Energy Prices and Energy Intensity in China:
A Structural Decomposition Analysis and Econometrics Study

by

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Abstract:

Since the start of its economic reforms in 1978, China's energy prices relative to other prices have increased. At the same time, its energy intensity, i.e., energy consumption per unit of Gross Domestic Product (GDP), has declined dramatically, by about 70%, in spite of increases in energy consumption. Is this just a coincidence? Or does a systematic relationship exist between energy prices and energy intensity?

In this study, we examine whether and how China’s energy price changes affect its energy intensity trend during 1980-2002 at a macro level. We conduct the research by using two complementary economic models: the input-output-based structural decomposition analysis (SDA) and econometric regression models and by using a decomposition method of own-price elasticity of energy intensity. Findings include a negative own-price elasticity of energy intensity, a price-inducement effect on energy-efficiency improvement, and a greater sensitivity (in terms of the reaction of energy intensity towards changes in energy prices) of the industry sector, compared to the overall economy.

Analysts can use these results as a starting point for China's energy and carbon emission forecasts, which they traditionally conduct in China without accounting for energy-intensity changes. In addition, policy implications may initiate new thinking about energy policies that are needed to conserve China's energy resources and reduce carbon emissions.

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1 Introduction

Although like other developing countries, the People's Republic of China (China) has a high energy intensity, defined as the ratio of real energy consumption in physical terms to real Gross Domestic Product (GDP), since 1978 China has decreased its energy intensity by approximately 70%. (Fisher-Vanden et al. 2004). China's energy-intensity decline is a unique phenomenon in the developing world. China is one of the few countries at a relatively early stage of industrialization in which energy demand has consistently–and over many years–grown significantly less rapidly than GDP (Lin, 1996; Zhang, 2003; Sinton et al., 1998).

Beginning in the 1990s, analysts have tried to account for this unique phenomenon through different empirical studies. Most of them, including Sinton and Levine (1994), Lin and Polenske (1995), Garbaccio et al. (1999), and Zhang (2003), argue that energy-efficiency improvement is the primary factor explaining the decline of China’s energy intensity. However, Smil (1990) and Kambara (1992) argue that the fact of structural shifts away from more energy-intensive industrial subsectors to less energy-intensive ones is the major causal factor. Others, Sinton (2000) and Fisher-Vanden et al., (2004) provide a multifactor explanation. They stress the importance of other factors, such as environmental and energy-efficiency policies, research and development expenditures, and ownership reform in enterprise sectors. Fisher-Vanden et al. show a negative elasticity of energy prices in relation to energy intensity, which is part of their study’s results on China’s energy-intensity decline. However, they base their study only on firm-level data during an extremely short time period (1997-1999) and examine only large and medium firms. However, except for Fisher-Vanden et al. (2004), few analysts incorporate energy prices into their analytical framework. In fact, energy prices in China increased, with some fluctuation, in the late 1990s, while China has gradually built a market-determined pricing system with the deregulation of energy prices by the central government.

In reviewing the China’s statistics, we find that on the one hand energy intensity declined and on the other hand energy prices increased over the last two decades. We want to examine the negative relationship between energy intensity and energy prices in China, if any, as in other OECD countries (Kaufmann, 2004; Miketa, 2001; Verbruggen, 2003). Although this negative effect would seem to be easy to understand, in practice analysts build most forecasts of energy use, energy security, and carbon emissions on an assumption of autonomous energy-intensity decline, that is, a decline trend that is independent of energy prices. (Kaufmann, 2004)

2. Methodology and Data

In order to empirically test the hypothesis of the negative relationship between China's energy intensity and energy prices, we use two complementary approaches. One is of the input-output-based structural decomposition analysis (SDA). The other is from the econometric studies on energy demand. The SDA analysis is based on a unified macro framework, describing the relationships between energy, other factor inputs, and other final products, and consequently, the relations between energy and the economy (Lin, 1996). Among this framework is a matrix of interindustry transactions, which is a natural focal point for the study of the impact of energy policy Hudson and Jorgenson (1978). The SDA model provides a powerful tool to capture all the energy-consumption changes that result either by final-demand shifts or by production-technology changes; however, it is only an accounting tool, not a behavioral model. The dynamic aspect of the interaction between demand and energy prices, which is conceptualized as the price elasticity, cannot be measured in the SDA model. Econometrics provides for the incorporation of behavioral and technological responses of patterns of production and consumption to alternative energy prices and permits analysts to determine the economic impact of energy prices on the demand for energy. (Hudson and Jorgenson, 1978)

First, we use econometric models to measure the price elasticity of overall energy intensity. Second, we decompose energy-intensity changes into two portions of the structural shift and energy-efficiency improvement effects, assuming that when there is no structural shift and technological improvement, energy consumption grows at the same rate as GDP. We obtain the effects on energy intensity of structural shifts and energy-efficiency improvements according to the results of the SDA analysis, in which energy consumption changes are decomposed into final-demand-shift effects and production-technology-improvement effects. Third, we use decomposed energy-intensity changes to measure the own-price elasticity of energy intensity due to structural shifts and also due to energy-efficiency improvements in econometric models.

