What Shaped the Chinese Manufacturing Energy Use Since 1995 and What's the Prediction for the Future?

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ABSTRACT

Unlike most countries, China's energy consumption pattern is unique because the industrial sector dominates the country's total energy consumption, accounting for about 70 percent of energy use in 2010. For this reason, the development path of China's industrial sector will greatly affect future energy demand and dynamics of not only China, but the entire world. This study analyzes energy use and the economic structure of the Chinese manufacturing sector. The retrospective (1995-2010) and prospective (2010-2020) decomposition analyses are conducted for manufacturing sectors in order to show how different factors (production growth, structural change, and energy intensity change) influenced industrial energy use trends in China over the last 15 years and how they will do so up to 2020. The forward looking (prospective) decomposition analyses are conducted for three different scenarios. The scenario analysis indicates that if China wants to realize structural change in the manufacturing sector by shifting from energy-intensive and polluting industries to less energy-intensive industries, the value added average annual growth rate (AAGRs) to 2015 and 2020 should be more in line with those shown in scenario 3. In other words, the value added AAGRs of energy intensive sectors such as smelting and pressing of ferrous metals and non-metallic mineral, and chemical industry should drop to 4%, 3%, and 8.5% respectively over this period. The assumed value added AAGRs for scenario 3 are relatively realistic and are informed by possible growth that is foreseen for each subsector.

Introduction

Unlike most countries, China's energy consumption pattern is unique because the industrial sector dominates the country's total energy consumption, accounting for about 70 percent of energy use and 72 percent of CO_2 emissions in 2010 (NBS, 2011a). For this reason, the development path of China's industrial sector will greatly affect future energy demand and dynamics of not only China, but the entire world.

A number of analyses of historical industrial energy use trends in China have been conducted (Wu 2012; Price et al. 2011; Ma and Stern 2008; Liu et al. 2007; Lin et al. 2006), but comprehensive analyses including all manufacturing subsectors and their role in historical energy use trends are scarce. More importantly, in the context of this study, careful projections of key factors affecting China's manufacturing sector energy use over the next decade are also rare. This study conducts such analyses.

Methodology

Table 1 lists the manufacturing subsectors included in this study. We collected energy use and value added data as well as other information on 18 subsectors of the manufacturing sector in China from 1995 to 2010.[1]

[1] In Chinese statistics, the term "industry" refers to manufacturing as well as mining of coal and minerals, oil and

Forecasting Chinese Manufacturing Energy Use and Value Added

Historical primary energy use (1995 – 2010) and value added (1995 – 2007) data for industrial subsectors used this analysis were obtained from various years of the China Energy Statistical Yearbook (NBS, 1996-2011) and the Annual China Industry Economy Statistical Yearbook (NBS, 1981-2011), respectively. For primary energy use reported by NBS (1996-2011), electricity use is converted from final to primary energy using the average power generation efficiency in China in various years. The losses in refining of petroleum products and for production of coke are not included in the primary energy values reported by NBS (1996-2011) .

Value added data for manufacturing subsectors have not been reported since 2007. Thus, value added for 2008-2010 for manufacturing subsectors was calculated using the officially released annual average growth rate of value added for manufacturing subsectors for these three years (NBS 2009, 2010, 2011b). The sum of value added of all manufacturing subsectors calculated in this way for these three years is equal to the aggregate data reported in NBS (1981-2011). All value added data are converted from current Chinese renminbi (RMB) to constant 2005 RMB and then used in the analyses.

1. We forecast primary energy use and value added of manufacturing subsectors in 2015 and 2020 in this analysis. To forecast primary energy use, we need to have the forecast of value added as well as energy intensity. From these two, we can calculate the forecast of primary energy use from equation 1.

$$\mathbf{E_i = EI_i * VA_i} \qquad \mathbf{(1)}$$

Where:
E_i : primary energy use of manufacturing subsector (i) [in PJ]
EI_i : primary energy intensity of manufacturing subsector (i) [in PJ/Million 2005 RMB]
VA_i : value added of manufacturing subsector (i) [Million 2005 RMB]

Below we explain how the value added and energy intensity of each manufacturing subsector in 2015 and 2020 are forecast.

2. The year 2010 is used as the base year for the forecast. We have primary energy use and value added data for each manufacturing subsector in 2010.
3. The forecast of primary energy use and value added is calculated for each manufacturing subsector separately. This is one of the unique features of this study since other similar studies typically constructed a forecast for the entire manufacturing sector in China and not by manufacturing subsector.
4. Because the forecast for the average annual growth rate (AAGR) given for each manufacturing subsector value added varied in different sources and since the forecast of value added significantly affects the results of the study, we developed three scenarios with different assumptions on the AAGR of value added for each manufacturing subsector. The three scenarios are:

    a. **Scenario 1** (MIIT/IERD/ERI/INNET): In this scenario the value added AAGR assumptions were mostly based on *Key Development Targets for 22 Industries During the 12th FYP* published by the Chinese Ministry of Industry and

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gas extraction, power generation, and production and distribution of water. These subsectors of industry (other than manufacturing) are not included in the present study.

