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Energy Efficiency Improvement and Technical Changes in Japanese Industries, 1955–2012*

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Abstract

The purpose of this paper is to analyze the sources of energy efficiency improvement in Japanese industries over the period 1955-2012, based on the new estimates of substitutions of KLEM (capital, labor, energy, and materials) inputs and the biases of technical changes. The first advantage of our analysis is that we apply the framework of econometric modeling developed in Jin and Jorgenson (2010), which provides a more flexible treatment of technology as an unobservable or latent variable. The second advantage is that we develop industry-level data of the quality-adjusted outputs and KLEM inputs for 35 non-government industries in Japan, maintaining as much consistency as possible with the Japanese System of National Accounts.

Our industry data indicate that energy efficiencies in most Japanese industries worsened before the oil embargo in 1973, reflecting the stabilization of oil prices relative to the increasing prices of capital and labor. The period from the mid-1970s to the mid-1980s was the golden age, in which energy efficiencies improved considerably mainly due to the substitution effects caused by the rapid increases in energy prices. The opportunities to involve the energy-saving technical change diminished until the late 1990s, and the bias of technology changed to energy-using in the 2000s in most industries. This indicates that it will be much harder for Japanese industries to improve their energy efficiencies in the future, compared to the past experiences during the golden age, not only from higher costs for substitutions from energy to other inputs, but also from our projected bias of technical changes for energy until 2030.

Keywords: Energy efficiency, Energy intensity, Productivity

JEL classification: C32 L16 Q41

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1 Introduction

A reduction in CO_2 emissions has been an important policy target of the Japanese government since the mid-1990s. In order to describe an ambitious target for future CO_2 emissions[1], the government has expected a radical improvement in energy efficiencies in the private sector regardless of a shortage of effective policy tools (Nomura, 2015). As a result the actual energy demands has exceeded the level projected by the government, except during the periods of the global financial crisis in 2008 and the Great East Japan Earthquake in 2011. Due to the Fukushima Daiichi nuclear accident in March 2011, all nuclear power plants are not in operation at present. Thus the Japanese economy has to rely too heavily on thermal power. In fiscal year 2013, the share of thermal power equals 88.3 percent of the total electricity generation, compared to 61.7 percent in fiscal year 2010, according to the survey of The Federation of Electric Power Companies of Japan. In fiscal year 2013, the Japan's CO_2 emission from energy uses reached 1,224 million t-CO_2, which is 15.6 percent larger than the 1990 level (1,059 million t-CO_2) and the largest emission record in Japanese history. This supply-side constraint is going to call for a larger demand-side effort at present.

Corresponding to the spike in oil prices since the first oil embargo in 1973, the Japanese economy has succeeded in saving energy in both the production and the household consumption sides. The energy intensity at the aggregate level, which is defined as a ratio of the final energy consumption per GDP at constant prices, has improved by about 40 percent for almost four decades from 1973 to 2012. Some of this might be due to the Energy Conservation Law (Act on the Rational Use of Energy) established in 1979. However, while the speed of improving energy efficiency has considerably declined since the 1990s, the Japanese government has revised the Energy Conservation Law to foster energy-saving efforts in the private sector. To the companies that consume over 1500 kl in crude oil equivalent per year, the revised law has a target to encourage their voluntary efforts to improve energy efficiency by more than 1 percent per year on average. Too ambitious targeting may lead to an inefficient allocation of resources and contribute to the de-industrialization of the Japanese economy.

The purpose of this paper is to analyze the sources of energy efficiency improvement in Japanese industries over the period 1955–2012, based on the new estimates of substitutions of KLEM (capital, labor, energy, and materials) inputs and the biases of technical changes, in order to depict the possibility of the future improvement in energy efficiencies in Japanese industries. A first advantage of our analysis is that we apply the framework of econometric modeling developed in Jin and Jorgenson (2010), which provided a considerably more flexible treatment of technology as an unobservable or latent variable. The latent variables are separately estimated using Kalman filter, thus the biases of technical changes of KLEM inputs and the level of technology can change over periods. Based on our estimates of the price function, the changes in energy efficiency (as the inverse of energy intensity) can be decomposed to the two sources: the price change effect and the

[1] In June 2009, the cabinet of the Prime Minister Taro Aso, the leader of the Liberal Democratic Party, determined the CO_2 emission target as 8 percent reduction below 1990 levels by 2020. After the Democratic Party of Japan won the election in September 2009, the following cabinet of the Yukio Hatoyama revised this target upward to an unrealistic level of the reduction in CO_2 emissions by 25 percent below 1990 levels by 2020.

technical change effect.

A second advantage is that we developed the industry-level data of the quality-adjusted outputs and KLEM inputs for 35 non-government industries in Japan, maintaining consistency with the *Japanese System of National Accounts* (JSNA) as much as possible, covering a long-term period including the period of Japan's rapid economic growth during the 1950s and the 1960s. In order to estimate the impact of the price change in energy, it is important that the price changes of other inputs, especially labor and capital, be taken into consideration. The capital inputs in our data are measured by 95 categories of 82 tangible assets, 6 intellectual property products (market and own-account R&D, 3 types of software, and mineral exploration), 3 types of inventory, and 4 types of land by industry. The labor inputs are measured by 440 categories, cross-classified by gender (2), age (11), educational attainment (4), and employment status (5) in each industry.

The remainder of this paper is organized as follows: Section 2 presents our methodological framework. In Section 3 we outline our data construction. The estimated results are presented in Section 4. Section 5 concludes.