2.1 Structural Decomposition

We use the SDA model to decompose energy-consumption savings into two effects: technological-change effects and final demand-shift effects. This model provides a comprehensive view of economic interdependence and is mathematically derived from the input-output (IO) model. We use hybrid energy IO tables. Starting from the conventional monetary IO tables, we incorporate into them energy flows in comparable thermal units for each different energy type to obtain the hybrid energy IO tables. This hybrid kind of IO table is preferable to the one from the conversion approach because the latter introduces inconsistencies in accounting for energy consumption and often needs to be adjusted to satisfy energy-conservation conditions (Miller and Blair, 1985; Lin 1996).

When analysts use energy IO tables, they view the overall energy consumption as a composition of two parts, that is, direct energy consumption and intermediate energy consumption. After some mathematical transformations, we are able to use the SDA model to decompose the energy-use change into two components: one due to the final-demand shift and the other due to production-technology change.

$$\begin{aligned} \Delta E &= FR[Y - YR] + e[Y - YR]n && \text{(final-demand shift)} \\ &\quad + [F - FR]\,Y && \text{(production-technology change)} \end{aligned} \tag{1}$$

where $F = e[(I-A)^{-1} - I]$;

A is the direct coefficient from hybrid IO tables;

e is a matrix consisting of ones and zeros, with ones in the diagonal locations corresponding to the upper-left quadrant of energy sectors within the whole matrix, and zeros in all other elements of the matrix. The e matrix selects the energy rows from the IO tables;

FR is the F matrix of the reference year;

Y is the vector of final demand;

YR is the vector of the final demand in the reference year; and

n is a matrix consisting of ones and zeros, with ones in the diagonal locations corresponding to those columns that are neither imports, exports, nor inventory changes, and zeros in all other elements of the matrix. We use it to exclude energy imports, exports, and inventory changes from the calculation of direct energy consumption.

Using this formula, we are able to answer the question of how much more/less energy would have been required in the current year (1987) if the reference year's (1981) production technology had still been used to satisfy the current (1987) final demand. If the question is how much less/more energy would be used in the reference year, say 1981, if the current, say 1987, production technology had been available to deliver the reference year’s, i.e. 1981’s, final demand, we use the following formula:

$$\begin{aligned} \Delta E = {} & F[Y - YR] + e[Y - YR]n && \text{(final-demand shift)} \\ & + [F - FR]\, YR && \text{(production-technology change)} \end{aligned} \tag{2}$$

2.2 Econometric Model

We use two econometric regression models to examine the correlation between energy prices and energy intensity (energy efficiency) in China over time. They are from econometric studies on energy-demand. We revise the functional specification of one of them to describe the relationship of energy prices and energy intensity. Specifically, the two models are a one-equation partial-adjustment model and a dynamic, economic-optimization model (Berndt and Field, 1981), both of which conform to the Marshallian framework about energy consumption and provide the starting point for the functional specifications for the price-elasticity analysis. At a microeconomic level, we can use the two models effectively, being able to obtain the needed data for China.

We assume that there are only two kinds of variable inputs, energy and non-energy inputs and two kinds of semi-fixed inputs, capital and skilled labor. Hence, for the purposes of this study, we use the functional specifications as follows.

One equation partial adjustment model:

$$\ln E_t = \alpha + \beta \ln EP + \delta \ln MP_t + \phi \ln GDP_t + (1 - \omega) \ln E_{t-1} \tag{3}$$

(Noticing that the log specification is convenient for measuring elasticities, we choose the log-specification.)

Short-run energy intensity equation from the dynamic optimization model:

$$EI_t = \alpha + \beta T + \lambda EP + \phi MP_t + \varepsilon K_{t-1} / GDP_t + \omega SL_{t-1} / GDP_t \tag{4}$$

where E_t is the actual amount of energy consumption at time t;
E_{t-1} is the energy consumption at time t-1;
GDP_t is gross domestic product or value added at time t;
EI_t is the energy intensity at time t;
EP_t is the aggregate energy price at time t;
MP_t is the price for non-energy intermediate materials at time t;
K_{t-1} is the number of total capital assets at time t-1;
SL_{t-1} is the amount of skilled labor at time t-1(K and SL are two quasi-fixed inputs);
T is a time-counter varying from 1 to T.

Analysts using the partial adjustment model of energy demand believe that energy demand is determined by energy prices, non-energy input prices, output, and previous year's energy demand. There is an implicit partial adjustment of energy-using facilities. Following this idea, we think that energy intensity, which is the energy demand per unit of output, is determined by energy prices, non-energy input prices, output, and previous year's energy intensity. Energy intensity is partially adjusted to this equilibrium. After some manipulations, we have two models for our energy-intensity analysis. The first model is specified in Equation (4) and the second one in Equation (5).

$$\ln EI_t = \alpha + \beta \ln EP + \delta \ln MP + \lambda \ln GDP + (1-\omega) \ln EI_{t-1}, \tag{5}$$

In this functional specification, ω is the proportional adjustment rate within the range of 0 and 1. 1/ω is the speed of adjustment. The long-run energy own-price elasticity of energy intensity is equal to β divided by ω, while the short-run own-price elasticity is β. Both elasticities are expected to be negative, meaning that holding everything else constant, when relative energy prices increase, energy-intensity declines. In the case of constant personal income, consumers decrease their consumption of energy through behavior adjustments, for example, shifting from private transportation to public transit for commuting, or new investment when facing higher energy prices. The energy intensities for these consumers accordingly decrease.

