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Article

Determinants of Electricity Demand in Nonmetallic Mineral Products Industry: Evidence from a Comparative Study of Japan and China

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Abstract: Electricity intensity is an important indicator for measuring production efficiency. A comparative study could offer a new perspective on investigating determinants of electricity demand. The Japanese non-metallic mineral products industry is chosen as the object for comparison considering its representative position in production efficiency. By adopting the cointegration model, this paper examines influencing factors of electricity demand in Japanese and Chinese non-metallic mineral products industries under the same framework. Results indicate that although economic growth and industrial development stages are different between the two countries, major factors that affect the sectoral energy consumption are the same. Specifically, economic growth and industrial activity contribute to the growth of sectoral electricity consumption, while R&D intensity, per capita productivity and electricity price are contributors to the decline of sectoral electricity consumption. Finally, in order to further investigate the development trend of sectoral electricity demand, future electricity consumption and conservation potential are predicted under different scenarios. Electricity demand of the Chinese non-metallic mineral products industry is predicted to be 680.53 TWh (terawatt-hours) in 2020 and the sectoral electricity conservation potentials are estimated to be 118.26 TWh and 216.25 TWh under the moderate and advanced electricity-saving scenarios, respectively.

Keywords: non-metallic mineral products industry; electricity demand; comparative study; cointegration method

1. Introduction

The electricity conservation potential of the non-metallic mineral products industry is investigated for the following three reasons: first, the non-metallic mineral products industry, one of the six highest energy-consuming industries in China, consumes 6% of national electricity; further, it is a pillar industry which contributes to nearly one percent of GDP each year [1]; second, considering the rapid urbanization in China, it plays a crucial role in national energy conservation and low carbon transition compared to other industrial subsectors; third, although many empirical works have contributed to the energy-saving literature, to the best of our knowledge, no studies thus far have examined determinants of the sectoral electricity demand by conducting a comparative study. In general, the indicator of electricity consumption per unit of value added (electricity intensity) is used to discuss the efficiency of electricity utilization. According to Ouyang and Lin [2], the substantial gap of electricity intensity between China and Japan indicates the large potential of energy conservation in China. During the period 1999–2010, the average electricity intensity of the Japanese non-metallic mineral products industry was 0.1619 kWh/CNY. Comparatively, the figure was 0.9468 kWh/CNY in the Chinese non-metallic mineral products industry (A per-unit-production figure (electricity consumption per unit of physical production) is of great significance for describing future technology policy measures [3,4] as well as obtaining meaning implications. For instance, bottom-up models have been adopted to simulate energy systems based on technologies for energy consumption and production, which could examine the physical reality of energy saving potential or the potential for carbon emissions mitigation [5]. This indicator was not included in this paper because the nonmetallic mineral products industry is a two-digit industrial sub-sector. Specifically, the unit of production cannot be unified due to various products in the nonmetallic mineral products industry. For example, products of the nonmetallic mineral products industry contain cement, concrete, plasterboards, bricks, tiles, plate glasses, glass products, refractory products, graphite and carbon products and so on, of which, the units are ton, cubic meter, weight box, meter, square meter, *etc*. Therefore, a per-unit physical production figure cannot be used for such two-digit industrial sub-sector).

The scope of this paper is to exploit influencing factors of electricity demand to evaluate electricity conservation potential in the Chinese non-metallic mineral products industry. Such a study is meaningful in terms of the relatively large potential of electricity-saving, significant impacts on low-carbon transition in China and even the international efforts of reducing greenhouse gases (GHG). More specifically, this paper addresses the following questions:

- What are determinants of electricity demand in the non-metallic mineral products industry?
- What implications can be drawn from the comparative study of Japan and China?
- Which factors are significant for electricity conservation?
- How large are the electricity conservation potentials in the Chinese non-metallic mineral products industry?

By conducting the comparative study, this paper analyzes the determinants of electricity consumption in the Japanese and Chinese non-metallic mineral products industries under the same framework. A comparative study is conducive to grasping a deeper understanding of factors that influence industrial energy demand. Furthermore, diverse impact magnitude of each factor reflects its certain role in electricity demand as well as industrial development stage, which has distinctive policy implications for electricity conservation in industries of different countries. More importantly, China can learn from Japan in the aspect of policy design on energy conservation as well as industrial development strategy. We use Japan as a comparison for two reasons: first, the Japanese non-metallic mineral products industry has the world's highest efficiency of energy utilization; second, Japan is geographically close to China so that the technology spillover and diffusion will be easier and more frequent by international trade and investment (According to Ministry of Commerce in China, Foreign direct investments (FDIs) from Japan, which ranked second in China's FDI inflows from Asian countries/regions (10.63% during 1995–2006) after Taiwan, were mainly concentrated in the manufacturing sector. Moreover, a number of studies have investigated the vertical or horizontal spillover effects of FDI. For the case of China, Zhou *et al.* [6] proved that FDI affected the productivity of domestic firms in China. Moreover, Dees [7] showed that FDI affected China's economic growth as well as industrial growth through the diffusion of ideas. Liu and Buck [8] indicated that learning-by-exporting (and importing) promoted innovation in the Chinese indigenous firms.).

The rest of this paper will be organized as follows. A concise literature review is presented in Section 2. Section 3 describes the methodology and data source and Section 4 will present the data processing in this study. The empirical results and discussion are in Section 5. Finally, Section 6 will present the conclusions and policy implications.

2. Literature Review

The industrial sector is one of the primary targets for the investigation of energy-saving potentials [9–13]. From the methodological perspective, "top-down" and "bottom-up" models are the mainstream approaches for assessing strategies for energy conservation and emissions reduction.

Top-down models can establish the relationship between energy consumption and economic variables. Data envelopment analysis (DEA) or a non-parametric approach to frontier analysis is the common research method for analyzing energy-saving potentials [14]. This method is developed by Charnes *et al.* [15] in measuring the efficiency of individual decision-making units in producing multiple outputs from multiple inputs. In comparison with the conservation supply curve (CSC) model, the advantage of DEA method is that the measurement of cost-effectiveness can be extended to all input factors. Several representative studies are cited in this paper. For example, Mukherjee [16,17] examined the energy efficiency in the Indian manufacturing sector. Yadav *et al.* [18] evaluated the relative overall efficiency, technical efficiency and scale efficiency of electricity distribution divisions of an Indian hilly state.

Different from top-down models, bottom-up models analyze future trends of energy demand based on technologies. For instance, by established a technology system within the Long-range Energy Alternatives Planning System (LEAP) model, Wen and Li [19] accessed energy conservation and CO_2 emissions abatement potentials for China's non-ferrous metals industry during 2010–2020. Based on

Asian-Pacific Integrated Model (AIM), Wen *et al.* [20] evaluated the potential for energy conservation and CO_2 emissions mitigation in China's iron and steel industry from 2010 to 2020. Based on the same model, Wen *et al.* [4] analyzed the effectiveness of energy savings and emission reductions in China's cement industry. Using bottom-up modeling, Wen *et al.* [21] predicted direct CO_2 emission trends, turning points, reduction potentials and costs for China's key sectors (energy, industry and consumption). The most common research on energy conservation potential is the conservation supply curve (CSC) model, which expresses energy conservation potential as a function of the marginal cost of conserved energy [22]. This analytical tool captures both the engineering and economic perspectives of energy conservation [23], which has been used in various studies to access the industrial energy-saving potentials [24,25]. From the perspective of the sectoral shifts within manufacturing, Huntington [26] improved the economic projections of industrial energy demand. Based on energy CSC, Worrell *et al.* [27] conducted an in-depth analysis of potentials for energy efficiency improvement in the US cement industry and identified cost-effective energy efficiency measures and potentials.