2 Framework

2.1 Price Function and Energy Intensity

The production function with the KLEM inputs is defined as

(1) $$Q_{n,t} = f\left(K_{n,t}, L_{n,t}, E_{n,t}, M_{n,t}, t\right) \qquad (n = 1, \cdots, 35),$$

where Q is the quantity of output, K, L, E, and M are the quantities of KLEM inputs which are capital, labor, energy and materials, respectively. The subscript n represents the industry number (see Table 1 for the industry list) and t the technology. Under perfect competition and the constant return to scale, we obtain the price function[2] such as

(2) $$P_{Q,n,t} = g\left(P_{K,n,t}, P_{L,n,t}, P_{E,n,t}, P_{M,n,t}, t\right).$$

The price function provides the unit output price as a function of the four prices of the KLEM inputs and technology (t). An advantage of the price function is that we can more easily derive the factor demand functions by partial differentiation doing a unit output price function at each factor price. Another advantage is that the price function can examine directly the influence to the factor demands by the changes in the prices of inputs. Thus, it is more convenient to analyze the substitutions among inputs and the technical change compared with the production function.

The standard translog price function is specified as follows:

(3) $$lnP_{Qt} = \alpha_0 + \sum_i \alpha_i lnP_{i,t} + \frac{1}{2}\sum_i \sum_j \beta_{i,j} lnP_{i,t} lnP_{j,t} + \alpha_T t + \sum_i \beta_{T,i,} lnP_{i,t} t + \frac{1}{2}\beta_{TT} t^2,$$
$$i,j = \{K, L, E, M\}, \ \ t = 1955, \cdots, 2012$$

where $\alpha_0, \alpha_i, \alpha_T, \beta_{ij}, \beta_{T,i}$ and β_{TT} are unknown parameters and estimated separately in each

[2] Jorgenson (2000) provided detail discussion about the property of duality between production function and price function.

industry. We omit industry subscripts for simplification. The parameter α_0 is a constant term, α_T is the parameter of time trend (t), and α_i are the elasticities of the factor inputs. The parameters β_{ij} are called share elasticities, when $\beta_{ij} = 0$, the price function in equation (3) corresponds to the Cobb-Douglas price function. The parameters β_{Ti} and β_{TT} are the biases of technical change with respect to each input price and the rate of technical change, respectively.

Some inflexibilities are pointed out in the model of equation (3). Firstly, all of the parameters are time invariant over the period. It seems to be a strict assumption especially for long time series data, and we need to check the validities of this assumption empirically. Secondly, although a time trend (t) is supposed to capture the technology as the linear and square of t, this treatment was restrictive to capture technical changes. We adopt the more flexible specification provided by Jin and Jorgenson (2010).

To solve the second problem, Jin and Jorgenson (2010) proposed a more flexible price function which includes latent or unobservable variables f_{it} and f_{pt} instead of a constant time trend (t). The variables f_{it} and f_{pt} are separately estimated using the Kalman filter, capturing the time-varying technologies in each industry.

$$(4) \quad lnP_{Qt} = \alpha_0 + \sum_i \alpha_i lnP_{i,t} + \frac{1}{2}\sum_i \sum_j \beta_{i,j} lnP_{i,t} lnP_{j,t} + \sum_i lnP_{i,t} f_{i,t} + f_{pt}, \quad i,j = \{K, L, E, M\}$$

where f_{it} stands for the biases of technical changes of *i*-inputs and f_{pt} stands for the level of technology. Using this price function, we show the cost share equation for the energy input by differentiating the price function with respect to the log of the energy price.

$$(5) \quad v_{Et} = \frac{P_{Et}E_t}{P_{Qt}Q_t} = \alpha_E + \beta_{KE} lnP_{K,t} + \beta_{LE} lnP_{L,t} + \beta_{EE} lnP_{E,t} + f_{Et}.$$

The latent variable f_{Et} represents the bias of technical change of energy and can be estimated every year. Holding input prices constant in equation (5), the difference of the share function between two periods is:

$$(6) \quad \Delta v_{Et} = f_{Et} - f_{Et-1}.$$

When f_{Et} is increasing in equation (6), the bias of technical change implies *energy using*, and if $f_{Et} - f_{Et-1}$ is negative, we understand that the bias of technical change is *energy saving*.

We define the *average energy intensity* (AEI) to use in our main analysis of section 4.2. Multiplying v_{Et} by P_{Qt}/P_{Et}, we can obtain AEI as following,

$$(7) \quad AEI = v_{Et} \times \frac{P_{Qt}}{P_{Et}} = \frac{E_t}{Q_t}.$$

Thus, by the estimations of the price function and share equations, we can decompose the AEI into the price change effect and the technical change effect by multiplying the both sides of $\hat{v}_{Et}$ by P_{Qt}/P_{Et}. We rewrite the AEI,

$$(8) \quad AEI = \hat{v}_{Et} \times \frac{P_{Qt}}{P_{Et}} = \frac{P_{Qt}}{P_{Et}}\left(\hat{\alpha}_E + \hat{\beta}_{KE} lnP_{K,t} + \hat{\beta}_{LE} lnP_{L,t} + \hat{\beta}_{EE} lnP_{E,t} + \hat{f}_{Et}\right),$$

where $\hat{v}_{Et}$ is the fitted value as the estimated result of equation (5), $\hat{\alpha}_E, \hat{\beta}_{KE}, \hat{\beta}_{LE}, \hat{\beta}_{EE}$, and $\hat{f}_{Et}$ are the estimates of unknown parameters. We define the technical change effect by $P_{Qt}\hat{f}_{Et}/P_{Et}$ in equation (8) and the sum of the remaining terms provides the price change effect.

