At the economy-wide level the government should create environment conducive for Thailand to have respectable growth together with economic stability. This favorable economic condition is necessary for the steel industry to grow to the full capacity level and in turn reduce the energy intensity. Our findings show that the demand for the iron and the steel products grew in line with the growth of the user industries such as construction, transport equipment, household electrical appliances, and canning and packaging industries. Thus, if the Thai economy grew favorably and all industries could grow reasonably well, the steel industry would also benefit from the growth. In particular, whenever the growth of the middle-stream production resumes in the future, these subsectors which are capital intensive and subject to economies of scale, would be able produce at full capacity and in turn reduce the energy intensity of the steel industry at both the subsector and the aggregate levels.

2. Implementation of appropriate energy pricing policy: The energy pricing policy is crucial for the behavior of energy consumption of steel producers. The government should, therefore, ensure the energy prices be consistent with the true energy costs. Our study finds that during the 2000s when energy prices increased persistently steel producers either small or large, most put their efforts to reduce the energy intensity in order to further reduce the overall production costs to survive in face of the turbulent time. This suggests that energy pricing policy is able to provide a mechanism for private producers to automatically adjust their energy consumption to enhance the energy efficiency. Actually, many studies have reached this similar conclusion and confirmed the effectiveness of an appropriate pricing policy. In the US the study of Rand (2003) finds that the increased energy prices during the periods of both from mid-1970s to mid-1980s and from mid-1990s to 2000, the energy intensity in the US experienced a rapid decline whereas the period of low energy prices during 1986 to 1994 the energy intensity did not decline as much. In fact, during 1973 to 1986 the energy intensity of the US declined at an annual rate of 2.3 percent. Later during 1994 to 2000 the energy intensity declined rapidly again at the rate of 2.1 percent a year. The study also reports that the energy intensity in the EU and Japan was lower than the US because their energy prices were normally set in such a way that they did not deviate much from the true energy costs.

3. Promotion of research and development on new energy-conservation technology: Our surveys and interviews results find that steel producers who had introduced new energy-conservation technology in their production process or were quick to implement interfuel substitution corresponding to varying price changes of different kinds of fuel were able to reduce the energy intensity much more than the rest of the producers. This implies that the government should promote and devise incentives policy for enhancing research and development on energy-conservation technology for firms to increase their energy efficiency. In fact, the OECD study (1994) finds the results consistent with our above findings. The study finds that the choice of production technology in the steel industry in the US, South Korea, and India had an impact on the measurement of energy intensity of these countries. During 1971 to 1994 the energy intensity of the steel industry in US, Japan, and South Korea declined rapidly because there was a change the production technology from open hearth furnace to EAF and continuous casting process. Meanwhile, the energy intensity of the industry in India was higher than the above three countries and did not change much because the industry did not attempt at finding a new energy-conservation technology, shown for instance by little use of continuous casting process. In this light it is recommended that government provide technical information in combination with fiscal and financial incentives for firms to put an effort to invest in new technology to save energy in the production process and help reduce the energy intensity of the industry.

4. Continuously monitoring and auditing the energy intensity of individual firms: Energy efficiency of the steel industry improves as the energy intensity declines, and this leads to energy conservation for future use. Therefore, it is crucial for the government to attach great weight to the policy of reducing energy intensity. For the policy to be effective in practice the government should set a target of energy intensity and continuously measure, monitor, and audit it to ensure all firms reduce the intensity to the level that meets the desirable target. As an incentive for firms that do exceptionally well on reducing the energy intensity the government should initiate certain packages of rewards for them to save energy on a sustainable basis.

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Appendix 1: Share of Production of the Steel and Steel Products Industry of Major Countries in the World