Despite the relative popularity of the above methods, the cointegration model is a preferred method for estimating industrial electricity demand and electricity saving potential. The popularity and widespread use of the cointegration model originate from the fact that it justifies the use of data on nonstationary variables to estimate coefficients as long as the variables are cointegrated [28]. Since the late 1980s, the cointegration analysis has become the standard component of studies of energy or electricity demand such as Engle *et al.* [29], Hunt and Manning [30], Bentzen and Engsted [31], Dergiades and Tsoulfidis [32], He *et al.* [33], Athukorala and Wilson [34], El-Shazly [35]. Considering the important role China plays in the international energy market and international efforts on greenhouse gas (GHG) emissions reduction, studies on industrial energy potential in China attract more interest from scholars, and the cointegration method has been commonly used. For example, Lin *et al.* [36] explored determinants of energy intensity in the Chinese steel industry. Lin and Ouyang [37] evaluated the electricity saving potential of the Chinese nonmetallic mineral products industry in 2020 based on scenario analysis.

3. Methodology and Data Source

3.1. Methodology

In this paper, the cointegration approach is applied to establish the long-term relationships between variables that influence electricity demand in the non-metallic mineral products industries of Japan and China. Since Engle and Granger [38] proposed a theorem-proving and operational framework of the cointegration model, many scholars use this analytical method to explore factors that affecting electricity demand.

There are various factors that affect the industrial electricity demand. Based on literature, we determine the main factors affecting the electricity demands of the non-metallic mineral products industries in Japan and China from the economic growth, industrial growth, electricity price, technical progress and per capita productivity. The function of the sectoral electricity demand is constructed as follows:

$$Q_t = f(EG_t, IA_t, P_t, RI_t, PCP_t) \tag{1}$$

where Q_t is the electricity demand of the non-metallic mineral products industry; EG_t is economic growth as measured by the gross domestic product, which indicates the sectoral electricity consumption from the demand side; IA_t is the industrial activity of the non-metallic mineral products industry as measured by value added, which identifies the sectoral electricity consumption from the supply side; P_t is the electricity price; RI_t is R&D intensity; PCP_t is the per capita productivity of the non-metallic mineral products industry. In order to avoid the heteroskedasticity, all variables are taken the logarithm. LN denotes the natural logarithm.

The function of electricity demand in Japanese non-metallic mineral products industry is as follow:

$$LNQ_t^J = \beta_0 LNEG_t^J + \beta_1 LNIA_t^J + \beta_2 LNP_t^J + \beta_3 LNRI_t^J + \beta_4 LNPCP_t^J + c \tag{2}$$

Likewise, electricity demand function of the Chinese non-metallic mineral products industry is expressed by:

$$LNQ_t^C = \beta_0 LNEG_t^C + \beta_1 LNIA_t^C + \beta_2 LNP_t^C + \beta_3 LNRI_t^C + \beta_4 LNPCP_t^C + c \tag{3}$$

Before conducting the cointegration analysis, stationary tests are essential for identifying stationarity of the time series. A stationary linear combination of economic variables indicates the existence of a long-run equilibrium relationship. The most popular testing procedures are augmented Dickey-Fuller (ADF) test [39] and Phillips-Perron (PP) test [40].

In order to avoid impacts of higher-order serial correlation, the ADF test includes the lagged difference of the dependent variable y_t in the right side of the regression equation:

$$\Delta y_t = \beta_0 + \alpha_0 t + \alpha_1 y_{t-1} + \sum_{i=1}^{m} \beta_i \Delta y_{t-i} + \varepsilon_t \qquad t = 1,2,3,...T \tag{4}$$

where β_0 is a constant; $\alpha_0 t$ is the linear trend; y_t is the tested variable in period t; Δy_{t-1} is $y_{t-1} - y_{t-2}$; $\varepsilon_t \sim i.i.d.N(0,\sigma^2)$ (independently and identically distributed).

In this paper, the ADF test and PP test are applied for a comprehensive assessment of the stationary time series. In order to test the null hypothesis of the presence of a unit root in y_t, we conduct the hypothesis testing that $\alpha_1 = 0$ in Equation (4). If α_1 is significantly less than zero, the null hypothesis of a unit root will be rejected:

$$\begin{cases} H_0 : \alpha_1 = 0 \\ H_1 : \alpha_1 \prec 0 \end{cases} \tag{5}$$

If the integration of each series is of the same order, then we can continue to test the existence of the cointegration relationship over the sample period. Engle-Granger (EG) two-step procedure [38] and Johansen-Juselius (JJ) method [41,42] are the most commonly used method for the cointegration test. JJ method can not only detect the existence of the cointegration among the variables but also accurately determine the number of the cointegrating vectors. Therefore, we use the JJ method trace test and the maximum Eigen value test to determine the number of the cointegrating vectors in our models.

JJ test has two test statistics: the maximum Eigenvalue statistic and trace statistic. The Eigenvalue statistic tests the assumption of the existence of r cointegrating vectors by calculating the maximum likelihood test statistic $LR_{\max}$:

$$LR_{\max} = -T \ln(1 - K_{r+1}) \tag{6}$$

where T is the number of samples; K_{r+1} is the Eigenvalue. Trace statistic tests the assumption that there are less than r cointegrating vectors by calculating the likelihood test statistic LR_{trace}:

$$LR_{trace} = -T \sum_{i=r+1}^{n} \ln(1 - K_r) \qquad r = 0,1,2,...,n-1 \tag{7}$$

where T is the number of samples; $K_{r+1},...,K_n$ is the $(n-r)$ smallest Eigenvalue of estimation.

3.2. Variables and Data Source

We use time series data of Japan and China ranging from 1990 to 2010. Major factors are economic growth (EG), industrial activity (IA), electricity price (P), R&D intensity (RI) and per capita productivity (PCP). Variables determining electricity demands of the non-metallic mineral products industries in Japan and China are illustrated in Table 1.

Table 1. Variables determining electricity demands of the non-metallic mineral products industries in Japan and China.

Variables	Abbreviation	Measurable Indicators	Units	Data Sources
Economic growth	EG^J, EG^C	Gross domestic product	Billion yen, Billion CNY (at constant 1990 prices)	[1,43]
Industrial activity	IA^J, IA^C	Sectoral value added	Million yen, Million CNY (at constant 1990 prices)	[43,44]
R&D intensity	RI^J, RI^C	Sectoral R&D-sales ratio	%, %	[43,45]
Electricity price	P^J, P^C	Consumer price index of electricity charges of Japan, Fossil fuel price index of China	1990 = 100, 1990 = 100	[1,43]
Per capita productivity	PCP^J, PCP^C	Sectoral value added per capita	10,000 yen/ person, 10,000 CNY/person	[1,43]