Table 1: List of Industries

no.	Industry name	no.	Industry name
1	Agriculture, Forestry, and Fishery	19	Metal Products
2	Mining	20	Machinery
3	Construction	21	Electric Machinery
4	Foods	22	Motor Vehicles
5	Textile	23	Other Transportation Equipment
6	Apparel	24	Precision Instruments
7	Woods and Related Products	25	Miscellaneous Manufacturing
8	Furniture and Fixture	26	Transportation
9	Paper and Pulp	27	Communication
10	Printing and Publishing	28	Electricity
11	Chemical Products	29	Gas and Water
12	Petroleum Refining	30	Wholesale and Retail
13	Coal Products	31	Finance and Insurance
14	Rubber Products	32	Real Estate
15	Leather Products	33	Education and Research
16	Stone, Clay, and Glass	34	Medical Care
17	Iron and Steel	35	Other Service
18	Non-ferrous Metal		

2.2 Econometric Model

In order to obtain the estimators of the unknown parameters and latent variables f_{it} and f_{pt}, we added the disturbance terms ε_t^p and $\boldsymbol{\varepsilon}_t^v$ to the price function and input share equations, respectively. We show more compact vector notation for the price function and inputs share equations.

(9) $$lnP_{Qt} = \alpha_t + \boldsymbol{\alpha}' ln\boldsymbol{P}_t + \frac{1}{2} ln\boldsymbol{P}_t'\boldsymbol{B} ln\boldsymbol{P_t} + ln\boldsymbol{P}_t'\boldsymbol{f}_t + f_{pt} + \varepsilon_t^p$$

(10) $$\boldsymbol{v}_t = \boldsymbol{\alpha} + \boldsymbol{B} ln\boldsymbol{p}_t + \boldsymbol{f}_t + \boldsymbol{\varepsilon}_t^v$$

where $\mathbf{p} = (P_{Kt}, P_{Lt}, P_{Et}, P_{Mt})'$, $\boldsymbol{v}_t = (v_{Kt}, v_{Lt}, v_{Et}, v_{Mt})'$, $\boldsymbol{f} = (f_{Kt}, f_{Lt}, f_{Et}, f_{mt})'$ and $\mathbf{B} = [\beta_{ik}]$. ε_t^p and $\boldsymbol{\varepsilon}_t^v$ are random variables with mean zero and represent shocks which are uncorrelated with explanatory variables in each equation.

It is necessary to impose some restrictions on translog model to consider that the model is a production function by production theory. The restrictions are also reflected by the dual price function. The first restriction is the symmetry condition for the share of elasticities that is given as $\beta_{ij} = \beta_{ji}$. The homogeneity condition denotes $\alpha_K + \alpha_L + \alpha_E + \alpha_M = 1$ and $\sum_i \beta_{ij} = 0$ for each j that is the second restriction. Third restriction is concavity condition which is described $\boldsymbol{B} + \boldsymbol{v}_t\boldsymbol{v}_t' - \boldsymbol{V}_t$, where $\boldsymbol{V}_t$ is a diagonal matrix with the share of inputs. $\boldsymbol{B} + \boldsymbol{v}_t\boldsymbol{v}_t' - \boldsymbol{V}_t$ should be non-positive definite at each time (t) over the sample period.

Using the symmetry and homogeneity conditions, we can save the number of parameters to estimate. For the share equations, the value of shares $v_{Kt}, v_{Lt}, v_{Et}, v_{Mt}$ for each industry at time (t) sum to unity and the biases of technical change $f_{Kt}, f_{Lt}, f_{Et}, f_{mt}$ for each industry at time (t) must sum to zero. Similarly, using these assumptions, we can drop one share equation to estimate.

In the setting, $\boldsymbol{\varepsilon}_t^v$ are white noise, and f_{it} are stationary because of v_{it} are non-negative and sum to unity for each industry at time *t*. On the other hand, the price data are well known to have a strong time trend or unit root process. In this setting, because ε_t^p is white noise in the price function, it is more natural that the series of $\{f_{pt}\}$ has a tendency to be non-stationary. When $\{f_{pt}\}$ has unit-root process, the first difference $\Delta f_{pt} = f_{p,t} - f_{p,t-1}$is stationary[3], also $\{f_{pt}\}$ is expressed as a Vector Auto Regression (VAR).

To obtain the estimator for all unknown parameters in equations (9) and (10), we use Kalman Filter methods following Jin and Jorgenson (2010). We rewrite the model of both the price function and the share equations using the Kalman Filter approach. Equation (11) is called the state equation and equation (12) is called the observation equation.