Market

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
World	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
The EU	18.62	17.55	16.60	15.77	14.43	13.89	13.05	12.63	9.57	10.41
North America	14.08	13.60	13.01	12.51	11.16	10.57	9.85	9.37	6.70	7.86
The US	10.59	10.13	9.66	9.30	8.30	7.90	7.29	6.87	4.72	5.68
CIS Republic	11.71	11.19	10.98	10.58	9.90	9.61	9.22	8.60	7.92	7.63
Russia	6.93	6.61	6.34	6.12	5.78	5.68	5.38	5.15	4.87	4.72
Ukarine	3.89	3.77	3.81	3.62	3.38	3.28	3.18	2.80	2.42	2.36
Latin America	4.39	4.52	4.44	4.28	3.96	3.63	3.58	3.56	3.07	3.10
Brazil	3.14	3.27	3.21	3.07	2.76	2.48	2.51	2.54	2.15	2.32
Asia	41.66	43.69	45.60	47.84	52.06	53.90	56.21	58.00	65.48	63.73
Japan	12.09	11.92	11.39	10.52	9.83	9.32	8.93	8.93	7.10	7.73
China	17.82	20.17	22.92	26.41	30.88	33.61	36.34	37.64	46.54	44.22
India	3.21	3.19	3.28	3.05	4.00	3.97	3.97	4.35	5.16	4.82
South Korea	5.15	5.02	4.77	4.44	4.18	3.89	3.83	4.03	3.94	4.12
Indonesia	0.33	0.27	0.21	0.34	0.32	0.30	0.31	0.29	0.28	0.26
Malaysia	0.48	0.52	0.41	0.53	0.46	0.47	0.51	0.48	0.43	0.40
Thailand	0.25	0.28	0.37	0.42	0.45	0.39	0.41	0.39	0.30	0.29
Others	9.53	9.45	9.38	9.02	8.50	8.40	8.10	7.84	7.27	7.28

Appendix 2: Share of Consumption of the Steel and Steel Products Industry of Major Countries in the World Market

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
World	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
The EU	18.38	16.84	16.53	15.19	13.50	13.82	13.66	12.78	8.72	9.52
North America	17.82	17.24	14.82	15.64	13.59	14.28	12.10	11.18	7.61	9.30
The US	13.40	13.02	10.92	11.71	10.02	10.37	8.61	7.83	5.13	6.53
CIS Republic	4.99	4.39	4.38	4.29	4.33	4.63	4.93	4.38	3.35	4.02
Russia	3.73	3.22	3.00	2.99	3.10	3.35	3.54	3.13	2.34	3.00
Ukarine	0.76	0.68	0.73	0.62	0.56	0.62	0.71	0.59	0.36	0.45
Latin America	3.55	3.29	2.88	3.24	2.95	3.21	3.32	3.59	2.93	3.50
Brazil	2.17	2.17	1.83	1.92	1.65	1.66	1.85	2.04	1.70	2.13
Asia	44.46	47.32	50.19	50.50	54.55	52.82	54.37	56.19	66.44	63.22
Japan	8.81	8.10	7.89	7.61	7.33	6.72	6.48	6.36	4.66	4.93
China	19.99	22.65	26.69	27.16	31.99	31.74	33.22	34.60	46.95	43.29
India	3.66	3.75	3.53	3.71	3.81	3.96	4.19	4.29	5.06	4.76
South Korea	4.65	5.00	4.90	4.64	4.33	4.21	4.33	4.67	3.89	3.94
Indonesia	0.66	0.60	0.52	0.60	0.80	0.60	0.66	0.81	0.73	0.79
Malaysia	0.97	0.87	0.69	0.76	0.67	0.64	0.68	0.75	0.64	0.69
Thailand	0.98	1.23	1.23	1.34	1.51	1.24	1.07	1.24	1.01	1.18
Others	10.80	10.92	11.21	11.14	11.08	11.23	11.62	11.88	10.96	10.45

Appendix 3: Share of Imports of the Steel and Steel Products Industry of Major Countries in the World Market