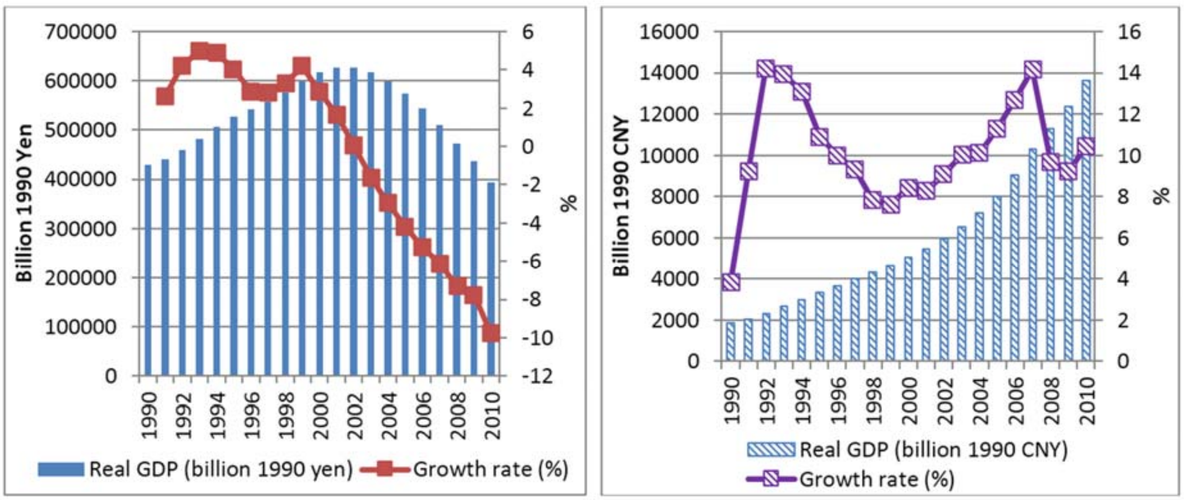
4. Data Processing

The dependent variables in this article are electricity demands of the non-metallic mineral products industries in Japan and China. The variables are labeled as Q^J for Japan and Q^C for China. Based on the literature, the following indexes are chosen as explanatory variables: (1) economic growth; (2) industrial activity; (3) R&D intensity; (4) per capita productivity and (5) electricity price. The five variables are labeled as EG^J, IA^J, RI^J, PCP^J, and P^J respectively for Japan and labeled as EG^C, IA^C, RI^C, PCP^C and P^C for China for the sake of briefness.

4.1. Economic Growth (EG^J / EG^C)

In the past three decades, numerous studies have examined the causal relationship between energy consumption and economic growth. The seminal empirical study dates back to Kraft and Kraft [46], which proved that there existed a constant and unchanging relationship between gross energy consumption and GNP. The finding was later supported by other studies such as Asafu-Adjaye [47], Al-Iriani [48], Ozturk *et al.* [49], Tang and Tan [50]. For the case of China, Herrerias *et al.* [51] found that the causality runs in the long run from economic growth to energy consumption across regions in China using data for the period 1999–2009.

Real GDP of Japan showed an inverted-U shape, which increased from 429,860.4 billion yen in 1990 to 626,761.8 billion yen in 2001 and then dropped to 393,387.2 billion yen in 2010 (at constant prices in 1990). The average annual growth rate of the real GDP of Japan was −0.3% (Figure 1. Panel A). Economic growth of China showed an increasing trend due to the promotion of urbanization and industrialization, which increased from 1866.8 billion CNY in 1990 to 13,643.5 billion CNY in 2010 (at constant prices in 1990). The average annual growth rate of GDP in China was 10.1% (Figure 1. Panel B).

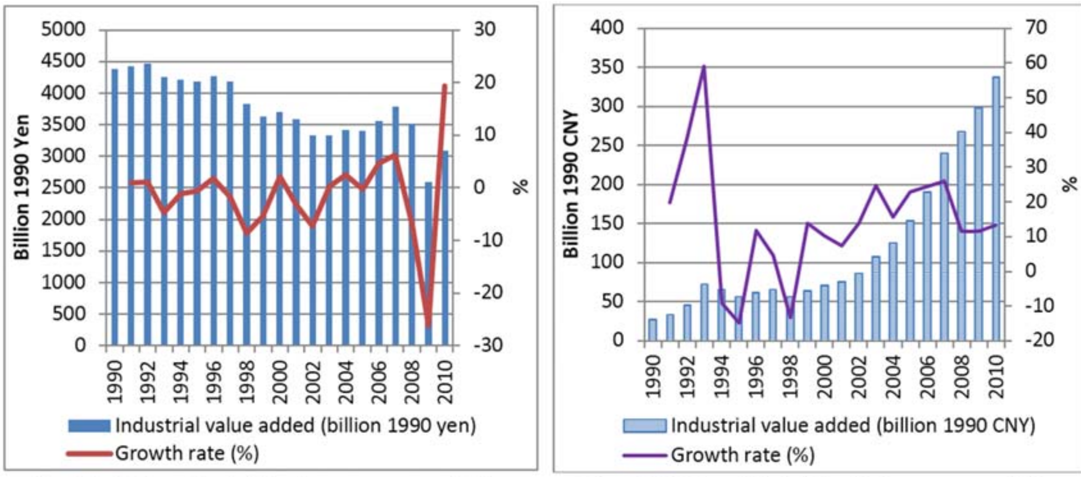


Panel A. Economic growth of Japan. **Panel B.** Economic growth of China.

Figure 1. Economic growth of Japan and China.

4.2. Industrial Activity (IA^J / IA^C)

Using the decomposition analysis, Steenhof [52] found that the industrial activity as measured by value added, contributed to the increase of electricity demand in China's industrial sector. From the perspective of carbon dioxide emissions or environment, other studies also proved that industrial CO_2 emissions or pollution increase in China were attributable to industrial activity (measured by value added) [53,54]. The value added of the Japanese non-metallic mineral products industry showed an overall downward trend during 1990–2010, of which the average annual growth rate was −1.36% (Figure 2. Panel A). Currently, China is undergoing a rapid process of urbanization and industrialization, which has promoted massive construction projects, thereby promoted the development of non-metallic mineral products industry in China [55]. The value added of the Chinese non-metallic mineral products industry grew from 27.42 billion CNY in 1990 to 338.22 billion CNY in 2010 (at constant prices in 1990)-equivalent to an increase of 1133.17% (Figure 2. Panel B). The average annual growth rate of value added in the Chinese non-metallic mineral products industry was 14.54% during 1990–2010.



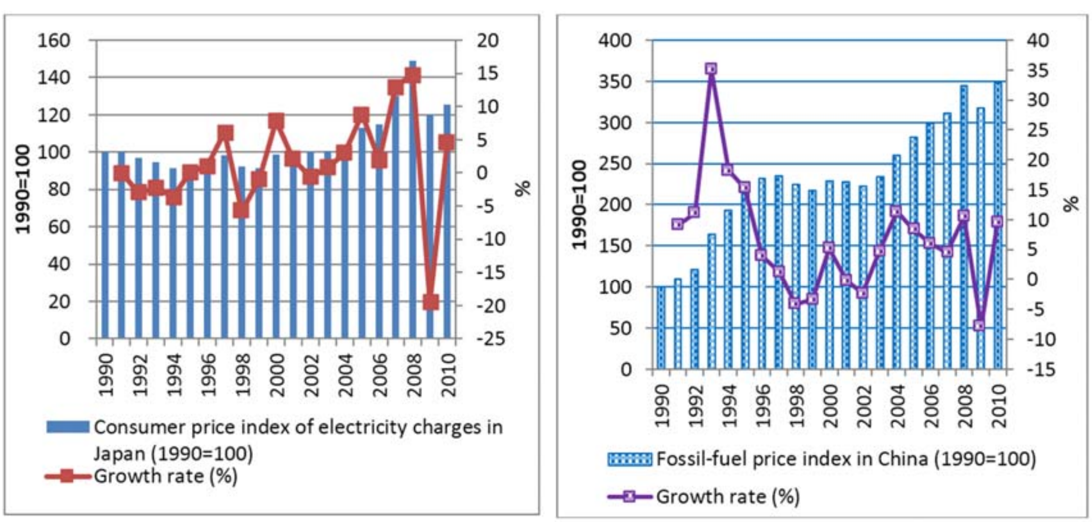
Panel A. Value added of the Japanese non-metallic mineral products industry.