$$(11)\quad \underset{(r\times 1)}{F_t} = \underset{(r\times r)}{\Phi}\underset{(r\times 1)}{F_{t-1}} + \underset{(r\times 1)}{u_t}$$

$$(12)\quad \underset{(n\times 1)}{y_t} = \underset{(n\times k)}{A'}\underset{(k\times 1)}{x_t} + \underset{(n\times r)}{H'}\underset{(r\times 1)}{F_t} + \underset{(n\times 1)}{\omega_t}$$

$$\mathrm{F}_t = \begin{bmatrix} 1 \\ f_{Kt} \\ f_{Lt} \\ f_{Et} \\ f_{pt} \\ f_{p,t-1} \end{bmatrix} \text{ and } \Phi' = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ \chi_K & \delta_{KK} & \delta_{KL} & \delta_{KE} & \delta_{Kp} & -\delta_{Kp} \\ \chi_L & \delta_{LK} & \delta_{LL} & \delta_{LE} & \delta_{Lp} & -\delta_{Lp} \\ \chi_E & \delta_{EK} & \delta_{Ep} & \delta_{EE} & \delta_{Ep} & -\delta_{Ep} \\ \chi_P & \delta_{pK} & \delta_{pL} & \delta_{pE} & \delta_{pp+1} & -\delta_{pp} \\ 0 & 0 & 0 & 0 & 1 & 0 \end{bmatrix}$$

denote a vector of latent variables about technology and unknown parameters of F_t, respectively. $y'_t = \begin{bmatrix} v_{Kt} & v_{Lt} & v_{Et} & ln\frac{P_{Qt}}{P_{Mt}} \end{bmatrix}$ is the vector of observations for the dependent variables. x'_t, A' and H'represent the vector of observations for explanatory variables, unknown parameters of x'_t and unknown parameters of F_t, respectively.

$$x'_t = \begin{bmatrix} 1 & ln\frac{P_{Kt}}{P_{Mt}} & ln\frac{P_{Lt}}{P_{Mt}} & ln\frac{P_{Et}}{P_{Mt}} & \frac{1}{2}\left(ln\frac{P_{Kt}}{P_{Mt}}\right)^2 & \frac{1}{2}\left(ln\frac{P_{Lt}}{P_{Mt}}\right)^2 & \frac{1}{2}\left(ln\frac{P_{Et}}{P_{Mt}}\right)^2 & ln\frac{P_{Kt}}{P_{Mt}}ln\frac{P_{Lt}}{P_{Mt}} & ln\frac{P_{Kt}}{P_{Mt}}ln\frac{P_{Kt}}{P_{Mt}} & ln\frac{P_{Lt}}{P_{Mt}}ln\frac{P_{Et}}{P_{Mt}} \end{bmatrix}$$

$$A' = \begin{bmatrix} \alpha_K & \beta_{KK} & \beta_{KL} & \beta_{KE} & 0 & 0 & 0 & 0 & 0 & 0 \\ \alpha_L & \beta_{KL} & \beta_{LL} & \beta_{LE} & 0 & 0 & 0 & 0 & 0 & 0 \\ \alpha_E & \beta_{KE} & \beta_{LE} & \beta_{EE} & 0 & 0 & 0 & 0 & 0 & 0 \\ \alpha_t & \alpha_K & \alpha_L & \alpha_E & \beta_{KK} & \beta_{LL} & \beta_{EE} & \beta_{KL} & \beta_{KE} & \beta_{LE} \end{bmatrix}$$

$$H' = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & ln\frac{P_{Kt}}{P_{Mt}} & ln\frac{P_{Lt}}{P_{Mt}} & ln\frac{P_{Et}}{P_{Mt}} & 1 & 0 \end{bmatrix}, \quad \omega_t = \begin{bmatrix} \varepsilon_{Kt} \\ \varepsilon_{Lt} \\ \varepsilon_{Et} \\ \varepsilon_{pt} \end{bmatrix}, \quad u_t = \begin{bmatrix} 0 \\ u_{Kt} \\ u_{Lt} \\ u_{Et} \\ u_{pt} \\ 0 \end{bmatrix}$$

The vectors of disturbances of ω_t and u_t were assumed to be random shocks in equations (9) and (10), so that they are uncorrelated each other at all lags. Q and R are covariance matrices of disturbances.

$$E(u_t u'_t) = \begin{cases} \underset{(r\times r)}{Q} & t=\tau \\ 0 & otherwise \end{cases}, \quad E(\omega_t \omega'_t) = \begin{cases} \underset{(n\times n)}{R} & t=\tau \\ 0 & otherwise \end{cases}$$

[3] This is, however, an empirical issue so that we will implement unit-root test for output price in Section 4.1.

The matrices of A, H, Φ, R, Q have unknown parameters, denoting the unknown parameters of the matrices by the parameter vector of θ. Kalman filter method is composed by two parts such as filtering and smoothing. In filtering, we assume the disturbances are normal distribution and use MLE method to estimate[4] the vector of unknown parameter of θ. The log-likelihood function is

$$\underset{\theta}{max}\, l(\theta|Y_t) = \underset{\theta}{max} \sum_{t=1}^{T} logN\left(y_t|\hat{y}_{t|t-1}, V_{t|t-1}\right),$$

where $Y_t = \left(y'_t, y'_{t-1}, \cdots, y'_1,\ x'_t, x'_{t-1}, \cdots, x'_1\right)$ and $V_{t|t-1}$ represents variance of y_t. The consistent estimators of mean and variance are

$\hat{y}_{t|t-1} = \mathrm{E}\left(y_t|y_{t|t-1}\right), V_{t|t-1} = E\left[\left(y_t - \hat{y}_{t|t-1}\right)\left(y_t - \hat{y}_{t|t-1}\right)\right]$. In filtering, we use the forward recursion to estimate θ and calculate the covariance matrix of $\hat{\theta}$ by numerical methods. In smoothing, we estimate F_t that is the vector of latent variables, given $\hat{\theta}$ using backward recursion[5].