Information Technology (MIIT 2012; MIIT 2011) and the report by the Industrial Economics Research Department, Development Research Center of the State Council, (IERD), Energy Research Institute of the National Development and Reform Commission (ERI), Institute of Nuclear and New Energy Technology, Tsinghua University (INNET) titled *2050 China Energy and CO_2 Emissions Report* (IERD/ ERI/ INNET 2009).

b. **Scenario 2** (Oxford Economics): In this scenario the assumptions on value added AAGR were mostly based on the Oxford Economics' *China Industry Forecast* (Oxford Economics 2012).

c. **Scenario 3** (Expert Judgment): In this scenario the assumptions on value added AAGR were mostly based on authors and expert judgment. The expert judgment was informed by national level GDP forecast data and the predicted share of total GDP of the industry sector in the national GDP in 2015 and 2020 as well as by the data used in scenario 1 and scenario 2. In particular scenario 3 tends to take into account the Chinese Government policy to shift the structure of industry away from heavy and energy-intensive industries toward lighter and less energy-intensive industries with higher value added as well as the policy to "rebalance" the economy, which focuses on greater reliance on domestic demand, as opposed to new fixed-asset investment and exports, to drive economic growth.

Table 1 shows the value added AAGR assumptions used in our analysis under each of the aforementioned scenarios. Under each scenario, there are two sets of AAGR assumptions, one for the period of 2011-2015 (12^{th} FYP) and the other for the period of 2016-2020 (13^{th} FYP). Table 1 also presents the energy intensity cumulative 5-year reduction rate for each subsector. Unlike the value added assumptions, only one set of assumptions is used for the energy intensity AAGR forecast.

5. Having the value added AAGR during 2011-2015 (12^{th} FYP) compared to 2010 value added (Table 1) and the actual 2010 value added data for manufacturing subsectors, we calculated the value added of each manufacturing in 2015 using equation 2.

$$\mathbf{VA_{i\,(2015)} = VA_{i\,(2010)} * (1+AAGR_{2011\text{-}2015})^5} \qquad \textbf{(2)}$$

Where:
$VA_{i\,(2015)}$: value added of manufacturing subsector (i) in 2015
$VA_{i\,(2010)}$: value added of manufacturing subsector (i) in 2010
$AAGR_{2011\text{-}2015}$: average annual growth rate of manufacturing subsector (i) during 2011-2015

6. Having calculated the value added of manufacturing subsectors in 2015 from equation 1 and the assumed value added AAGR during 2016-2020 (13^{th} FYP) compared to 2015 value added (Table 1), we calculated the value added of each manufacturing in 2020 using equation 3.

$$\mathbf{VA_{i\,(2020)} = VA_{i\,(2015)} * (1+AAGR_{2016\text{-}2020})^5} \qquad \textbf{(3)}$$

Where:
$VA_{i\,(2020)}$: value added of manufacturing subsector (i) in 2020
$VA_{i\,(2015)}$: value added of manufacturing subsector (i) in 2015
$AAGR_{2016\text{-}2020}$: average annual growth rate of manufacturing subsector (i) during 2016-2020

The value added for each manufacturing subsector was calculated under each scenario separately using different AAGR assumptions given in Table 1 for each scenario. It should be noted that all value added data and their shares presented in this paper are in constant 2005 prices; thus, the shares of value added given for manufacturing or each subsector might be slightly different from the shares calculated using value added data in current prices.

Table 1. Value added AAGR assumptions used under each scenario and primary energy intensity AAGR forecasts