Panel B. Value added of the Chinese non-metallic mineral products industry.

Figure 2. Value added of the non-metallic mineral products industries in Japan and China.

4.3. Electricity Price (P^J/P^C)

Elkhafif [56] showed that a substantial part of energy conservation came from the higher aggregate price of energy by estimating an industrial energy demand model for the province of Ontario. For the case of China, Yuan *et al.* [57] proved that higher energy price would decrease energy consumption in the Chinese industrial sector. Generally, price indexes are used for the measurement of price changes. Electricity price of Japan was relatively stable over the years, of which the average annual growth rate was 1.4% (Figure 3. Panel A). Due to the limitation of data, we use fossil-fuel price index as the electricity price in China. Similar method of data handling has been used by several studies such as Lin *et al.* [58], Lin and Ouyang [59]. As can be seen from Figure 3 Panel B, the average annual growth rate of fossil-fuel price index in China was 6.80% during 1990–2010. However, energy prices in China were still regulated or controlled by the government, and there existed large amounts of subsidies [60].



Panel A. Electricity price of Japan.

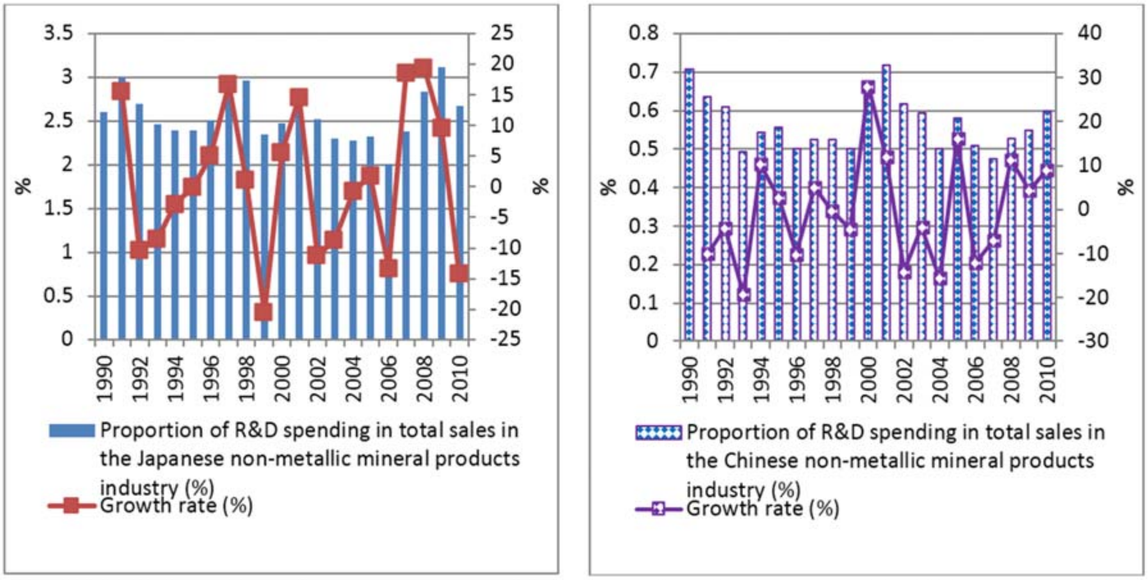
Panel B. Electricity price of China.

Figure 3. Electricity prices of Japan and China.

4.4. R&D Intensity (RI^J / RI^C)

In this paper, the indicator of technological progress has been defined as "the percentage of intramural R&D expenditure to sales" for two reasons. First, in Japan Statistical Yearbook, research activities of enterprises by industry only includes the indicators of "Intramural expenditure on R&D (disbursement)" and "its percentage to sales (%)". Although China Statistical Yearbook on Science and Technology includes the indictor of "purchase of instrument", the change of the categorization of enterprises and missing data due to statistical breaks make the time series analysis difficult to conduct (Based on China Statistical Yearbook on Science and Technology, Research and Development (R&D) Expenditure consists of Service Fees, Raw Material Expenditure, Purchases of Fixed Assets, Research and Product Development Expenditures and Spending for Scientific and Technology (S&T) Institutes, and Purchase of Equipment is part of the Purchases of Fixed Assets.). Moreover, the purpose of this paper is to investigate the determinants of electricity demand in nonmetallic mineral products industries in China and Japan under the same framework, variables are thus kept consistent in order to obtain meaningful statistical results and policy implications. Second, based on the historical literature, knowledge or innovation is a function of R&D expenditures, implying that technological knowledge can be produced by investing resources into R&D activities [61,62]. Empirically, many studies have identified that technological progress is closely related with the increase of R&D expenditure [63]. Specifically, R&D intensity or R&D-sales ratio (expenditures on R&D divided by sales), which represents the level of R&D activity and indicates the level of technological opportunity [64], has traditionally been used as an indicator of a firm's innovative activity [65] and has been used to capture new economic knowledge [66]. For example, Mueller-Fuerstenberger and Stephan [67] used R&D-driven technical progress in production to represent technological change. According to Nordhaus [62], innovation is a function of R&D expenditure, implying that technological knowledge can be produced by investing resources into R&D activities. According to Grossman and Helpman [68], from the perspective of economics, a broad interpretation of "capital" includes human capital. Therefore, considering that R&D expenditure consists of the investment in physical capital (purchase of equipment) as well as the investment in human capital (payment for researchers in R&D laboratories), the indictor of R&D expenditure used in this paper is also acceptable and meaningful. Additionally, several studies have also used the indicator of R&D expenditure to represent technology such as Liang *et al.* [69], Lin *et al.* [55], Lin and Wang [70], *etc*. Based on the existing literature, the indicator of R&D investment out of total sales, which reflects the level of R&D investment as well as the capacity of R&D of profit-seeking enterprises, is used in this paper.

R&D intensity level of the Chinese non-metallic mineral products industry was much lower than that of Japan's. The average growth rate of R&D-sales ratio in the Japanese non-metallic mineral products industry was 0.82% during 1990–2010 (Figure 4. Panel A); however, the value was −0.14% in the Chinese non-metallic mineral products industry (Figure 4. Panel B).