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
World	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
The EU	35.29	32.57	31.71	31.75	30.07	32.45	33.64	30.85	25.75	27.15
North America	14.26	14.77	11.01	13.94	13.51	15.82	10.72	9.99	8.90	10.65
The US	9.55	9.68	6.51	9.03	8.30	10.31	6.51	5.81	4.77	5.96
CIS Republic	1.85	1.49	2.34	2.47	2.78	3.18	3.95	3.65	3.54	3.41
Russia	1.05	0.68	1.00	1.14	1.25	1.42	1.71	1.35	1.12	1.38
Ukarine	0.19	0.22	0.25	0.23	0.29	0.37	0.51	0.57	0.31	0.47
Latin America	2.00	1.44	1.62	1.29	1.63	2.09	2.14	2.61	2.46	3.92
Brazil	0.37	0.21	0.17	0.15	0.21	0.47	0.39	0.60	0.73	1.56
Asia	29.13	31.95	34.50	32.01	30.79	25.18	26.45	26.81	32.00	30.25
Japan	1.40	1.03	0.98	1.16	1.43	1.09	1.12	1.06	0.94	1.18
China	8.74	9.36	12.99	9.16	7.51	4.67	4.04	3.69	6.94	4.55
India	0.61	0.57	0.61	0.76	1.46	1.38	1.81	1.64	2.58	2.42
South Korea	3.70	4.54	4.71	4.89	5.18	5.48	6.16	6.74	6.32	6.56
Indonesia	0.99	1.08	0.96	1.24	1.49	1.15	1.34	1.90	1.77	1.87
Malaysia	1.56	1.39	1.37	2.08	1.22	1.13	1.25	1.21	1.21	1.33
Thailand	2.46	3.12	2.95	3.07	3.45	2.63	2.30	2.79	2.81	3.25
Others	17.47	17.77	18.83	18.55	21.24	21.27	23.11	26.10	27.36	24.61

Appendix 4: Share of Exports of the Steel and Steel Products Industry of Major Countries in the World Market

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
World	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
The EU	35.52	34.20	33.40	33.79	32.34	31.77	31.05	31.04	29.23	29.47
North America	5.11	5.31	5.75	5.46	5.96	5.24	5.13	5.89	5.61	6.25
The US	1.94	1.78	2.32	2.13	2.53	2.29	2.21	2.74	2.83	3.05
CIS Republic	18.27	18.21	18.01	17.58	17.06	16.11	14.97	14.55	17.53	14.90
Russia	8.52	8.67	8.48	8.32	8.31	7.52	6.63	6.52	8.46	7.08
Ukarine	8.12	8.11	7.98	7.71	7.37	7.32	6.83	6.57	7.35	6.51
Latin America	4.50	5.32	5.14	4.36	4.68	3.84	3.10	2.69	3.38	2.76
Brazil	3.08	3.65	3.89	3.28	3.38	3.02	2.35	2.10	2.64	2.32
Asia	23.45	24.26	24.29	25.81	27.12	31.92	33.91	32.59	30.84	34.18
Japan	9.82	11.02	10.13	9.50	8.63	8.26	8.03	8.46	10.21	11.05
China	2.42	2.08	2.48	5.48	7.38	12.36	14.95	12.91	7.35	10.77
India	1.06	1.14	1.52	1.50	1.62	1.64	1.48	1.72	1.70	1.51
South Korea	4.69	4.06	4.23	4.10	4.34	4.31	4.11	4.52	6.20	6.37
Indonesia	0.28	0.31	0.29	0.33	0.31	0.41	0.34	0.35	0.34	0.15
Malaysia	0.58	0.64	0.80	1.05	0.80	0.89	0.87	0.63	0.89	0.25
Thailand	0.54	0.50	0.57	0.60	0.58	0.54	0.63	0.57	0.49	0.46
Others	13.16	12.70	13.41	13.00	12.85	11.12	11.84	13.25	13.41	12.44

Appendix 5: Production Value of the Steel Industry in Thailand by Subsector, 1999-2010