No.	Manufacturing subsector	Value added AAGR *						Primary energy intensity cumulative reduction rate over 5-year **	
		Scenario 1		Scenario 2		Scenario 3			
		AAGR in 2011-2015	AAGR in 2016-2020	AAGR in 2011-2015	AAGR in 2016-2020	AAGR in 2011-2015	AAGR in 2016-2020	Cumulative reduction rate over 2011-2015	Cumulative reduction rate over 2016-2020
1	Food, beverage and tobacco	9.0%	7.0%	7.9%	6.1%	8.0%	7.0%	16.0%	14.0%
2	Textile, Apparel, Chemical Fibers, Leather, Fur	7.0%	5.5%	5.3%	4.8%	6.0%	5.0%	18.0%	15.0%
3	Timber, Wood, Bamboo, etc.	9.0%	7.0%	11.5%	6.2%	9.0%	7.0%	16.0%	14.0%
4	Furniture	9.0%	6.6%	9.4%	7.0%	9.0%	7.0%	16.0%	13.0%
5	Paper and Paper Products	8.0%	6.7%	8.3%	6.9%	7.5%	7.0%	20.0%	16.0%
6	Printing and Publishing	8.0%	8.0%	6.6%	8.4%	7.0%	8.0%	16.0%	14.0%
7	Petroleum refining and Coking	7.5%	6.0%	7.5%	5.7%	7.0%	6.0%	20.0%	16.0%
8	Raw Chemical Materials and Chemical Products	12.0%	9.0%	10.5%	9.7%	9.5%	8.5%	20.0%	16.0%
9	Medicines	15.0%	10.0%	13.8%	8.9%	12.0%	10.0%	21.0%	17.0%
10	Rubber and Plastics	7.0%	7.0%	6.5%	6.5%	6.5%	6.5%	16.0%	14.0%
11	Non-metallic Mineral Products	8.0%	6.0%	6.4%	6.8%	3.5%	3.0%	15.0%	13.0%
12	Smelting and Pressing of Ferrous Metals	7.0%	5.7%	6.6%	5.4%	4.5%	4.0%	18.0%	15.0%
13	Smelting and Pressing of Non-ferrous Metals	7.0%	6.0%	6.8%	6.2%	6.2%	5.5%	16.0%	14.0%
14	Metal Products	10.0%	7.4%	12.3%	8.7%	10.0%	7.8%	16.0%	14.0%
15	Machinery	10.0%	7.0%	12.1%	8.2%	10.0%	8.0%	16.0%	14.0%
16	Transport Equipment	9.5%	7.0%	9.2%	7.3%	9.0%	7.5%	16.0%	14.0%
17	Electric and Electronic Equipment	11.0%	9.0%	10.5%	8.5%	10.0%	8.5%	16.0%	14.0%
18	Other industries	8.0%	7.0%	8.1%	7.0%	8.0%	7.0%	16.0%	14.0%

* Value added AAGR for 2011-2015 are compared to 2010 value added and for 2016-2020 are compared to 2015 value added (see equation 2 and 3 below).
* Energy intensity cumulative reduction rate over 2011-2015 are compared to 2010 energy intensity and over 2016-2020 are compared to 2015 energy intensity (see equation 4 and 5 below).
*** 2011-2015 period is equal to 12th FYP and 2016-2020 period is 13th FYP in Chinese Government national policy planning.

7. The assumptions on primary energy intensity reduction of manufacturing subsectors were mostly based on the forecast given in *Key Development Targets for 22 Industries during 12th FYP* published by the Chinese Ministry of Industry and Information Technology (MIIT 2012; MIIT 2011). Some subsectors (e.g. smelting and pressing of non-ferrous metals, manufacturing of metal products, manufacturing of machinery, and manufacturing of transport equipment) were not included in this paper (MIIT 2012; MIIT 2011). For these subsectors China's overall national cumulative energy intensity reduction target during 12th FYP set by the Chinese government, which is 16

percent compared to the 2010 level, is used.[2] However, all reduction forecasts are for cumulative percentage reduction in energy intensity for each manufacturing sub-sector during 2011-2015 (12^{th} FYP). To forecast the energy intensity of manufacturing sub-sectors in 2020, expert judgment is used for the assumption on cumulative reduction of energy intensity during 2016-2020. The primary energy intensities in 2015 and 2020 are calculated using equations 4 and 5, respectively.

$$\mathbf{EI_{i\,(2015)} = EI_{i\,(2010)} * (1 - CR_{2011\text{-}2015})} \quad (4)$$
$$\mathbf{EI_{i\,(2020)} = EI_{i\,(2015)} * (1 - CR_{2016\text{-}2020})} \quad (5)$$

Where:
$EI_{i\,(2010)}$: primary energy intensity of manufacturing subsector (i) in 2010
$EI_{i\,(2015)}$: primary energy intensity of manufacturing subsector (i) in 2015
$EI_{i\,(2020)}$: primary energy intensity of manufacturing subsector (i) in 2020
$CR_{2011\text{-}2015}$: cumulative reduction energy intensity of manufacturing (i) during 2011-2015 in percentage (the sign is positive)
$CR_{2016\text{-}2020}$: cumulative reduction energy intensity of manufacturing (i) during 2016-2020 in percentage (the sign is positive)

8. Having the forecast of value added and primary energy intensity calculated for each manufacturing subsector, we can calculate the primary energy use of each subsector in 2015 and 2020 using equation 1. Since we calculated value added for three different scenarios, we will also have three scenarios for the primary energy use forecast.