Panel A. R&D intensity of the Japanese non-metallic mineral products industry

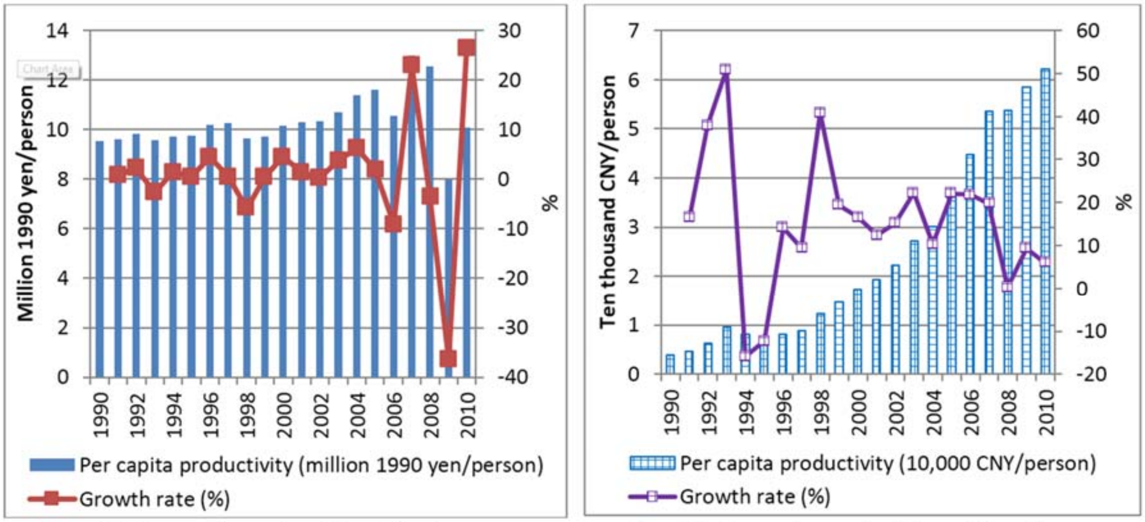
Panel B. R&D intensity of the Chinese non-metallic mineral products industry

Figure 4. R&D intensities of non-metallic mineral products industries in Japan and China.

Following the above analysis, pros and cons of using the indicator of R&D intensity as a proxy of technological progress are also discussed. Concerning the uncertainty of production of knowledge (innovation), R&D spending does not all pay off. Considering that R&D expenditure does not necessarily end up in patents or simply in new knowledge, using R&D intensity as a proxy of technological progress also has limitations. Since R&D investments have a high degree of irreversibility, the adverse effect of uncertainty on R&D outlays is more severe than on many other types of investment [71]. Kothari *et al.* [72] presented evidence of a positive relation between R&D expenditures and the uncertainty of future benefits from the investments. Based on the above analysis, we should be prudent about using the indicator of R&D intensity as a proxy of technological progress as well as the estimated results computed from the indicator. In addition to this, we should also note the issue of externalities (knowledge spill over). That is, technological progress that accrues to other firms, industries and society cannot be captured by R&D expenditures of the original investors [73].

4.5. Per Capita Productivity (PCP^J / PCP^C)

Improvements in the overall productivity are likely to reduce energy use; hence productivity is associated with energy efficiency or energy intensity [58]. Many studies have proved that productivity improvements can reduce energy consumption by improving energy efficiency [16,74]. The overall per capita productivity of the Japanese non-metallic mineral products industry was relativity stable during 1990–2010, of which the average annual growth rate was about 1.04% (Figure 5. Panel A). Comparatively, per capita productivity of the Chinese non-metallic mineral products industry improved greatly over the past 20 years, which increased from 0.39 ten thousand CNY per person in 1990 to 6.21 ten thousand CNY per person in 2010 (at constant prices in 1990). The average annual growth rate was 15.8% (Figure 5. Panel B).



Panel A. Per capita productivity of the Japanese non-metallic mineral products industry

Panel B. Per capita productivity of the Chinese non-metallic mineral products industry

Figure 5. Per capita productivity of the non-metallic mineral products industries in Japan and China.

5. Results and Discussion

5.1. Results of the Unit-Root Test

To check the stationary of variables used in the model, the ADF and PP tests are adopted in this paper. Results of the unit root test of variables for the Japanese non-metallic mineral products industry are shown in Table 2.

Table 2. Unit root test of variables (the Japanese non-metallic mineral products industry).

Series	Level		First Difference		Second Difference	
	ADF	PP	ADF	PP	ADF	PP
LNQ^J	1.1311	0.5152	−4.9569 ***	−5.3006 ***	−5.7623 ***	−6.1252 ***
$LNEG^J$	−1.2334	−1.7143	1.5763	0.0232	−5.4226 ***	−4.9489 ***
$LNIA^J$	−0.8445	−1.0175	−5.4582 ***	−7.4310 ***	−6.4063 ***	−4.9137 ***
$LNPCP^J$	−0.8889	−3.3509 *	−8.5866 ***	−8.7428 ***	−13.1735 ***	−9.2960 ***
LNP^J	−0.8249	−0.6669	−3.5487 **	−5.0048 ***	−6.2832 ***	−11.7678 ***
$LNRI^J$	−3.8770 ***	−2.4852	−4.7318 ***	−5.1346 ***	−3.2524 **	−7.8020 ***

Note: ***, ** and * indicate that results are statistically significant at the 1%, 5% and 10% levels, respectively.

Results of the unit root test of variables for the Chinese non-metallic mineral products industry are shown in Table 3.

As shown in Tables 2 and 3, both the ADF test and PP test indicate that all the variables for non-metallic mineral products industries in Japan and China are second-difference stationary.

Table 3. Unit root test of variables (the Chinese non-metallic mineral products industry).

Series	Level		First Difference		Second Difference	
	ADF	PP	ADF	PP	ADF	PP
LNQ^C	0.4862	0.1156	−2.2874	−2.2874	−4.1693 ***	−4.2109 ***
$LNEG^C$	−0.7708	−0.4969	−2.0625	−2.2175	−4.8386 ***	−4.8550 ***
$LNIA^C$	−0.2148	−0.2148	−3.6329 *	−2.9535 *	−2.2096	−7.4610 ***
$LNPCP^C$	−0.8644	−0.8885	−3.4667 **	−3.4668 *	−5.3574 ***	−7.4432 ***
LNP^C	−2.6389	−2.48	−2.6288	−2.5923	−5.6489 ***	−5.6766 ***
$LNRI^C$	−3.0982 **	−3.1057 ***	−4.7255 ***	−4.9111 ***	−5.6494 ***	−18.362 ***

Note: Tests in this paper have been carried out using EViews 8; ***, **, and * indicate that results are statistically significant at the 1%, 5% and 10% levels, respectively; Critical values for the ADF statistics are from MacKinnon [75] and critical values for the PP statistics are from Phillips and Perron [76].

5.2. Selection of the Lag Intervals for VAR Models

As shown in Table 4, the lag interval of 2 is conformably chosen by all the criteria of LogL, LR, FPE, AIC, SC and HQ.

Table 4. VAR lag order selection criteria (the Japanese non-metallic mineral products industry).

Lag	LogL	LR	FPE	AIC	SC	HQ
0	222.8412	NA	4.93E-18	−22.8254	−22.5271	−22.7749
1	353.6276	165.2039	2.84E-22	−32.8029	−30.7152	−32.4496
2	464.8284	70.23209 *	5.22e-25 *	−40.71878 *	−36.84161 *	−40.06261 *

Note: (1) Endogenous variables are $LNEG^J$, $LNIA^J$, $LNRI^J$, $LNPCP^J$, and LNP^J; (2) Exogenous variable is C; (3) Sample period covers from 1990 to 2010; (4) * indicates the lag order selected by the criterion; LR: sequential modified LR test statistic; FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion.

Table 5. VAR lag order selection criteria (the Chinese non-metallic mineral products industry).

Lag	LogL	LR	FPE	AIC	SC	HQ
0	72.67842	NA	3.61E-11	−7.018781	−6.720537	−6.968306
1	219.7184	185.7347	3.76E-16	−18.7072	−16.61949	−18.35387
2	359.5257	88.29938 *	3.40e-20 *	−29.63429 *	−25.75711 *	−28.97811 *

Note: (1) Endogenous variables are $LNEG^C$, $LNIA^C$, $LNRI^C$, $LNPCP^C$, and LNP^C; (2) Exogenous variable is C; (3) Sample period covers from 1990 to 2010; (4) * indicates that results are statistically significant at the level of 10%.