Equation 4 is employed by C. J. Morrison and E. R. Berndt. (Berndt and Field, 1981) The short-run energy intensity (energy input-output coefficient) is affected by prices of the variable inputs of energy and non-energy intermediate materials, output quantity, stocks of the quasi-fixed inputs K and SL, and the state of technology. The short-run own-price elasticity of energy intensity is $\varepsilon_{EE}^{SR} = \varepsilon_{EEI}^{SR} = (EP/EI) * \lambda$, which is expected to be negative and varies with energy intensity and energy prices in a given year.[1]

Because the data series of energy intensity, GDP, and price data are highly trended, we include T, the time variable in the partial-adjustment model to detrend the time-series data. In the functional specification of the dynamic optimization model of energy consumption, T not only stands for the technology, it also functions to detrend the data series in the regression. After we modify the partial adjustment model, the models are:

$$EI_t = \alpha + \beta T + \lambda EP_t + \gamma MP_t + \varepsilon K_{t-1} / GDP_t + \omega SL_{t-1} / GDP_t \quad (4)$$

$$\ln EI_t = \alpha + \theta T + \beta \ln EP + \delta \ln MP + \lambda \ln GDP + \gamma \ln EI_{t-1}, \quad (6)$$

2.3 Decomposition of Own-Price Elasticity

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[1] We derived the short-run own-price elasticity of energy intensity as follows:
similar to the derivation of the short-run own-price elasticity of energy consumption of $\varepsilon_{EE}^{SR} = (\mathrm{EP/E}) * \mathrm{GDP} * \lambda$ we hold capital assets and skilled labor constant in the short run, the own-price elasticity of energy intensity is:
$\varepsilon_{EE}^{SR} = \Delta EI / \Delta EP * (EP / EI) = (EP / E) * GDP * \lambda = \varepsilon_{EE}^{SR}$.

The econometric models discussed earlier provide a way to measure the dynamic relationship between energy prices and energy intensity generally. However, energy intensity is not divisable, and its changes could be caused by two fundamentally different factors, final-demand shifts and real energy-efficiency improvements (production-technology improvements). In order to measure the potentially different effects of energy-price changes on these two energy-intensity-change components, we decompose the own-price elasticity of energy intensity. Conceptually, we think that part of the own-price elasticity change of energy intensity is due to the efficiency improvements and the remaining part is due to the structural shifts.

First, we decompose energy intensity changes. Assuming that there is neither a structural shift effect nor a technology-improvement effect on energy consumption, energy consumption grows at the same rate as GDP. In other words, controlling for the effect of the structural-shift effect and technology-improvement effect on energy consumption, energy consumption grows at the same rate, g, with GDP. We define this effect on energy consumption as pure growth effect. We decompose energy intensity changes as follows:

$$\begin{aligned} \Delta EI &= -EI_{t-1} g/(1+g) + \Delta E^{shift}/GDP_t + \Delta E^{improvement}/GDP_t \\ &= -E_{t-1} g/[GDP_{t-1}(1+g)] + \Delta E^{shift}/GDP_t + \Delta E^{improvement}/GDP_t \\ &= (-\Delta E^{growth} + \Delta E^{shift} + \Delta E^{improvement})/GDP_t \end{aligned} \tag{7}$$

where g is the growth rate of GDP;

ΔE^{shift} is the energy-consumption changes due to the final-demand shift effects;
$\Delta E^{improvement}$ is the energy-consumption changes due the technology-improvement effects, which, together with ΔE^{shift}, is from the SDA modeling;
E_t is the energy consumption at time t;
EI_t is energy intensity at time t;
GDP_t is the gross domestic product at time t.

ΔE^{growth} is the pure growth effect of energy consumption, net of structural shifts and technological improvements.

Hence, energy-intensity change is the joint result, with GDP at the current level, of three components of the energy-consumption changes: those due to the pure final demand growth, final demand shift, and technological improvements. The final-demand shift includes both structural shifts and final-demand growth. Pure final demand growth is the final demand growth, net of structural change. Hence, these two components of energy-intensity change are able to be integrated into the structural-shift effect on energy intensity. Mathematically, the relationship of the structural-shift effect on energy consumption with pure final-demand growth and final-demand shift effects is as follows:

$$\Delta E^{structural} = \Delta E^{growth} + \Delta E^{shift} \tag{8}$$

Then, the energy-intensity change is the sum of two subcomponents of the structural-shift effect and the technology-improvement effect.

$$\Delta EI = \Delta E^{structural} / GDP_t + \Delta E^{improvement} / GDP_t = \Delta EI^{structural} + \Delta EI^{improvement} \tag{9}$$

Second, we incorporate the decomposed energy-intensity changes into the dynamic optimization model.

$$EI_t = \alpha + \beta T + \lambda EP_t + \gamma MP_t + \varepsilon K_{t-1} / GDP_t + \omega SL_{t-1} / GDP_t \tag{4}$$