Unit: Billion of Baht

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Steel Bar, with EAF	3.11	3.42	3.38	4.13	3.89	4.44	6.06	5.71	6.60	4.57	3.74	5.30
Steel Bar, without EAF	1.98	1.49	2.30	3.62	3.08	4.55	4.29	3.51	2.21	3.39	2.86	2.52
Wired Rod, with EAF					1.67	1.72	3.29	3.40	3.84	2.65	3.85	5.35
Wired Rod, without EAF	1.81	1.86	1.85	2.89	2.99	3.46	0.85	0.78	0.88	1.23	0.75	1.09
Hot-rolled Section, with EAF	3.14	4.19	4.19	5.23	6.28	6.28	1.55	1.42	1.60	1.60	1.42	1.48
Hot-rolled Section, without EAF			0.62	0.90	0.98	1.27	0.31	0.29	0.32	0.45	0.28	0.40
Hot-rolled Coil, with EAF					8.80	15.06	18.50	17.94	20.47	17.31	10.92	10.94
Hot-rolled Coil, without EAF	13.77	11.06	19.01	18.94	18.42	20.02	15.74	16.80	16.84	15.06	20.88	25.07
Cold-rolled Coil	3.15	6.67	7.64	9.82	11.76	11.39	20.45	19.53	22.22	18.97	13.59	18.64
Hot-Dip Galvanized Iron	0.00	5.39	5.93	6.19	6.16	4.88	5.83	5.27	5.38	5.09	2.80	10.29
Electro Galvanized Plates	2.40	2.38	2.32	2.87	3.03	3.10	2.23	2.35	2.27	2.13	1.09	2.02
Tin Plates, Tin Free	6.87	5.45	5.60	6.23	7.28	8.26	4.43	5.62	4.57	4.41	4.18	4.22
Cold-rolled Section	0.30	0.27	0.37	0.58	0.52	0.44	1.65	1.64	2.24	2.50	2.53	3.59
Electric Resistance Welding Pipes	2.34	3.02	3.24	3.51	3.58	3.77	1.82	2.37	2.68	6.90	9.62	10.15
Galvanized Steel Pipes	1.23	1.22	1.29	0.92	0.91	0.97	0.86	0.75	0.74	1.08	0.43	0.70
Total	40.10	46.41	57.75	65.82	79.34	89.62	87.86	87.38	92.87	87.36	78.94	101.77

Appendix 6: Production Share of the Steel Industry in Thailand by Subsector, 1999-2010

UniContribution (%)

t : %

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Steel Bar, with EAF	7.75	7.36	5.86	6.28	4.91	4.96	6.90	6.54	7.11	5.24	4.73	5.21
Steel Bar, without EAF	4.95	3.21	3.98	5.50	3.88	5.07	4.88	4.02	2.38	3.88	3.62	2.47
Wired Rod, with EAF					2.10	1.92	3.74	3.89	4.13	3.04	4.87	5.26
Wired Rod, without EAF	4.50	4.00	3.20	4.38	3.77	3.86	0.97	0.89	0.95	1.41	0.95	1.07
Hot-rolled Section, with EAF	7.83	9.02	7.25	7.95	7.91	7.01	1.76	1.62	1.73	1.83	1.80	1.45
Hot-rolled Section, without EAF			1.08	1.36	1.24	1.42	0.36	0.33	0.35	0.52	0.35	0.39
Hot-rolled Coil, with EAF					11.09	16.80	21.05	20.53	22.04	19.81	13.83	10.75
Hot-rolled Coil, without EAF	34.35	23.84	32.92	28.77	23.22	22.34	17.91	19.23	18.14	17.24	26.45	24.63
Cold-rolled Coil	7.86	14.36	13.22	14.91	14.82	12.71	23.27	22.35	23.93	21.72	17.22	18.32
Hot-Dip Galvanized Iron		11.62	10.28	9.40	7.76	5.45	6.64	6.03	5.79	5.83	3.55	10.11
Electro Galvanized Plates	5.97	5.12	4.02	4.35	3.82	3.46	2.54	2.69	2.45	2.44	1.38	1.99
Tin Plates, Tin Free	17.15	11.75	9.70	9.46	9.18	9.22	5.04	6.43	4.92	5.05	5.30	4.15
Cold-rolled Section	0.74	0.59	0.64	0.89	0.66	0.49	1.88	1.88	2.41	2.86	3.21	3.53
Electric Resistance Welding Pipes	5.83	6.50	5.62	5.34	4.51	4.21	2.08	2.71	2.88	7.90	12.19	9.97
Galvanized Steel Pipes	3.08	2.62	2.23	1.40	1.14	1.08	0.98	0.86	0.80	1.24	0.55	0.69
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Appendix 7: Energy Consumption of the Steel Industry in Thailand by Subsector, 1999-2010