Decomposition Analysis Method

A decomposition analysis separates the effects of key components on energy end-use trends over time. Three main components that are usually considered in a decomposition analysis are: 1) aggregate activity, 2) sectoral structure, and 3) energy intensity. The IEA defines these three components as (Unander et al., 2004):

1. *Aggregate activity*: Depending on the economic sector, this component is measured in different ways. For manufacturing, it is often measured as value added of the sector.
2. *Sectoral structure*: This component represents the mix of activities within a sector and further divides activity into subsectors.
3. *Energy intensity*: This component refers to energy use per unit of activity (i.e. value added).

Ang et al. (2010) propose the use of the Logarithmic Mean Divisia Index (LMDI) method, which is recognized as superior in comparative studies such as Liu and Ang (2003). For this study, the authors used additive LMDI decomposition analysis with non-changing analysis. Non-changing decomposition is used because for future projections, the changing analysis (which requires annual data) is less relevant and non-changing analysis with a 5-year period is more appropriate since the AAGR forecast of value added for manufacturing sub-sectors is given for 5-year terms. The energy intensity reduction forecasts are also cumulative over the 5-year periods. Ang (2005) provides practical guidelines for using the LMDI method.

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[2] The 16 percent reduction in energy intensity for these subsectors during 12^{th} FYP is rather a conservative assumption. However, if the energy intensity reduction in this period is assumed to be 20 percent instead for these subsectors, the impact on the overall manufacturing primary energy use is minimal (around 1 percent decrease compared to 16 percent assumption) because these subsectors cumulatively only represent less than 20 percent of the total manufacturing primary energy use.

The formulas used in the additive LMDI method for decomposing energy use into activity, structural, and energy intensity effects are shown below (Ang, 2005):

$$\Delta E_{tot} = E^T - E^0 = \Delta E_{act} + \Delta E_{Str} + \Delta E_{int} \quad (6)$$

$$\Delta E_{act} = \sum_i \frac{E^T{}_i - E^0{}_i}{\ln E^T{}_i - \ln E^0_i} \ln\left(\frac{Q^T}{Q^0}\right) \quad (7)$$

$$\Delta E_{Str} = \sum_i \frac{E^T{}_i - E^0{}_i}{\ln E^T_i - \ln E^0_i} \ln\left(\frac{S^T{}_i}{S^0{}_i}\right) \quad (8)$$

$$\Delta E_{int} = \sum_i \frac{E^T{}_i - E^0{}_i}{\ln E^T{}_i - \ln E^0{}_i} \ln\left(\frac{I^T{}_i}{I^0{}_i}\right) \quad (9)$$

Where: i: subsector, T: last year of the period, T=0: base year of the period, E: total energy consumption, ΔE_{tot}: aggregate change in total energy consumption

The subscripts "act," "str," and "int" denote the effects associated with the overall activity level, structure, and sectoral energy intensity, respectively.

$$Q = \sum_i Q_i \text{ : total activity level} \quad (10)$$

$$S_i = \sum_i Q_i / Q \text{ : activity share of sector I} \quad (11)$$

$$I_i = \sum_i E_i / Q_i \text{ : energy intensity of sector I} \quad (12)$$

In this study we conduct a retrospective decomposition analysis of China's manufacturing sector using historical data from 1995 to 2010. In addition, we conduct a prospective decomposition analysis using forecast data calculated based on the method explained above. We conducted the decomposition analysis for each of the three scenarios explained in section 2.1., separately. This shows how different assumptions regarding the value added AAGR of manufacturing subsectors will affect the decomposition results.

Results and Discussion

Chinese Manufacturing Energy Use and Value Added

Industry value-added trends. The total Chinese manufacturing value added (in 2005 RMB) increased by 383 percent over the period 1995-2010. This rate of increase is 2.8 times higher than the rate of increase in primary energy use, which increased by 137 percent over the same period. Smelting and pressing of non-ferrous metals had the largest increase in value added during 1995-2010 with an 808 percent increase, while petroleum refining, coking, processing of nuclear fuel had the lowest increase in value added among all other subsectors with only 183 percent during the same period. Overall, the value added of all subsectors increased during this period.

The electric and electronic equipment manufacturing, food and beverage production, and the textile industry had the highest value added during the period 1995-2010. Figure 2 shows that these sectors thus have the largest contribution to the total manufacturing value added in that period. Manufacturing of furniture, printing and publishing, and processing of timber, manufacturing of wood, bamboo, etc. subsectors have the lowest share of total manufacturing value added.