By incorporating a one-period lag into Equation 4 and calculating the first difference, we have:

$$\begin{aligned}\Delta EI = EI_t - EI_{t-1} = \beta + \lambda(EP_t - EP_{t-1}) + \gamma(MP_t - MP_{t-1}) + \varepsilon(K_{t-1}/GDP_t - K_{t-2}/GDP_{t-1}) \\ + \omega(SL_{t-1}/GDP_t - SL_{t-2}/GDP_{t-1})\end{aligned} \tag{10}$$

Incorporating Equation (9) into Equation (10), we have

$$\Delta EI^{structural} + \Delta EI^{improvement} = \beta + \lambda(EP_t - EP_{t-1}) + \gamma(MP_t - MP_{t-1}) + \varepsilon(K_{t-1}/GDP_t - K_{t-2}/GDP_{t-1}) + \omega(SL_{t-1}/GDP_t - SL_{t-2}/GDP_{t-1}) \tag{11}$$

Equation 11 shows that the overall energy-intensity change has a similar functional specification on the right-hand side as the overall energy intensity, while the dependent and independent variables are not levels at a given time but changes between two periods. Furthermore, we assume that both of the two models of energy-intensity changes due to structural shifts and technological improvements have the same functional specification as the overall energy-intensity change.

$$\Delta EI^{structual} = \beta_1 + \lambda_1(EP_t - EP_{t-1}) + \gamma_1(MP_t - MP_{t-1}) + \varepsilon_1(K_{t-1}/GDP_t - K_{t-2}/GDP_{t-1}) + \omega_1(SL_{t-1}/GDP_t - SL_{t-2}/GDP_{t-1}) \tag{12}$$

$$\Delta EI^{improvement} = \beta_2 + \lambda_2(EP_t - EP_{t-1}) + \gamma_2(MP_t - MP_{t-1}) + \varepsilon_2(K_{t-1}/GDP_t - K_{t-2}/GDP_{t-1}) + \omega_2(SL_{t-1}/GDP_t - SL_{t-2}/GDP_{t-1}) \tag{13}$$

(12)+(13),

$$\Delta EI^{structural} + \Delta EI^{improvement} = \beta_1 + \beta_2 + (\lambda_1 + \lambda_2)\Delta EP + (\gamma_1 + \gamma_2)\Delta MP + (\varepsilon_1 + \varepsilon_2)\Delta(K/GDP) + (\omega_1 + \omega_2)\Delta(SL/GDP) \tag{14}$$

Finally, we have

$$\lambda = \lambda_1 + \lambda_2 \tag{15}$$

Therefore, the own-price elasticity of energy intensity is decomposed into two portions: (1) the portion due to efficiency improvements, and (2) the portion due to structural shifts, with the two-portion method being jointly exhaustive and mutually exclusive. Here, structural shift refers to the structural shift of final demand, instead of the structural shift among different production sectors, which analysts we normally use. The structural-shift effect is the final-demand shift effects net of pure growth effect. Under the

SDA modeling framework, it is similar in concept to the sum of the final-demand distribution and pattern effects, that is, the final-demand effect net of final-demand level effect.

As stated earlier, we expect a negative short-run own-price elasticity of energy intensity of β, which means that at least one of the decomposed coefficients in the two-portion approach is negative. Ideally, the short-run own-price elasticity of energy intensity due to efficiency improvements of β_1 is negative. This means that the increase of energy prices induces production-technology improvements (energy- efficiency improvements) and hence energy savings. Consequently, energy intensity declines with energy-efficiency improvements. In short, energy prices are negatively related to energy intensity through their inducement effect on energy efficiency. We also expect a negative expectation of the coefficient estimate of energy prices in the model for energy intensity changes due to the structural shift. Popp's study on U.S. patents (2002) shows that energy prices have strongly significant positive effects on innovations in energy-saving technology.

2.4 Data Sources

In this study, we obtained all the data for the econometric models from published statistical or census books.[2] The 1980-2002 time series for modeling of the overall

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[2] Books include the *China Energy Databook* by China Energy Group at the University of California, Berkeley, the annual *China Statistical Yearbook*, *China Labor Statistical Yearbook*, *China Population Statistical Yearbook*, *China Census Booklet 1982* (Zhongguo 1982 Nian Ren Kou Pu Cha Zi Liao), and *China Science and Technology Statistical Data Book*. In order to keep consistency in terms of sector classification, measurement coverage, and statistical method as much as possible, we mainly use data from various editions of the *China Statistical Yearbook*. We obtain some figures for several data series

economy and the industry sector are annual. Four IO tables in 1990 constant prices and energy-flow data of coal, crude oil, refined oil, natural gas, and electricity are for 1981, 1987, 1992, and 1995, which our colleague, Professor Chen Xikang at the Chinese Academy of Sciences, generously provided. We obtained coke-flow data mainly from various editions of *China Statistical Yearbook and China Energy Statistical Yearbook*.

3 Decomposition of Energy Consumption

We now present the results of the energy decomposition calculations both for the final-demand shifts and the production-technology change effects.

3.1 Energy Effects of Final-Demand Shifts

Generally speaking, China's total energy consumption has been increasing from 602.8 Million tones of standard coal equivalent (Mtce) in 1980 to 1482 Mtce in 2002 (CSB, 2004). However, China's energy consumption has grown more slowly than its output during the last two decades and even decreased in the late 1990s. From this point of view, China has experienced a process of energy saving. However, there may be two different factors driving it: final-demand shifts and production-technology improvements.