In this framework, the explanatory variables of both price and share functions are KLEM inputs prices. It is difficult to say whether the prices are exogenous variables. Jin and Jorgenson (2010) attempt to avoid the endogeneity of the prices data, they modify the standard Kalman filter by adopting the instrumental variables z_t. We can rewrite the matrix of explanatory variables x_t,

$$\underset{(k\times 1)}{\hat{x}_t} = \underset{(k\times m)}{\Pi}\underset{(m\times 1)}{z_t} + \underset{(k\times 1)}{\eta_t}$$

where z_t are uncorrelated with η_t and ω_t, and η_t can be correlated with ω_t but is uncorrelated with u_t. We show the estimation procedures of Jin and Jorgenson (2010), as a first step, estimates $\widehat{\Pi} = \mathrm{X}\mathrm{Z}'(ZZ')^{-1}$ using OLS estimation to obtain the consistent estimator of Π, where X and Z are observation matrices of x_t and z_t. We prepared the same definitions of instrumental variables as Jin and Jorgenson (2010) employed using Japanese data. Table 2 shows the list of instrumental variables and we draw Figure 1 to know the behavior of changes at time for each instrumental variable. We use same instrumental variables set for 35 industries.

Table 2: List of Instrumental Variables

Instrumental variables	
1	Constant
2	Average Marginal Tax Rate on Personal Labor Income
3	Effective Corporate Income Tax Rate
4	Average Marginal Tax Rate on Dividends
5	Rate of Taxation on Consumption Goods
6	Time endowment in 2000 dollars / Lagged Private wealth including claims on government and the ROW
7	Lagged price of personal Consumptions Expenditure / Lagged price index of private domestic labor input
8	Lagged price of leisure and unemployment / Lagged price index of private domestic labor input
9	Lagged price of capital services for household / Lagged price index of private domestic labor input
10	Lagged real full consumption / Lagged private wealth including claims on government and the ROW
11	Population / Lagged private wealth including claims on government and the ROW
12	Governent Demand / Lagged private wealth including claims on government and the ROW

As second step, replacing X in the standard Kalman filter with $\widehat{\mathrm{X}} = \widehat{\Pi}\mathrm{Z}$, at time t, we replace x_t with fitted value $\hat{x}_t$ and implement the standard filtering to obtain two-step MLE of unknown

[4] Hamilton (1994) explain about the detailed of methods about filtering, smoothing and projection.
[5] See Hamilton (1994).

parameters[6] θ in A, H, Φ, R, Q. Using the results of two-step MLE, we estimate of the covariance matrix of θ numerically.

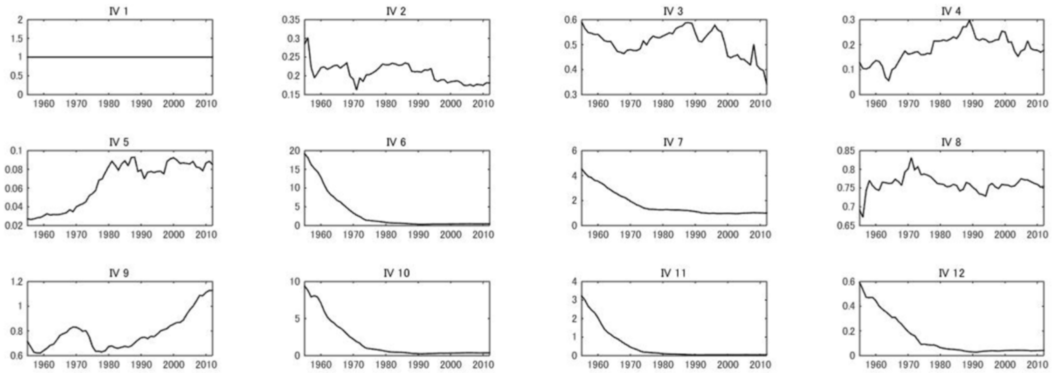

Figure 1: Instrumental Variables

3 Data

This section describes the data construction of outputs and KLEM inputs used in our estimation of price function by industry. The price and volume data of outputs and intermediate inputs (EM), labor inputs (L), and capital inputs (K) are discussed in the following three subsections, respectively.

3.1 Outputs and Intermediate Inputs

The industry-level outputs and intermediate inputs are provided by the time-series supply and use tables (SUT) we developed covering the period 1955–2012. Our SUT has 47 industries (including household sector as a producer) and 51 products (including 4 types of non-competitive imports for Japan).[7] The outputs, final demands, and value added in our SUT are basically consistent with the corresponding components in the *Japanese System of National Accounts* (JSNA) compiled by the Economic and Social Research Institute (ESRI) of the Cabinet Office.[8] However, since the latest 2005 benchmark JSNA (based on the 1993 SNA) are backwardly estimated only to 1980, our SUT was estimated on the basis of the past JSNA (based on the 1968 SNA) with some adjustments (i.e., capitalization of software, capital consumption for infrastructure[9], FISIM[10], and others[11]).

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[6] Wooldridge (2002) shows $\hat{\theta}$ is a consistent estimator of θ and its asymptotic normality.

[7] Although the documentation for the latest version of our SUT is not yet published, Kuroda, Shimpo, Nomura, and Kobayashi (1997) provides a detailed explanation of the estimation of time-series SUT for the Japanese economy. We basically follows this framework with some extensions (e.g. capitalization of R&D) and more harmonization with the JSNA-SUT.

[8] Our SUT has incorporated the commodity flow data from the JSNA. We are indebted to ESRI for the time-series commodity flow data from the JSNA.

[9] See Jorgenson and Nomura (2005) for the details on the adjustment process of capitalization of software and capital consumption for infrastructure. This led to revise the final demands and GDP in the past JSNA as well.