5.3. Johansen Cointegration Test

In this article, we adopt the method of Engle and Granger [38] in the estimation of cointegrating vectors. Table 6 shows that the null hypothesis, there is no cointegration equation, is rejected at the 5% significance level. Therefore, there exists a long term equilibrium relationship between variables in the Japanese non-metallic mineral products industry.

Table 6. Johansen cointegration test (the Japanese non-metallic mineral products industry).

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.999024	280.2414	103.8473	0
At most 1 *	0.922853	148.5401	76.97277	0
At most 2 *	0.888222	99.86129	54.07904	0
At most 3 *	0.814209	58.22769	35.19275	0
At most 4 *	0.640704	26.24817	20.26184	0.0066
At most 5	0.300839	6.79961	9.164546	0.1374
Hypothesized No. of CE(s)	**Eigenvalue**	**Max-Eigen Statistic**	**0.05 Critical Value**	**Prob.****
None *	0.999024	131.7013	40.9568	0
At most 1 *	0.922853	48.67884	34.80587	0.0006
At most 2 *	0.888222	41.6336	28.58808	0.0006
At most 3 *	0.814209	31.97952	22.29962	0.0016
At most 4 *	0.640704	19.44856	15.8921	0.0132
At most 5	0.300839	6.79961	9.164546	0.1374

Note: Trace test indicates 5 cointegrating eqn(s) at the 0.05 level; Max-Eigenvalue test indicates 5 cointegrating eqn(s) at the 0.05 level; * denotes rejection of the hypothesis at the 5% level; ** MacKinnon-Haug-Michelis [75] *p*-values.

Similarly, Table 7 shows that the null hypothesis, there is no cointegration equation, is rejected at the 5% significance level. Therefore, there exists a long-term equilibrium relationship between variables in the Chinese non-metallic mineral products industry.

Table 7. Johansen cointegration test (The Chinese non-metallic mineral products industry).

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.999984	363.1655	103.8473	0
At most 1 *	0.96277	152.7468	76.97277	0
At most 2 *	0.888088	90.22437	54.07904	0
At most 3 *	0.75748	48.61361	35.19275	0.0011
At most 4 *	0.529567	21.69687	20.26184	0.0315
At most 5	0.321478	7.368928	9.164546	0.1083
Hypothesized No. of CE(s)	**Eigenvalue**	**Max-Eigen Statistic**	**0.05 Critical Value**	**Prob.****
None *	0.999984	210.4187	40.9568	0.0001
At most 1 *	0.96277	62.52239	34.80587	0
At most 2 *	0.888088	41.61075	28.58808	0.0007
At most 3 *	0.75748	26.91674	22.29962	0.0105
At most 4	0.529567	14.32794	15.8921	0.0866
At most 5	0.321478	7.368928	9.164546	0.1083

Note: Trace test indicates 5 cointegrating eqn(s) at the 0.05 level; Max-Eigenvalue test indicates 4 cointegrating eqn(s) at the 0.05 level; * denotes rejection of the hypothesis at the 0.05 level; ** MacKinnon-Haug-Michelis [75] *p*-values.

In reality, it is necessary to choose the cointegrating vector that makes economic sense [77]. We find that there is only one cointegrating vector that has the expected signs and makes economic sense both in electricity demand functions of non-metallic mineral products industries in Japan and China.

Comparison of coefficients in cointegration equations between non-metallic mineral products industries in Japan and China is shown in Table 8.

Table 8. Comparison of coefficients in cointegration equations between non-metallic mineral products industries in Japan and China.

LNQ^J [a]	$LNEG^J$	$LNIA^J$	$LNRI^J$	$LNPCP^J$	LNP^J	C^J
1	−0.502227 (0.01202)	−1.923447 (0.03754)	0.435954 (0.02208)	3.984515 (0.03827)	3.920969 (0.21894)	−2.856658 (0.30846)
LNQ^C [b]	$LNEG^C$	$LNIA^C$	$LNRI^C$	$LNPCP^C$	LNP^C	C^c
1	−1.546948 (0.00164)	−0.000245 (0.0005)	0.138289 (0.00082)	0.231137 (0.00085)	0.355525 (0.00083)	4.7116 (0.01078)

Note: Normalized cointegrating coefficients (standard error in parentheses); [a] Log likelihood (The Japanese non-metallic mineral products industry): 397.3910; [b] Log likelihood (The Chinese non-metallic mineral products industry): 283.1523.

As shown in Table 8, the numbers in parentheses are the resulted standard errors. All coefficients accord with the expectation. Economic growth and industrial activity will increase the electricity demand of non-metallic mineral products industries in both Japan and China. On the other hand, technological progress, the improvement of per capita productivity and energy prices rise will decrease the electricity demand of non-metallic mineral products industries in both Japan and China. However, due to different stages of economic development, degrees of marketization, industrial development environment and so on, the impact magnitude of each variable on the sectoral electricity demand is differentiated.

For the case of Japan, elasticity coefficients show that a 1% increase in economic growth and industrial activity will produce a 0.5022% and 1.9234% increase of electricity consumption in the Japanese non-metallic mineral products industry, respectively. A 1% increase of R&D intensity, per capita productivity and energy price will produce a 0.4359%, 3.9845% and 3.9209% decline of electricity consumption in the Japanese non-metallic mineral products industry, respectively.

For the case of China, elasticity coefficients show that a 1% increase in economic growth and industrial activity will produce a 1.5469% and 0.0002% increase of electricity consumption in the Chinese non-metallic mineral products industry, respectively. A 1% increase of R&D intensity, per capita productivity and energy price will produce a 0.1383%, 0.2311% and 0.3555% decline of electricity consumption in the Chinese non-metallic mineral products industry, respectively.

From the comparison above, we can prudently draw several conclusions: first, different from Japan, the electricity demand of the Chinese non-metallic mineral products industry is mainly driven by the high speed of economic growth; second, the rise of electricity price can significantly cut the sectoral electricity consumption; third, R&D intensity and per capita productivity have larger impacts on the reduction of sectoral electricity demand in Japan.

The electricity demand function of the Chinese non-metallic mineral products industry is shown in Equation (8):

$$\underset{}{LNQ_t^C = 1.5469LNEG_t^C + 0.0002LNIA_t^C - 0.1383LNRI_t^C - 0.2311LNPCP_t^C - 0.3555LNP_t^C - 4.7116} \\ \qquad (0.00164) \quad (0.0005) \quad (0.00082) \quad (0.00085) \quad (0.00083) \quad (0.01078) \tag{8}$$

Before the projection of electricity demand in the Chinese non-metallic mineral products industry, it is necessary to measure the prediction accuracy of Equation (8). Therefore, we substitute historical data of Q^C, EG^C, IA^C, RI^C, PCP^C and P^C into cointegration Equation (8). The fitted electricity demand in the Chinese non-metallic mineral products industry over 1990–2010 is shown in Figure 6. We can find that the model fits the historical data of LnQ^C well (the average error is -2.4714×10^{-5}), thus providing evidence that the cointegration equation has good prediction accuracy.