We use the SDA analysis to explore how much each of the two factors impacts the energy consumption in China during each period with available data (1981-1987, 1987-1992, and 1992 to 1995). The resulting final-demand shift effects on energy

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from other data source when they are not available in the *China Statistical Yearbook*, for example, the skilled labor amount in 1982.

consumption not only include the direct energy-use changes by final consumers, but also changes in intermediate or indirect energy use induced by changes in the demand for both energy and non-energy products of final consumers. (Lin, 1996

Decomposition results (Table 1) show that most of the energy consumption changes are due to final-demand shifts, which have raised energy consumption in China. In the period of 1981-1987, if China had used 1981 technology to deliver 1987 final demand, China's final-demand shift, in total, would have raised its energy consumption by 506.6 Mtce, among which 92.0% would be due to the indirect energy-demand effect of final-demand shifts. In China, it is primarily the changes in non-energy consumption of final consumers that have raised the total energy consumption in China, but this has occurred indirectly.

Table 1 Decomposition of China Energy-Consumption Changes (Mtce)

	Energy use changes ΔE	Final demand shift FR[Y - YR]	e[Y– YR]n	Production-technology change [F - FR] Y
1987-1981	267.9	466.2	40.4	-238.7
1992-1987	222.1	428.8	4.0	-210.7
1995-1992	218.0	457.7	3.7	-243.4

Source: the author

Note: The difference between the results of SDA modeling and the results from published energy data from China Statistical Yearbook is due to allocation errors.

3.2 Energy Effects from Technological Improvements

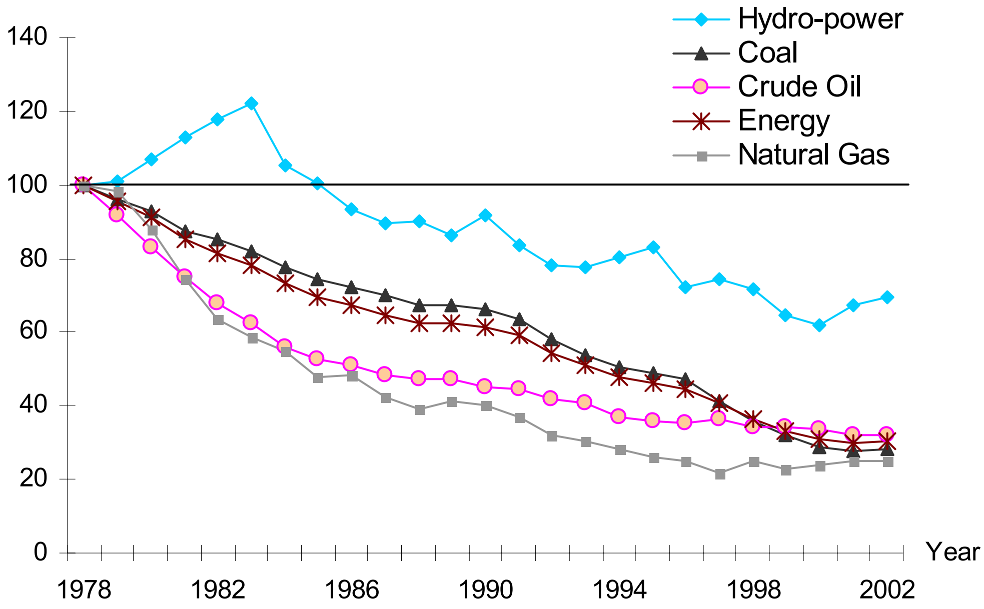
We use a production-input mix to describe production technology for a particular product sector, which refers to a column of direct input or technical coefficients of that product sector in IO models. We obtain the technical coefficients for a particular sector by dividing each element in the column of that sector by the total output for that sector. (Polenske and Fournier 1993) A systematic tabulation of production-input mixes of all production sectors of an economy provides a concise and detailed description of the technological structure of the economy at a given time. (Leontief 1958) Production-technology changes alter the input requirements of direct-energy inputs and also other non-energy intermediate inputs.

Compared to the increasing effects of final-demand shifts, China's production-technology improvement had negative effects on energy consumption (Table 1), helping China saved energy in the 1980s and early 1990s. The improvement of production technology in 1987 over that of 1981 helped China save 238.63 Mtce of primary energy in the process of delivering 1987 final demand. In other words, if the production technology had not improved from its 1981 level to the 1987 level, China would have consumed, in addition to the final-demand effect, 238.63 Mtce more energy than it consumed in 1981 in order to meet all the 1987 realized final demand. Similarly, for the periods of 1987-1992 and 1992-1995, the figures are 210.75 and 243.42 Mtce, respectively. Thus, the ratios between the final-demand-shift effect and the production-technology-improvement effect are 2.12:-1, 2.05: -1, and 1.9:-1 for the periods of 1981-1987, 1987-1992, and 1992-1995, respectively. Within any time period, production-technology improvements significantly decreased the energy consumption, but these effects on energy consumption are not as large as those of final-demand shifts. Over time, the production-technology effect on energy consumption was larger in early 1990s than that in the1980s.