[10] In the JSNA, the Financial Intermediation Services Indirectly Measured (FISIM) was introduced in the 2005 benchmark JSNA, published as of the end of 2011. We estimate the output and consumptions of FISIM based on the data of imputed interests, which has been estimated in the past JSNA, to cover the whole observation periods. This

The use of the quality-adjusted prices for output and intermediate inputs is of importance in estimating the price function to control for quality changes in products over periods. The Bank of Japan (BOJ) produces the *Corporate Goods Price Index* (CGPI), a system which is similar to the *Producer Price Index* (PPI) constructed by the U.S. Bureau of Labor Statistics (BLS). Although the current CGPI provides good estimates of the quality-adjusted prices, the past estimates were not fully adjusted the quality changes in products. Compared to the U.S. PPI by BLS, some adjustments are required for Japan's data, especially in computers. We use the prices, in which that the quality changes in Japan's computers were backwardly corrected as much as possible (Jorgenson and Nomura, 2005).

A new improvement is that our SUT are recompiled to be evaluated at basic prices, applying the framework in Nomura, Miyagawa, and Okamoto (2014). The consumption tax was first introduced in Japan in April 1989. Both deductible and non-deductible consumption taxes are included in indirect taxes in the official benchmark input-output tables and production accounts in the JSNA. This is a large obstacle in productivity analysis for the Japanese economy. By removing the impacts of the consumption tax in our measures of prices and volumes for outputs and intermediate inputs, the noises by the changes in the consumption tax rate are expected to be eliminated in our estimation of price function.

The price for energy inputs is measured by means of the translog index from the prices including indirect taxes on domestic products and imports (excluding deductible consumption tax) of petroleum products, coal products, electricity, and gas. The price for material inputs is measured by the translog index from the prices of other goods and services. The output price is defined at basic prices, excluding indict taxes on products (excluding deductible and non-deductible consumption taxes and others).

3.2 Labor Inputs

For labor input, we use the new estimates of cross-classified labor data in Nomura and Shirane (2014), updated from the estimates in Kuroda, Shimpo, Nomura, and Kobayashi (1997) and Jorgenson and Nomura (2005). The data they developed consist of the number of workers, the hours worked per worker, and the hourly wage, which are cross-classified by five categories: gender (2 types), educational attainment (4), age (11), employment status (5), and industry (46, excluding household sector), totally 20,240 types of workers, during the period of 1955–2012. The sum of the labor income of employees for the whole economy consistently corresponds to the compensation of employees in the JSNA.

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led to revise the final demands and GDP in the past JSNA as well.

[11] In addition with the adjustment of the conceptual differences, we have to take some large revisions in the different benchmark JSNAs into consideration. For example, the imputed rent of owner occupied housings (OOH) was downwardly revised in the 2000 benchmark JSNA (it has been overestimated by about 20 percent in the past estimates). The adjustment in the past estimates of the imputed rent of OOH to sustain the consistency with this revision led to revise the household consumption and GDP in the 1990 benchmark JSNA. Another example is the work-in-progress inventory on cultivated assets, which was revised in the 2005 benchmark JSNA. Nomura (2006) pointed out the considerable overestimation of the stock of the work-in-progress inventory on cultivated assets in the 2000 benchmark JSNA. We replace the past estimates by the estimates in Nomura (2006).

Our previous estimates on labor inputs were based on a limited number of published cross-tabulations, supplemented by sample surveys of educational attainment. Nomura and Shirane (2014) have replaced these sources by custom-made tables with fully cross-classified data for 1980–2010 from the Japanese *Census of Population*. These tables have been compiled at five-year intervals by the National Statistics Center (NSTAC).[12]

By taking the changes in the composition of different types of labor inputs and its relative wages, which are assumed to reflect the differences in their marginal productivities, into consideration, the prices and volumes of the quality-adjusted labor inputs (QALI) are estimated by industry. The improvement in labor quality (i.e., higher education attainment, accumulation of work experience, and so on) is measured as an increase in volume of labor inputs, as the aggregate measures of the industry-level QALI. In other words, the improvement in labor quality is measured as a decline in the constant-quality price of labor inputs, since the total labor cost is unchanged. The use of the quality-adjusted prices of labor inputs expects to capture a better impact of labor cost in output price, in our estimation of price function by industry.

3.3 Capital Inputs

For capital inputs, we follow the framework in Nomura (2004) and update the estimates in Jorgenson and Nomura (2005) until 2012. The assets are classified by 95 categories s of 82 tangible assets, 6 intellectual property products, 3 types of inventory, and 4 types of land. Nomura (2004) developed the times-series gross fixed capital formation and stock matrices. Based on the similar framework, the official capital stock estimates was fully revised in the 2005 benchmark JSNA, published as of the beginning of 2012 by ESRI. Our estimate tries to a consistency with this revised estimates in JSNA. One of the key parameters in measuring capital stocks is depreciation rates by type of assets. The ESRI has developed their special surveys since 2006, in which the prices of many types of retired assets are collected.[13] We use new estimates developed by Nomura and Suga (2013) at ESRI in our capital measurement of produced assets.[14]

Another new feature in our capital measurement is that we capitalized research and development (R&D) by industry in our time-series SUT and capital services data in order to follow the SNA 2008. We developed the R&D investment series covering the period 1952–2012, based on the *Survey of Research and Development* by the Statistics Bureau of Japan, and estimated the time-series of capital stock and capital services by industry for 1955–2012. The prices for

[12] The NSTAC is an incorporated administrative agency, created in April 2003 as part of the central statistical organization in Japan. Unpublished tabulations of fully cross-classified data for Japan were made available through full implementation of the Statistics Act implemented in April 2009.