Figure 2. Share of each manufacturing subsector value added of the total value added of manufacturing in China, 1995-2010 (NBS, 1981-2011)

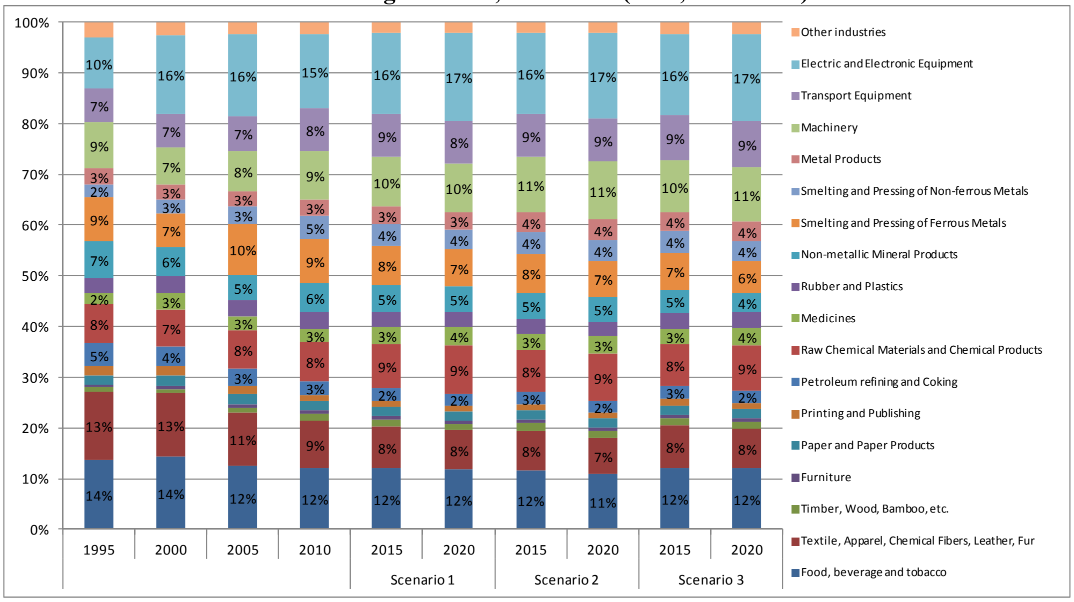


Table 2 shows the total manufacturing value added AAGR and share of manufacturing value added from China's total GDP under each scenario. It shows that scenario 1 has the highest AAGR for overall manufacturing value added, whereas scenario 3 has the lowest AAGR for manufacturing value added. This is clearly the result of value added AAGR assumed for manufacturing subsector under these two scenarios. Another interesting observation is that the share of manufacturing value added from China's total GDP is increasing under scenario 1 and scenario 2 and is decreasing under scenario 3 at the end of both periods. The results for scenario 3 are more in line with China's national policy to reduce the share of manufacturing from China's total GDP during the 12th FYP and the 13th FYP.

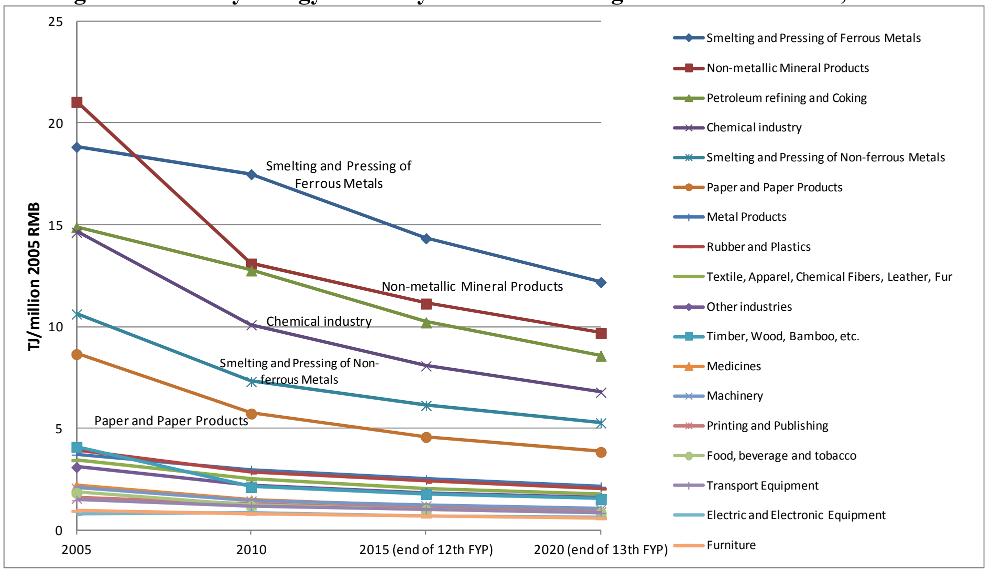
Table 2. Total manufacturing value added AAGR under each scenario and share of manufacturing value added from China's total GDP [a]