4. Hypothesis Testing

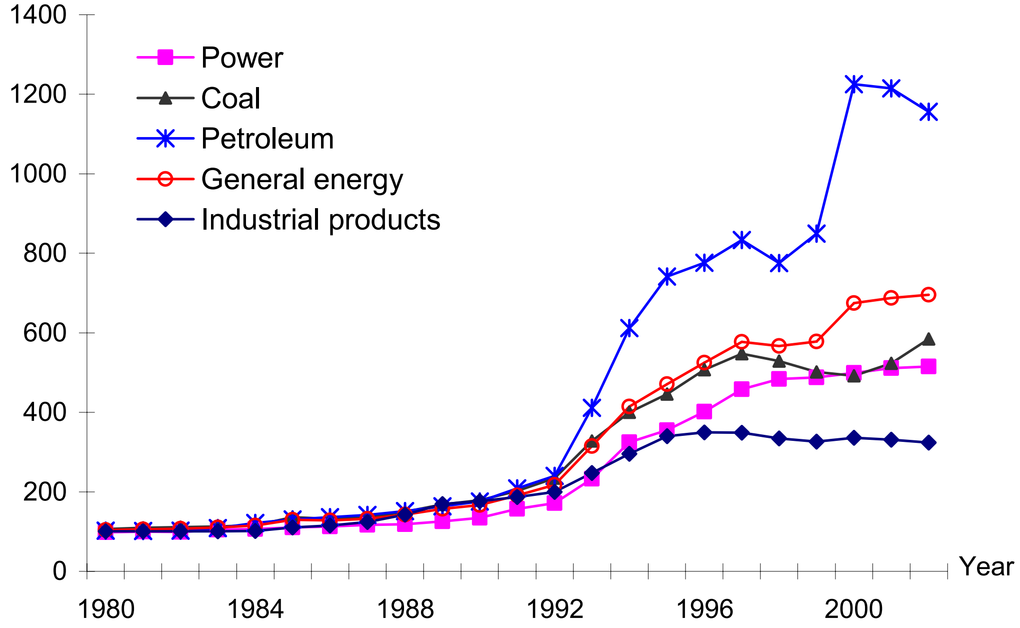
In China, the overall energy intensity in 2002, which is .46 ksce (kilogram standard coal equivalent) per RMB (ren min bi), was 70% less than the one in 1978, while, energy prices increased generally over time (Figure 1). The price increases changed the previous situation before the pricing-system reform, when coal prices were usually lower than the equilibrium prices and even than the production costs of coal (Changle, Yan, and Zhilin, Zhao 2003).

Figure 1 China's Energy-Intensity Index, 1978- 2002, 1978=100



Source: China Statistical Yearbook 2003.

Figure 2 China's Energy-Price Indices by Energy Type, 1980-2002, 1980=100



Source: China Statistical Yearbook 2003

Note: We calculated the aggregate (general) energy prices using the weighted average of four types of primary energy and three energy-price indices, coal consumption for the price index of the coal industry, hydro-power consumption for the electricity industry, and crude oil as well as natural gas consumptions for that of the petroleum industry. We assume that the differences of hydro-power prices and thermal power prices are zero.

4.1 General Relationship in the Overall Economy and the Industry Sector

Generally speaking, all regressions of the functional specifications and for the overall economy and the industry sector are statistically significant. Each of the regressions has an equation F-statistic value larger than the critical values at the .05 significance level. However, some of the individual parameters are not statistically significantly different from zero even at the 0.2 significance level. We will primarily discuss the parameters of energy prices.

In the partial-adjustment models for the overall economy, the t-statistics of the parameter estimate of the log energy prices is less than its critical value at the 0.1

significance level, with 17 degrees of freedom, and we cannot reject its null hypothesis; while in the dynamic optimization model for the same overall economy, the t-statistic of energy prices is larger than their corresponding critical value even at the .05 significance level, and we can reject the null hypothesis of the zero parameter of energy prices. We prefer the results of the dynamic model because we use the energy price index in the industry sector to approximate the prices for the overall economy. In China, energy prices are differentiated among different users. For example, residential consumers face different energy prices from the consumers in the industry sector. The dynamic model is more complex and includes two other important quasi-fixed assets in the model, which control for the effect of other variables on energy intensity when measuring the effect of energy prices.

Turning to the industry sector, we find that the regressions also present perplexing results, as those of the overall economy do, but the results are opposite. We can reject the null hypotheses about the zero parameter of the energy prices in the partial-adjustment models, while we cannot reject them in the dynamic model without policy change as regressors. Personally, we think the results from the partial-adjustment models are more reliable for the industry sector. The reasons are again related to the limited data availability, data assumptions, and the model features; for example, we assume a fixed distribution of national skilled labor among sectors, which is problematic. We think that the dynamic model is more reliable for the overall economy, while the partial- adjustment model is preferable for the industry sector.

Crossing the two sectors and the two basic models, we have the following results. First, the energy-price deregulation of the central government does not have a significant effect on energy intensity not only in the overall economy but also in the industry sector. At the 0.1 significance level, we cannot reject the null hypotheses about the zero parameter of the policy-change dummy variable with the post-deregulation as well as about the zero parameter of the interaction term of the dummy variable and energy prices. This result is opposite to the expectation that after deregulation the economy would present a higher elasticity of energy intensity with respect to energy prices, because energy prices before deregulation were lower than the production cost for a long time due to China's intention to protect general growth. Although the policy- change measures are not significant, we stress one point. The rejection of the null hypotheses related to policy changes depends on the level of predetermined significance level and the sector.