[13] The ESRI is going to incorporate new estimates on depreciation rates in the next 2011 benchmark revision of JSNA (based on the 2008 SNA), which is scheduled to be published as of the end of 2016.

[14] Nomura and Suga (2013) estimated asset lives and rates of depreciation for a very finely divided classification of assets. This classification distinguishes 369 asset types and uses data on retired assets collected in ESRI's Survey on Capital Expenditures and Disposals in Japan from 2006 to 2012. The survey collected observations on 838 thousand asset disposals from business accounts of private corporations. These data were used to estimate asset lifetimes. For about 60 thousand observations the assets were sold for continued use and the prices were used to estimate rates of deprecation. Based on this study, many of the depreciation rates what we employ are higher than those used in the JSNA.

own-account R&D are measured as the cost indices reflecting the differences in the input prices and the cost shares of capital, labor, and other intermediate inputs by industry. No TFP growths are considered.

In measuring capital services by industry, we assume the flow of capital services for each industry and each asset is proportional to the installed stock of capital. The ex-post rates of return are estimated by industry. Tax considerations also provide a key component of the prices of capital inputs, as described by Jorgenson, Ho, and Stiroh (2005) for the U.S. and Nomura (2004) for Japan.[15] By taking the changes in the composition of different types of capital inputs and its relative user costs of capital, which are assumed to reflect the differences in their marginal productivities of capital, into consideration, the prices and volumes of the quality-adjusted capital input are estimated by industry. Disaggregation of capital measurement enables us to estimate more properly the industry-level measures of price and volume for capital inputs. For example, an expansion of information and communication technology (ICT) capital, which have larger marginal productivities, from the late 1990s are measured appropriately as a higher growth in volume of capital input and a lower growth in price of capital by industry. The use of the quality-adjusted prices of capital inputs expects to capture a better impact of use cost of capital in output price, in our estimation of price function by industry.

4 Results

Based on the estimated results of the price function and share functions for Japanese economy, we address the advantages of new econometric model by Jin and Jorgenson (2010) in section 4.1. Section 4.2 analyzes the sources of energy efficiency improvement by industry over the period 1955–2012, based on the estimates on the price substitutions and the biases of technical changes.

4.1 Estimated Parameters

With the data set described in section 3, we apply the framework of econometric modeling of Jin and Jorgenson (2010) for Japanese industries. In the previous literatures, time trend (t) is supposed to capture the level of technology and equation (3) includes the linear and square of (t) with time invariant parameters. Compared to this restrictive assumption on technology, Jin and Jorgenson (2010) specified a more flexible treatment for the level of technology with f_{it} and f_{pt} in equation (4). These latent variables f_{it} and f_{pt} can capture time varying technical changes. In the case of the bias of technical changes for energy input, the estimates are shown in Figure 5 of section 4.2. We can see the estimates of f_{Et} change over periods in many industries. In particular, the changes in the period 1955–73, in which the energy price was more stable than other input prices, are significant. The estimates of f_{Et} declined in 31 of 35 industries, suggesting that these industries could benefit from energy-saving technical change in this period. This trend of our estimates in Japan is considerably different from the estimates of f_{Et} in the U.S., which are more stable as

[15] In measuring capital input in Japan, capital consumption allowances, income allowances and reserves, special depreciation, corporate income tax, business income tax, property taxes, acquisition taxes, debt/equity financing, and personal taxes are taken into account.

provided in the supplement of Jin and Jorgenson (2010).[16] It is more fruitful to apply the time varying technology model for analyzing the Japanese economy, which could enjoy the advantages of backwardness in the caching-up process.

For technical change f_{pt}, it is considered that the series contains a non-stationary process. It is well known that the price data has a strong time trend, drifts, or unit root process.[17] In the setting of Jin and Jorgenson (2010), ε_t^p is white noise in the price function, so that the series of f_{pt} should be non-stationary. When f_{pt} has unit-root process, the first difference $\Delta f_{pt} = f_{p,t} - f_{p,t-1}$ is stationary. Under the setting, they adopt the Kalman filter for non-stationary state space model. However, it is an empirical issue whether f_{pt} is non-stationary or not. We implemented the augmented Dickey-Fuller test for output price as a representative unit-root test.[18] The test results indicated that only 8. Furniture and Fixture was rejected the null hypothesis at 5 percent significant level and other 34 industries were not rejected. It should be appropriate to consider unit root process in f_{pt} for our dataset.

The input prices are treated as the explanatory variables in both of the price function and the input share functions. In general, it is natural to treat that the prices are endogenous variables because they are determined by the markets of products and factor inputs.[19] To solve the endogeneity problem, Jin and Jorgenson (2010) modified the standard Kalman filter using the instrumental variables (hereafter, IVs)[20] and tested the exogeneity of the IVs. We follow this idea that the input prices are endogenous variables, since the IV method provides consistent estimators whether input prices are endogenous or exogenous.[21] On the other hand, the OLS estimators are inconsistent while the prices are endogenous variables. We compared the actual dependent variables ($v_{Kt}, v_{Lt}, v_{Et}, v_{Mt}$, and P_{Qt}) and fitted variables of them graphically[22]. It seems that our estimation results fitted well to actual data.