Unit : ktoe

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Steel Bar, with EAF	45.65	47.42	49.92	50.32	55.12	51.94	78.96	72.66	89.00	58.00	48.69	56.99
Steel Bar, without EAF	11.62	8.95	12.78	17.30	15.03	22.24	19.87	17.86	11.29	15.61	13.57	11.01
Wired Rod, with EAF					19.21	18.22	42.45	40.03	47.58	31.47	48.51	63.51
Wired Rod, without EAF	19.92	15.03	15.29	23.13	23.54	28.46	6.22	5.58	6.83	7.46	5.52	7.72
Hot-rolled Section, with EAF	46.46	66.62	61.39	66.32	79.27	84.05	18.36	16.49	20.18	20.18	18.05	18.32
Hot-rolled Section, without EAF			4.53	5.83	6.13	8.11	1.77	1.59	1.95	2.13	1.57	2.20
Hot-rolled Coil, with EAF					112.33	176.52	202.99	201.19	217.29	186.57	142.75	134.68
Hot-rolled Coil, without EAF	74.97	59.23	95.96	95.32	94.10	108.12	86.72	92.67	95.45	84.24	114.25	127.28
Cold-rolled Coil	15.47	23.69	26.12	32.57	34.02	32.83	67.64	63.70	70.41	62.64	48.65	63.32
Hot-Dip Galvanized Iron		8.25	9.12	9.31	9.82	7.70	11.64	12.42	11.58	9.53	4.22	7.83
Electro Galvanized Plates	2.70	2.17	2.37	3.41	3.63	3.49	4.11	4.32	4.13	3.72	1.86	2.81
Tin Plates, Tin Free	7.20	6.47	6.17	7.07	7.66	9.21	5.23	6.23	4.84	4.61	3.78	3.73
Cold-rolled Section	0.00	0.00	0.00	0.01	0.01	0.01	0.35	0.39	0.39	0.38	0.54	0.77
Electric Resistance Welding Pipes	0.56	0.70	0.79	0.89	0.97	1.07	0.50	0.77	0.94	1.05	1.83	2.30
Galvanized Steel Pipes	3.73	4.13	4.55	3.44	3.83	4.83	2.13	1.98	2.02	2.38	1.56	2.11
Total	228.28	242.68	288.98	314.90	464.65	556.80	548.91	537.89	583.87	489.94	455.36	504.60

Appendix 8: Share of Energy Consumption of the Steel Industry in Thailand by Subsector, 1999-2010

Unit : %

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Steel Bar, with EAF	20.00	19.54	17.27	15.98	11.86	9.33	14.38	13.51	15.24	11.84	10.69	11.29
Steel Bar, without EAF	5.09	3.69	4.42	5.49	3.23	3.99	3.62	3.32	1.93	3.19	2.98	2.18
Wired Rod, with EAF	0.00	0.00	0.00	0.00	4.13	3.27	7.73	7.44	8.15	6.42	10.65	12.59
Wired Rod, without EAF	8.73	6.19	5.29	7.35	5.07	5.11	1.13	1.04	1.17	1.52	1.21	1.53
Hot-rolled Section, with EAF	20.35	27.45	21.24	21.06	17.06	15.10	3.34	3.06	3.46	4.12	3.96	3.63
Hot-rolled Section, without EAF	0.00	0.00	1.57	1.85	1.32	1.46	0.32	0.30	0.33	0.43	0.35	0.44
Hot-rolled Coil, with EAF	0.00	0.00	0.00	0.00	24.17	31.70	36.98	37.40	37.22	38.08	31.35	26.69
Hot-rolled Coil, without EAF	32.84	24.41	33.21	30.27	20.25	19.42	15.80	17.23	16.35	17.19	25.09	25.22
Cold-rolled Coil	6.78	9.76	9.04	10.34	7.32	5.90	12.32	11.84	12.06	12.78	10.68	12.55
Hot-Dip Galvanized Iron	0.00	3.40	3.15	2.96	2.11	1.38	2.12	2.31	1.98	1.95	0.93	1.55
Electro Galvanized Plates	1.18	0.89	0.82	1.08	0.78	0.63	0.75	0.80	0.71	0.76	0.41	0.56
Tin Plates, Tin Free	3.15	2.66	2.14	2.24	1.65	1.65	0.95	1.16	0.83	0.94	0.83	0.74
Cold-rolled Section	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.07	0.07	0.08	0.12	0.15
Electric Resistance Welding Pipes	0.24	0.29	0.27	0.28	0.21	0.19	0.09	0.14	0.16	0.21	0.40	0.46
Galvanized Steel Pipes	1.63	1.70	1.57	1.09	0.82	0.87	0.39	0.37	0.35	0.49	0.34	0.42
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00