Second, at the .05 significance level using the Chow-test, we cannot reject the null joint hypotheses about the stability of parameters over time within each of the two economic sectors. We find the null hypothesis to be valid in the overall economy and in the industry sector when using both of the basic models. This is consistent with the test results of the non-rejected null hypothesis of the zero parameters of the policy change and the interaction term. We are 95% confident that the economy's reaction to energy-price changes persisted over time.

Third, the overall economy and the industry sector are different in terms of the degrees of the reactions to the energy-price changes in the process of using energy. Compared to the own-price elasticity of the energy intensity in the overall economy, the one in the industry sector is higher. The regressions show that the industry sector has a short-run own-price elasticity of energy intensity of -0.29, according to the partial-adjustment model, while the overall economy has one of -0.13 on average, according to the dynamic optimization model. Both of them are in the reasonable range. In the long-run, the own-price elasticity for the industry sector is -0.78. For the overall economy, we cannot derive the long-run elasticity. We prefer the dynamic optimization model for the overall economy, and we apply only the short-run specification in this study on China's energy intensity due to limited data availability.

4.2 Energy Efficiency and Energy Prices

We define production technology to be the input requirements for a unit of production of a particular product sector. Usually, analysts define energy efficiency as the energy requirement for a unit of production or product output per unit of energy input. Thus, any changes in technological coefficients for a particular product sector will lead to changes in energy efficiency. In this sense, the energy-efficiency effect on energy consumption is the same as the technology-improvement effect.[3] This measurement of energy-efficiency effects on energy consumption reflects the managerial and technical features at a given time.

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[3] Starting from here, we use the term "energy-efficiency effects" instead of "production-technology-improvement effects".

In order to get the estimation of the annual effects of structural shift and energy-efficiency-improvement effects on energy intensity, we assume that within any period both the structural shifts and production-technology improvements possess a simple linear-growth trend in terms of their individual effects on energy consumption. After decomposing the energy intensity for the overall economy, we use the dynamic optimization model for the decomposition study since the overall economy prefers the dynamic optimization model as this study shows earlier. The regression results show that the three models of overall energy-intensity change and its subcomponent are statistically significant at the 0.1 significance level.[4] In the modeling for the own-price elasticity of energy intensity due to the energy-efficiency improvement, the coefficient estimate of energy prices is statistically significant at the .05 significance level. The short-run own-price elasticity of energy intensity due to efficiency improvements is negative, around .19 in absolute value on average over the years from 1981 to 1995, while the own-price elasticity for the overall energy intensity over the same period is -.25 on average. Hence, we show that the technology-inducement effect of energy prices on energy intensity is the primary factor representing the own-price effect on energy intensity. By contrast, the coefficient estimate of energy prices in the modeling of energy intensity changes due to the structural shift is not statistically significant at the 0.1 significance level.

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[4] To be exact, the regression of energy-intensity changes due to the technology-improvement effect has an equation F-statistic value of 0.115 at the 6 and 8 degrees of freedom level.

Table 3: Decomposition Regression for the Overall Economy, 1981-1955

	EI	EITS	EIT	EIS
C	7.39			
T	-0.27	-0.29	-0.28	-0.01
EP/CEP	-.0215(6.1).0	-.0187(2.9).02	-.0185(2.8).02	-0.0002(.17).87
MP/CMP	.0076(.85).4	0.0088(1).4	0.0086(.93).38	0.0001(.1).9
ST/CST	18.6(4.6).0	17.4(3.1).01	13.1(2.3).05	4.2 (5.2).0
SL/CSL	3.(1.2).3	1.8(.65).53	1.1 (.4).7	0.7(1.7).13

Source: the author

Notes: Each set of three figures are, respectively, the coefficient estimate, t-statistic value, probability of that coefficient to be zero.

The sum of each set of decomposed coefficient estimates is not equal to its corresponding estimate according to the original/non-decomposed energy-intensity data. This is different from the ideal case due to effects of error terms.

Hence, energy price increased induced energy-efficiency improvement and contributed to the decline of energy intensity in China from 1981 to 1995. However, the own-price elasticity of energy intensity due to energy-efficiency improvements maybe upwardly biased. The exactness of this finding relies on the decomposition of energy-consumption changes, on which the fineness of production industry classification in the IO tables has an impact. Lin (1996) points out that some of the final-demand-shift effect at a finer level of sectoral classification on energy savings may be accounted for by technological changes.

5 Summary and Conclusion

China’s energy-intensity decline is of considerable importance for China and the global environment (Garbaccio, et al., 1999). In this paper, we primarily examine the hypothesized negative relationship between energy prices and energy intensity in China, taking account of the continuously declining energy intensity and the increasing energy prices in the real world. We have noted a shortage in analytical studies of such a relationship although there are many discussions on energy intensity of China..

We examine this topic in a systematic way. We use the own-price elasticity of energy intensity as the indicator for this relationship between energy intensity and energy prices. Besides the revised empirical models of energy intensity, we also propose a decomposition approach of own-price elasticity of energy intensity, which utilize the results from the IO-based SDA modeling. We investigate the possible different relationships between energy prices and energy intensity for the overall economy and for the industry sector. We also examine the possible different reactions towards the changes in energy prices between total energy intensity and energy efficiency, that is, energy intensity subject to energy-efficiency/production-technology-improvement impacts.