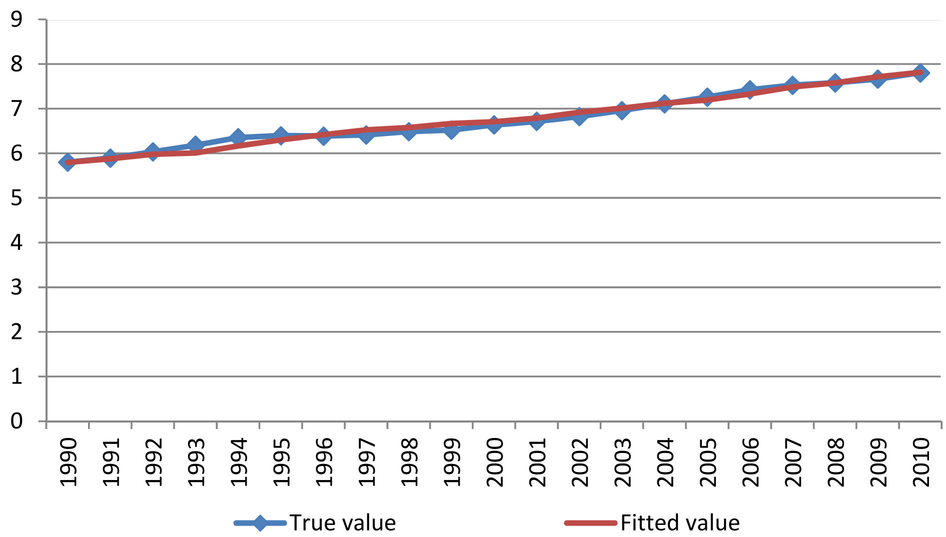


Figure 6. True value and fitted value of LnQ^C.

5.4. Estimates of Electricity Demand and Conservation Potentials in China

5.4.1. Estimates of Electricity Demand in the Chinese Non-Metallic Mineral Products Industry

In order to obtain the future electricity conservation potentials of the Chinese non-metallic mineral products industry, we set three scenarios: the business as usual scenario (BAU), the moderate scenario and the advanced scenario. The advanced scenario is a situation in which explanatory variables are limited under the aggressive energy conservation policies compared with those under the BAU scenario. The set of variables under the BAU scenario is based on the historical trend of time series, and the BAU scenario is therefore used as a benchmark for other scenarios. The moderate scenario is a mild situation, which is between the BAU and the advanced scenario. Aiming at describing the change of driving forces and indicating critical uncertainties as well as future images, this paper sets three scenarios which take studies such as Bazilian *et al.* [78], Ma *et al.* [79], Lin and Ouyang [37] for reference.

A per-unit-production figure (electricity consumption per unit of physical production) is of great significance for describing future technology policy measures [3,4] as well as obtaining meaning implications. For instance, bottom-up models have been adopted to simulate energy systems based on technologies for energy consumption and production, which could examine the physical reality of energy saving potential or the potential for carbon emissions mitigation [5,20,80]. This indicator was not included in this paper because the nonmetallic mineral products industry is a two-digit industrial sub-sector, products of which contain cement, concrete, plasterboards, bricks, tiles, plate glasses, glass products, refractory products, graphite and carbon products and so on. In summary, a per-unit-production figure is not available because units of physical products cannot be unified.

Similar scenario analysis has been adopted by many scholars [38,81–83].

The set of variables are as follows:

Economic growth (EG^C): The set of economic growth rate in the BAU scenario is based on the historical growth trend. The set of growth rate in the moderate scenario takes a reference to estimates from the IMF [66] and The World Bank [84]. The growth rate in the advanced scenario is one percentage lower during each time interval compared to the level in the moderate scenario.

Industrial activity (IA^C): Steenhof [85] demonstrated that industrial activity promoted industrial electricity demand in China between 1998 and 2002. The growth rate of value added of the Chinese non-metallic mineral products industry in BAU scenario is based on the historical trend. The growth rate under the advanced scenario is two percentages lower during each time interval compared to the level under the moderate scenario.

Energy price (P^C): Energy prices in China, which are depressed by the government for a long-term, could not reflect the true value of energy [60]. In addition, energy price reform promoted by the Chinese government has been relatively slow because of the consideration of economic growth and social stability. On one hand, we expect that the Chinese government would continue to promote energy pricing reforms [55]; on the other, taking the increasing depletion of fossil fuels and the development of renewable energy into account, we assume that future energy prices will show an upward trend.

R&D intensity (RI^C): The growth of technical R&D spending of the Chinese non-metallic mineral products industry accelerated from the year 2008. Notably, the Chinese government has shown great determinations to promote technological progress in the industrial sector. According to "12th Five-Year (2011–2015) Plan for China's Building Materials Industry", the ratio of R&D investment over sales revenue in industrial enterprises above designated size (enterprises with an annual sales over 5 million CNY) in China's non-metallic mineral products industry will increase by 1.5% in 2015 [86]. Therefore, we assume that the sectoral R&D intensity will keep improving under the three scenarios.

Per capita productivity (PCP^C): The proportion of skilled labors in the Chinese non-metallic mineral products industry has improved greatly over the years. We assume that the per capita productivity in the Chinese non-metallic mineral products industry will keep improving while the growth speed will slow down. Both literature and experiences from developed countries support the above assumptions [87].

The hypothesis of variables is summarized in Table 9.

Table 9. Hypothesis of variables (Unit: %).

Variables	BAU (%)		The Moderate Scenario (%)		The Advanced Scenario (%)	
	2012–2015	2016–2020	2012–2015	2016–2020	2012–2015	2016–2020
EG^C	9.3	8	8.3	7	7.3	6
IA^C	15	12	13	10	11	8
PCP^C	6	7	7	8	8	9
RI^C	1	2	2	3	3	4
P^C	5	4.5	6	5.5	7	6.5

Based on the hypothesis above, estimates of electricity demand in the Chinese non-metallic mineral products industry in 2020 are shown in Figure 7. The scenario-differentiated growth rates for the independent variables are reasonable, because various important factors such the actual economic growth in China, economic planning by the government and the industrial development have been taken into account.

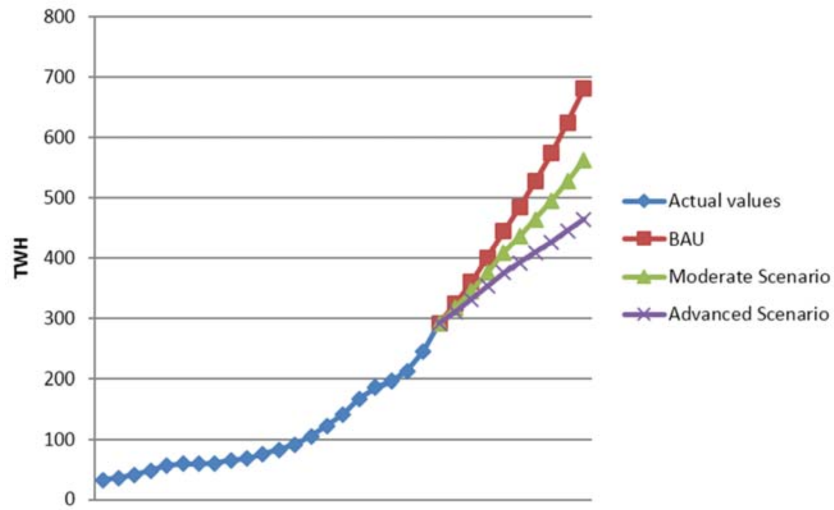


Figure 7. Actual values and estimates of electricity demands in the Chinese non-metallic mineral products industry under different scenarios.

As shown in Figure 7, under the BAU scenario, electricity consumption of the Chinese non-metallic mineral products industry will keep increasing during 2013–2020. However, electricity demand can be significantly reduced and the growth rate of electricity consumption can be slowed down by more strict energy-saving policies. Table 10 illustrates the estimates of electricity demand of the Chinese non-metallic mineral products industry.