	Historical	Scenario 1		Scenario 2		Scenario 3	
	2005-2010	2011-2015	in 2016-2020	2011-2015	in 2016-2020	2011-2015	in 2016-2020
Total manufacturing value added AAGR	12.8%	9.2%	7.3%	8.9%	7.3%	8.0%	7.0%
Share of manufacturing value added from China's total GDP* by end of the period (i.e. 2010, 2015, or 2020)	34.8%	35.8%	36.3%	35.2%	35.7%	33.9%	33.9%

[a] China's total GDP in 2015 and 2020 is calculated by taking China's total GDP in 2010 (in 2005 constant prices) and assuming the AAGR for China's total GDP of 8.6 percent during 2011-2015 compared to the 2010 level and 7 percent during 2016-2020 compared to the 2015 level. It worth mentioning that the AAGR for China's total GDP during 2006-2010 was 11.2 percent compared to the 2005 level.

Primary energy intensity trends. For past years (1995-2010), primary energy use was divided by the value added (in 2005 constant prices) of each subsector to determine the total primary energy intensity for each subsector. For future years (2015 and 2010), the energy intensity of manufacturing subsectors was calculated using equation 4 and 5 in section 2.1. The results of the energy intensity calculations are shown in Figure 4.

Figure 4. Primary energy[3] intensity of manufacturing subsectors in China, 2005-2020



Note: Only data from 2005, 2010, 2015, and 2020 are used to plot this graph; thus, the fluctuations in actual energy intensities between 2005 and 2010 are not shown here.

Figure 4 shows the primary energy intensity of manufacturing subsectors in China during 2005-2020. The 2015 and 2020 energy intensities are based on energy intensity reduction rates given in Table 1. Since we assumed steady reduction rates for all manufacturing subsectors by the end of the 12th FYP (2015) and the 13th FYP (2020), we can see that the energy intensity of all subsectors drops during these periods. The reduction rate during the 13th FYP (2016-2020) is lower than that in the 12th FYP (2011-2015). The reduction rates assumed for the 12th FYP are mostly based on Chinese government energy intensity reduction targets for manufacturing subsectors or for industry as a whole. The reduction rates for the 13th FYP are based on expert judgment which is informed by qualitative information on the overall energy intensity reduction target expected for Chinese industry during this period as well as previous targets set in the 11th and 12th FYPs.

Overall manufacturing energy intensity drops from 4.9 TJ/million 2005 RMB in 2010 to 3.9 TJ/million 2005 RMB in 2015 (a 20 percent drop compared to the 2010 level) and further declines to 3.2 TJ/million 2005 RMB in 2020 (a 17 percent drop compared to the 2015 level). The 20 percent reduction in manufacturing energy intensity in the 12th FYP is in line with the Chinese government target for energy intensity reduction during this period. The government target is to reduce national energy intensity (energy use per GDP) by 16 percent during the 12th FYP. It is expected that the industrial sector will contribute the most to achieving this reduction target because it accounts for around 70 percent of primary energy use in China and significant energy efficiency potential exists in the industrial sector. Thus, the higher rate of energy intensity reduction (20 percent reduction compared to national target of 16 percent reduction) for the overall manufacturing sector in China derived from our bottom-up, sub-sector level calculations is acceptable.

Using the value added and primary energy intensity presented above for each manufacturing subsector, we calculated the primary energy use of each subsector in 2015 and 2020 using equation 1. Since we have three different scenarios for future subsector value

[3] In primary energy use reported in NBS (1996-2011), electricity use is converted from final to primary energy using average power generation efficiency in China in various years. The losses in the refining for the production of petroleum products and in coke making for production of coke are not included in the primary energy reported in NBS (1996-2011) .

added, we have three primary energy use values calculated under each scenario for the manufacturing subsectors.

Decomposition of Chinese Manufacturing Energy Use

Figures 7-9 show the results of the additive non-changing decomposition analysis of total primary energy use for Chinese manufacturing for the time periods mentioned above under each scenario, separately. During the 11th FYP (2005-2010), the activity effect increased manufacturing energy use by 27,379 PJ due to high value added output from manufacturing. However, the structural effect slightly reduced manufacturing primary energy use in this period by 1,081 PJ. After the intensity effect, which also reduced primary energy use by 12,281 PJ, is taken into account, the total change in Chinese manufacturing primary energy use during 11th FYP was equal to an increase of 14,017 PJ.