Generally speaking, the results of studies on China's energy over the last two decades confirmed the hypothesis that China's energy intensity was negatively correlated with energy prices, which is consistent with Kaufmann's findings (2004) for the United States. The short-run inelasticity of energy intensity with respect to energy prices existed not only in the overall economy but also in the industry sector, while the one in the overall economy was less in absolute value than the one in the industry sector. The industry sector was more sensitive to the changes of energy prices than the overall economy in terms of the intensity of using energy to make products. In the short-run, the own-price elasticity of energy intensity for the overall economy on average is -0.13, while that for the industry sector is -0.29. In the long run, the own-price elasticity of energy intensity for the industry sector is -0.78. In addition, we find that energy prices have an inducement effect on energy-efficiency improvement. Energy intensity varies statistically significantly with energy prices through the price-inducement effect on energy efficiency. For 1981 to 1995, the decomposed short-run own-price elasticity of energy intensity due to energy-efficiency effects for the overall economy is around -0.19 on average, whose corresponding total own-price elasticity is -0.25. Energy-intensity declines are not independent of energy prices in China.

Other findings include the following three points. First, in China, the energy-price effect on energy intensity was persistent over time from 1980 to 2002 and the own-price elasticity of energy intensity did not depend on whether or not energy pricing was controlled by Chinese central government. Second, energy-price changes did not have a statistically significant impact on energy intensity subject to structural shifts of final demand. The first two are different from our expectation. Third, the decomposition of China's energy- consumption changes over the three time periods, from 1981 to 1987, from 1987 to 1992, and from 1992 to 1995, show that the negative effect of production-technology changes on energy consumption. It also show that the effects of final-demand shifts were positive but the effect of final-demand shifts net of GDP growth, that is, the structural-shift effect of final-demand was negative. Thus, energy consumption in China grew but at a lower rate than GDP did in the last two decades. These findings confirm that energy consumption continued the 1980s style in the 1990s.

China’s economy has been growing at a high rate of 9% and was the second largest energy consumer globally after the United States in 2002. China’s energy consumption was 43 quadrillion Btu (EIA, 2005), accounting for 15% of total world energy consumption. How China consumes its energy, or how China’s energy consumption grows compared to its GDP, is very critical for the whole world. In the past two decades, China’s energy intensity has continuously decreased. We have shown that energy price increases played an important role in that process.

Historically, we want to understand the energy intensity decline in China, especially when China’s economy is becoming more and more involved in the global market. For example, growth of China’s coke output is making China a major supplier in the world coke market. China’s domestic coke prices are equivalent to its international prices (Polenske, forthcoming). China’s energy prices are not only determined domestically, but they also extensively influence and are influenced by the international market. Incorporating energy prices in the forecasting models of energy consumption, energy conservation, and carbon emission is critical. The type of good understanding of the relationship between energy intensity and energy prices we have created by this study helps to improve the credibility of future projections.

In addition, this study has some policy implications. First, results show that the industry sector is more sensitive to changes in energy prices than the overall economy with respect to energy intensity. This implies that the non-industry sectors less sensitive than the industry sector regarding the relationship between energy intensity and energy prices. According to this, energy-policy makers need to differentiate their policy packages among different sectors. Energy-related policies and programs could be adjusted according to energy price changes and budget needs over years.

Second, compared to the final-demand-shift effect and also the final-demand-*structural*-shift effect, production-technology improvement had a more significant negative effect on energy consumption based on our study of China's energy use from 1981 to 1995. The energy-intensity decline was not so much a result of economic development with final-demand-structural shifts and production-structural shifts, as it is the product of production-technology improvements. In addition, final-demand's pure growth, which increases the welfare of residents, had a larger impact on energy-consumption changes than the other component of final-demand shifts, that is, the final-demand's structural shift. Energy policymakers need to concentrate on the promotion of production-technology improvements, which results in energy consumption decline indirectly. However, it is foreseeable that the direct consumers of energy, residential household and public agencies, will use more energy among all the direct and intermediate energy consumers in the near future when Chinese living standard gets improved more. Then, final-demand structural shifts may have a larger impact on energy-consumption changes. For example, more and more households own and use their family cars. Energy-policy guiding final users to shift their expenditure patterns towards energy savings and to adapting energy-efficient household appliances and facilities are also necessary from now on.

Third, energy prices had an inducement-effect on technology and innovations. This inducement effect of energy prices on technology was the major factor, which contributed to the decline of energy consumption and energy intensity in China from 1981 to 1995. Energy policy makers need to define packages that target means of facilitatating innovation and also technology dispersion and adoption with consideration of the inducement effect of energy prices.

In our study, we identify issues and raise questions rather than provide precise answers. The study is exploratory. Ideally, the insights gained will constitute the basis for a later, more comprehensive, research effort. We believe that this study at least provides us a guideline or a warning sign to include energy prices in the analytical framework for future studies on energy intensity, energy consumption, carbon emission, energy conservation, and energy securities, etc. It also sheds light on the consideration of the energy-price factor in the policymaking process concerning energy and provides a set of tools for future studies.

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