Table 10. Estimates of electricity demands of the Chinese non-metallic mineral products industry.

Year	BAU		The Moderate Scenario		The Advanced Scenario	
	Amount (TWH)	Share (%)	Amount (TWH)	Share (%)	Amount (TWH)	Share (%)
2015	444.80	7.86	408.76	7.23	375.54	6.64
2020	680.53	9.04	562.27	7.47	464.28	6.17

Note: Shares of sectoral electricity demand in China's total electricity demand are based on the estimates from He *et al.* [33]. The results show that, under the moderate development scenario, the total electricity consumption of China will be 5656 TWh in 2015 and 7527 TWh in 2020.

As shown in Table 10, electricity demand of the Chinese non-metallic mineral products industry in 2020 is predicted to be 680.53 TWh under the BAU scenario, which will account for 9.04% of China's total electricity consumption. The sectoral electricity consumption in 2020 is predicted to be 562.27 TWh under the moderate electricity-saving scenario, while the value is 464.28 TWh under the advanced electricity-saving scenario, which are 17.37% and 31.77% lower than that under the BAU scenario, respectively. Under the moderate electricity-saving scenario, the share of sectoral electricity consumption in China's total electricity usage drops to 7.47%, and the figure can be further reduced to 6.17% under the advanced electricity-saving scenario.

5.4.2. Electricity Conservation Potentials

Electricity conservation is important from various policy perspectives, especially for China, considering that about eighty percent of China's electricity is generated from coal. Hence, the objective of electricity conservation in China is to conserve energy derived from fossil fuels, which is in favor of the reduction of carbon dioxide emissions and the prevention of further environmental deterioration at the same time. As to the industrial sectors, electricity conservation has economic implications of cost reduction. From the perspectives of cost minimization and sustainable development, it is highly important for industrial sector to reduce electricity consumption during periods of energy scarcity and high-energy prices.

In order to estimate the amount of electricity conservation in the Chinese non-metallic mineral products industry, two electricity conservation scenarios are set. In the moderate electricity-saving scenario, electricity consumption of the Chinese non-metallic mineral products industry is assumed to transform from the BAU scenario to the moderate scenario. Accordingly, in the advanced electricity-saving scenario, electricity consumption of the Chinese non-metallic mineral products industry is assumed to transform from the BAU scenario to the advanced scenario. According to the predictions of electricity consumption in the Chinese non-metallic mineral products industry under different scenarios, the amounts of electricity conservation and their impacts on the national electricity demand are thus calculated. Results are shown in Table 11.

Table 11. Electricity conservation potential of Chinese non-metallic mineral products industry and its impact on China's total electricity demand.

Year	**The Moderate Electricity-Saving Scenario**		**The Advanced Electricity-Saving Scenario**	
	Electricity-Saving Amount	**Impact on National Electricity Demand**	**Electricity-Saving Amount**	**Impact on National Electricity Demand**
2015	36.04 TWh	0.64%	69.26 TWh	1.22%
2020	118.26 TWh	1.57%	216.25 TWh	2.87%

Note: Share of electricity demand of the Chinese non-metallic mineral products industry in China's total electricity demand is based on the estimates from He *et al.* [33].

As shown in Table 11, there are substantial electricity conservation potentials in the Chinese non-metallic mineral products industry. If electricity consumption in the Chinese non-metallic mineral products industry transforms from the BAU scenario to the moderate scenario, 118.26 TWh of electricity will be saved in 2020, which is higher than the total electricity consumption of Norway in 2009 (112.51 TWh) or Netherlands in 2010 (110.04 TWh) [88]. The above results are consistent with those in Lin and Ouyang [37]. Moreover, the share of sectoral electricity conservation in China's total electricity consumption will increase from 0.64% in 2015 to 1.57% in 2020.

Furthermore, if electricity consumption in the Chinese non-metallic mineral products industry transforms from the BAU scenario to the advanced scenario, 216.25 TWh of electricity will be saved in 2020, which is equivalent to the total electricity consumption of South Africa in 2010 (214.98 TWh) [88]. Accordingly, the share of sectoral electricity conservation in China's total electricity consumption will increase from 1.22% in 2015 to 2.87% in 2020.

6. Conclusions and Policy Recommendations

The non-metallic mineral products industry plays an important role in China's economic growth and the undergoing mass urbanization. However, as one of the six most energy-consuming industries in China, the increasing electricity demand of the non-metallic mineral products industry has put more pressure on China's electricity supply as well as the corresponding carbon emissions reduction. We cannot stop the urbanization process artificially or the growth of industrial activity because no country is willing to sacrifice the economic development. Therefore, electricity conservation is an inevitable choice for China to mitigate the growing electricity demand as well as the increasing carbon dioxide emissions in the industrial sector. The great challenges faced by the Chinese government lie in three aspects: how to balance economic growth with sufficient and affordable energy, how to reduce greenhouse gas emissions and how to realize the sustainable industrial development.

In this article, we focus on the electricity demand as well as electricity conservation potentials of the Chinese non-metallic mineral products industry in the medium and long-term. In order to further investigate determinants of sectoral electricity demand, the comparative study is applied. On the basis of the cointegration model, we analyze electricity consumption of the non-metallic mineral products industries in Japan and China under the same framework. The long-term relationships between electricity demand and factors such as economic growth, industrial activity, electricity price, R&D intensity and per capita productivity are established. Results indicate that although major factors of electricity demand are the same, the impact magnitude of each variable is differentiated in the Japanese and Chinese non-metallic mineral products industries. Hence, policy implications for industrial electricity conservation should be distinctive for different countries. Moreover, electricity demand of the Chinese non-metallic mineral products industry would be significantly reduced if more aggressive electricity-saving policies were adopted. Industrial sector has the largest potential for energy conservation, mainly because of the high energy and carbon intensity of industrial activities, the large impacts on other economic sectors and efforts on national carbon emissions reduction.

Policy implications are thus summarized.

Firstly, we cannot stop the rapid economic growth in China, but we can take it as an important opportunity for cutting electricity demand in the industrial sector. Different from Japan, electricity consumption of the Chinese non-metallic mineral products industry, which is mainly driven by the economic growth, has the highest coefficient to sectoral electricity demand. Generally, the electricity consumption would be extensive during the current development stage. It implies that comparing to industries in other developed countries such as Japan, the Chinese non-metallic mineral products industry has a larger potential to cut the electricity consumption as well as the related carbon dioxide emissions. Policy-makers in China should realize and seize the opportunity to reduce more electricity consumption during the rapid economic development process.

Secondly, the Chinese government should further promote the electricity price reform. The price of electricity has the highest influence coefficient to the reduction of electricity demand in the Chinese non-metallic mineral product industry, followed by the per capita productivity and technological progress. In comparison with other countries, electricity price in China is still relatively low [89], implying that there would be large space for encouraging electricity conservation in China's industrial sector. The price of electricity in China has been controlled and suppressed by the government for a long time by subsidizing the consumption of fossil fuels, especially coal. On 1 January 2013, the Chinese government abolished the dual-track system of coal pricing (market price and contract price) and realized the complete marketization of coal. However, the price of electricity is still regulated by the government for the consideration of economic growth and social stability. Gradually eliminating subsidies to fossil fuels is helpful to reflect the true cost of energy as well as to reduce wasteful consumption.

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Author Contributions

Gang Du outlined the manuscript and made substantial contributions to the design of this study. Chuanwang Sun provided some core advices and checked the whole paper. All authors have read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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