Figures 7-9 show that under all three scenarios, except in the period of 2000-2005 (10th FYP), the activity and intensity effects were the two dominant influences working against each other to drive energy use upward (activity effect) or downward (intensity effect).

Figure 7. Scenario 1: Results of retrospective and prospective decomposition of primary energy use of Chinese manufacturing during the 9th, 10th, 11th, 12th, and 13th Five Year Plans

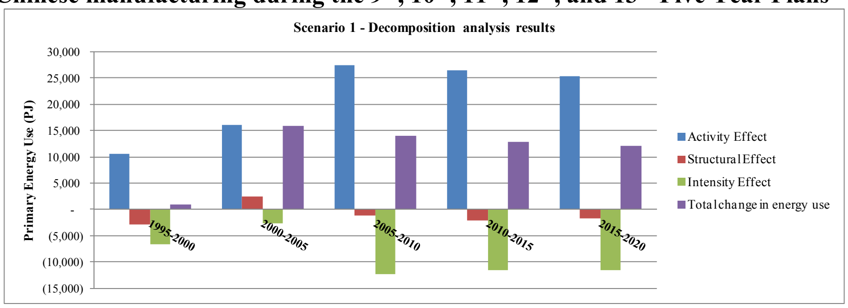
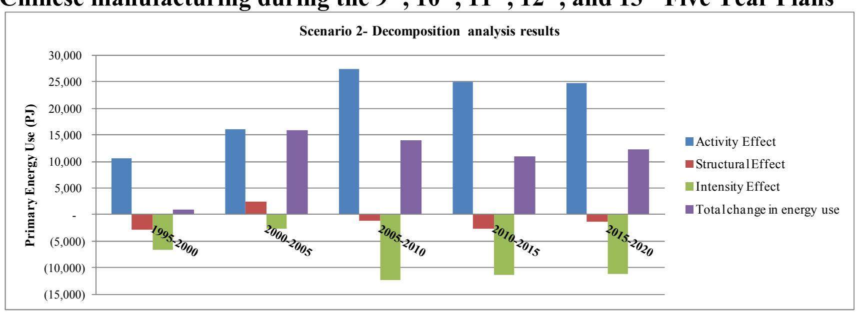
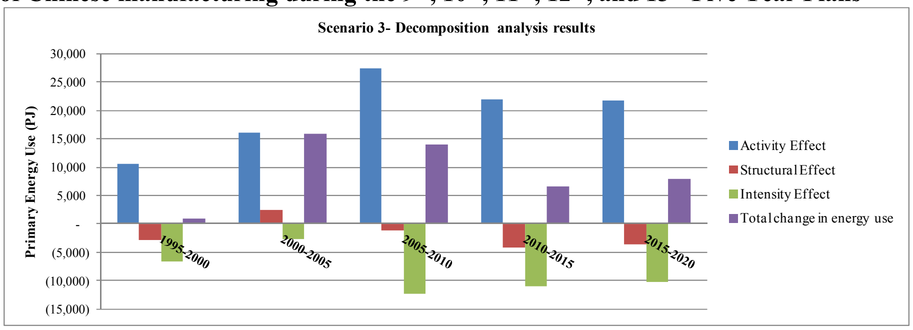


Figure 8. Scenario 2: Results of retrospective and prospective decomposition of primary energy use of Chinese manufacturing during the 9th, 10th, 11th, 12th, and 13th Five Year Plans



In the period 2000-2005, the intensity effect had a much smaller impact compared to all other periods studied. Also, 2000-2005 is the only period when the structural effect is positive, driving manufacturing energy use upwards. During all other periods the structural effect was negative and helped to reduce manufacturing energy use even though its impact was rather small compared to other effects. The primary reason why the structural effect was positive in 2000-2005 (10th FYP) is that the share of value added from smelting and pressing of ferrous metals in total manufacturing value added increased from 7 percent in 2000 to 10 percent in 2005. Since this sector has the highest energy intensity among all other sectors, such a seemingly small change in its share of value added in total manufacturing value added can significantly impact the structural effect in the decomposition analysis. The same issue is applicable to raw chemical materials and chemical products manufacturing which is one of the top three energy-intensive industries in China; a slight increase in its share from total manufacturing value added (from 7 percent in 2000 to 8 percent in 2005) can result in a positive increase in the structural effect.

Figure 9. Scenario 3: Results of retrospective and prospective decomposition of primary energy use of Chinese manufacturing during the 9th, 10th, 11th, 12th, and 13th Five Year Plans



For the 12th FYP and 13th FYP, the results of the decomposition analyses show a similar pattern across the scenarios but with different magnitudes for various effects. The differences between the three scenarios and the primary reasons for such differences can be summarized as:

- In the 12th FYP and 13th FYP, the activity effect is largest in scenario 1 and smallest in scenario 3. This is directly because of the higher value added AAGRs assumed in scenario 1, which are mostly based on Chinese reported data, and the lower value added AAGRs assumed in scenario 3, which are mostly based on expert judgment informed by various sources of information and taking into account China's overall GDP growth rate and the expected share of industry from China's overall GDP in 2015 and 2020.
- In the 12th FYP and 13th FYP, contrary to the activity effect, the structural effect is largest (in negative value) in scenario 3. This is primarily because of the fact that the share of value added of smelting and pressing of ferrous metals and non-metallic mineral products sector, which were the two top energy-intensive sectors, in total manufacturing value added in 2015 and 2020 declined the most in scenario 3 when compared to the 2010 shares. In other words, the share of these two sectors in total manufacturing value added in 2015 and 2020 is lower in scenario 3 compared to scenarios 1 and 2 (see Figure 2). This is the result of our assumptions on value added AAGRs for different subsectors (Table 1). In scenario 3, we assumed a further shift from energy-intensive industries to non-energy intensive industries by assuming lower value added AAGRs for the energy-intensive sectors and higher value added AAGRs for the less energy-intensive sectors. This is necessary if China wants to adjust the structure of its manufacturing and move towards less energy-intensive and lower polluting manufacturing.
- In the 12th FYP and 13th FYP, the intensity effect is almost in the same range across all three scenarios, with scenario 1 having slightly greater (in negative value) energy intensity effect. This is mainly because we assumed a similar energy intensity reduction rate during the 12th FYP and 13th FYP for all three scenarios (Table 1). The slight differences between intensity effects across scenarios comes from the differences in absolute energy use in manufacturing subsectors in 2015 and 2020 under each scenario which is the result of different value added AAGR assumptions. As can be seen in equation 9, absolute energy use of a manufacturing subsector plays a

role in the calculation of the intensity effect in addition to the energy intensity of the subsectors. Nonetheless, the intensity effect plays a significant role in reducing primary energy use during the 12^{th} FYP and 13^{th} FYP. This is primarily because of aggressive policies by the Chinese government to reduce the energy use per value added of the manufacturing sector. The "Top-1000 Enterprises Energy Saving Program" and the "10 Key Energy Saving Projects Program" implemented during the 11^{th} FYP have both been extended to the 12^{th} FYP with the Top 1000 program expanding to the "Top-10,000 Enterprises Energy Saving Program". These programs along with other policies and incentives are helping to reduce the energy intensity of the manufacturing in China; hence we see a strong intensity effect in the decomposition analysis.

Conclusions

The retrospective decomposition analysis described in this paper shows that energy intensity reduction was not the only reason for reduced energy use in Chinese manufacturing between 1995 and 2010. Structural effects played an important role in reducing energy demand between 1995 and 2000 and a minor role between 2005 and 2010. However, during 2000-2005 the structural effect was positive and drove manufacturing energy use upward primarily because the share of value added from top energy-intensive sectors like smelting and pressing of ferrous metals and raw chemical materials and chemical products manufacturing in total manufacturing value added increased during this period.

The three scenarios produced for the forward looking (prospective) decomposition analysis for 2010-2020 show a similar pattern for different effects with only varying magnitudes for each effect across the scenarios. The scenario analysis indicates that if China wants to shift from energy-intensive and polluting industries to less energy-intensive industries, the value added AAGRs in 2015 and 2020 should be more in line with scenario 3, which is the value added AAGR of energy intensive sectors such as smelting and pressing of ferrous metals and non-metallic mineral, and chemical industry should drop to 4%, 3%, and 8.5% respectively over this period while value added AAGR of non-energy intensive industries declines with a slower pace. The assumed value added AAGRs for scenario 3 are informed by possible growth rates that are foreseen for each subsector. Such structural change is also a result of shifts in demand for manufactured products. The government can influence demand for manufactured products indirectly, but only to some extent, and generally only temporarily.

The results of our analysis also show that the intensity effect always reduces primary energy use during the study period. Over the time period of 2010-2020, the intensity effect reduced the primary energy use by 23,000 PJ, 22,700 PJ, and 21,400 PJ under scenario 1,2, and 3, respectively. This could be for various reasons including aggressive policies and programs to reduce energy intensity, fiscal incentives given by the Chinese government for energy efficiency projects (e.g. the 10 Key Energy Saving Projects Program), modernization of the industry and phasing out of the inefficient, backward technologies, increased energy prices, etc. These reasons along with other influential factors have continued pressuring industries to improve energy efficiency to comply with regulations and to reduce costs. This is likely to continue up to 2020 and perhaps beyond.

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