By the estimation results of equation (4), the sign of the elasticities of each input (α_i) should be positive. The signs of the substitutions of capital, labor, energy, and materials inputs (β_{ij}) can be positive or negative. Table 5 shows the unknown parameters of the state-space model, with the standard errors of the estimates in the parenthesis.[23] Comparing the results of Jin and Jorgenson (2010), the magnitude of the estimators seems to be similar. The signs of parameters are

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[16] Jin and Jorgenson (2010) provides all estimation results in Table S1 and S2 of the supplement to their paper (www.economics.harvard.edu/faculty/jorgenson/).

[17] As well known, GDP, the stock price, the land price and money supply also have non-stationary process.

[18] The null hypothesis is that the output price contains a unit root, and the alternative is that the output price was generated by a stationary process. We also include four year lagged value and a trend term in the regression model of the null hypothesis.

[19] In the production function approach, we also face on the endogeneity problem. TFP is often computed as a residual from production function estimation so that as pointed out by Marschak and Andrews (1944) and subsequent papers, there can exist an endogeneity problem between the level of inputs and TFP (disturbance term).Several methods have been proposed to handle this endogeneity problem, such as Olley and Pakes (1996), Levinsohn and Petrin (1999, 2003), and Ichimura, Konishi, and Nishiyama (2011).

[20] They showed the two step MLE method to obtain the consistent estimator of unknown parameters.

[21] IV estimators are less efficient than OLS estimator, if the prices are exogenous.

[22] For more accurate statistical inferences, we should check the endogeneity problem using the Hausman test by industry. Based on the test results, we can select the standard Kalman filter or the 2 step-MLE based Kalman filter either.

[23] We estimated 65 unknown parameters, but show 31 parameters which are related with analysis in section 4.2.

interpretable for each industry, but we should note that the standard error looks bigger than we expected.

Table 3: Sings of Parameters for the Share Function of Energy

Industry	α_E	β_{KE}	β_{LE}	β_{EE}	Industry	α_E	β_{KE}	β_{LE}	β_{EE}
1.Agriculture, Forestry, and Fishery	+	+	+	−	19.Metal Products	−	+	+	−
2.Mining	+	−	+	−	20.Machinery	+	+	+	−
3.Construction	+	+	+	−	21.Electric Machinery	+	+	+	−
4.Foods	+	+	+	−	22.Motor Vehicles	+	+	+	−
5.Textile	+	+	+	−	23.Other Transportation Equipment	+	+	+	−
6.Apparel	+	+	+	−	24.Precision Instruments	+	+	+	−
7.Woods and Related Products	+	+	+	−	25.Miscellaneous Manufacturing	+	+	+	−
8.Furniture and Fixture	+	+	+	−	26.Transportation	+	+	+	−
9.Paper and Pulp	+	+	+	−	27.Communication	+	+	+	−
10.Printing and Publishing	+	+	+	−	28.Electricity	+	−	+	−
11.Chemical Products	+	+	+	−	29.Gas and Water	+	+	+	−
12.Petroleum Refining	+	+	+	−	30.Wholesale and Retail	+	+	+	−
13.Coal Products	+	−	+	−	31.Finance and Insurance	+	+	+	−
14.Rubber Products	−	+	+	−	32.Real Estate	+	+	+	−
15.Leather Products	+	+	+	−	33.Education and Research	+	+	+	−
16.Stone, Clay, Glass	+	+	+	−	34.Medical Care	+	+	+	−
17.Iron and Steel	+	−	+	−	35.Other Service	+	+	+	−
18.Non-ferrous Metal	+	+	+	−					

Table 3 shows the signs of parameter for the energy share function in equation (5) and (8). Our estimates of β_{KE} are positive in many industries. In these industries, capital and energy inputs are substitutable in our estimation period and the increase in energy price induces an increase in the cost share of capital (to save energy, more capital are required). On the other hand, in industries of 2. Mining, 13. Coal Products, 17. Iron and Steel, and 28. Electricity with negative estimates of β_{KE}, capital and energy inputs are complementary in our estimation period and the decrease in the price of capital brings out an increase in the energy cost share (capital requires more energy uses). In the case of labor and energy, our estimates of β_{LE} are positive for all industries, suggesting that the increase in wage stimulates the energy cost to increase. To foster the improvement in labor productivity reflecting the increase in wages, more energy inputs are required in our estimation period. In other words, the increase in energy price induces an increase in the cost share of labor (to save energy in business sector, more labor are required).[24]

4.2 Sources of Energy Efficiency Improvement

We begin with an observation of energy price changes over a half century in the Japanese economy, relative to the price changes of capital, labor, and materials. Figure 2 presents the changes in the KLEM Input prices at the aggregate level, by means of the translog indices from the industry-level price changes. We divide the whole observation period into three sub-periods. The first term (1955–73) is the period, in which energy prices are very stable, compared to high growth rates in the prices of the capital and labor inputs. In this period, the growth rate of Japanese GDP

[24] The parameters on the substitutions are assumed to be constant a priori in our model. It is one of the subjects in our further research to examine the accuracy of this assumption, especially over the different stages of developments of the Japanese economy.

averaged 10.6 percent per year, three times higher than the U.S. economic growth rate (3.8 percent), as described in Jorgenson, Nomura, and Samuels (2015). The second term (1973–91) includes two spikes in the oil prices as of 1973/74 and 1979/80 and the rapid decline of oil prices in the middle 1980s. Compared to the first period, the increases in the prices of capital and labor are considerably moderate in the second period. The third term (1991–2012) includes the spike of oil price in 2008 and the sharp decline of energy prices after the global financial crisis. The average growth rates of the prices for capital and labor inputs are almost zero and negative, respectively, in the period of the so called Japan's Lost Decade.

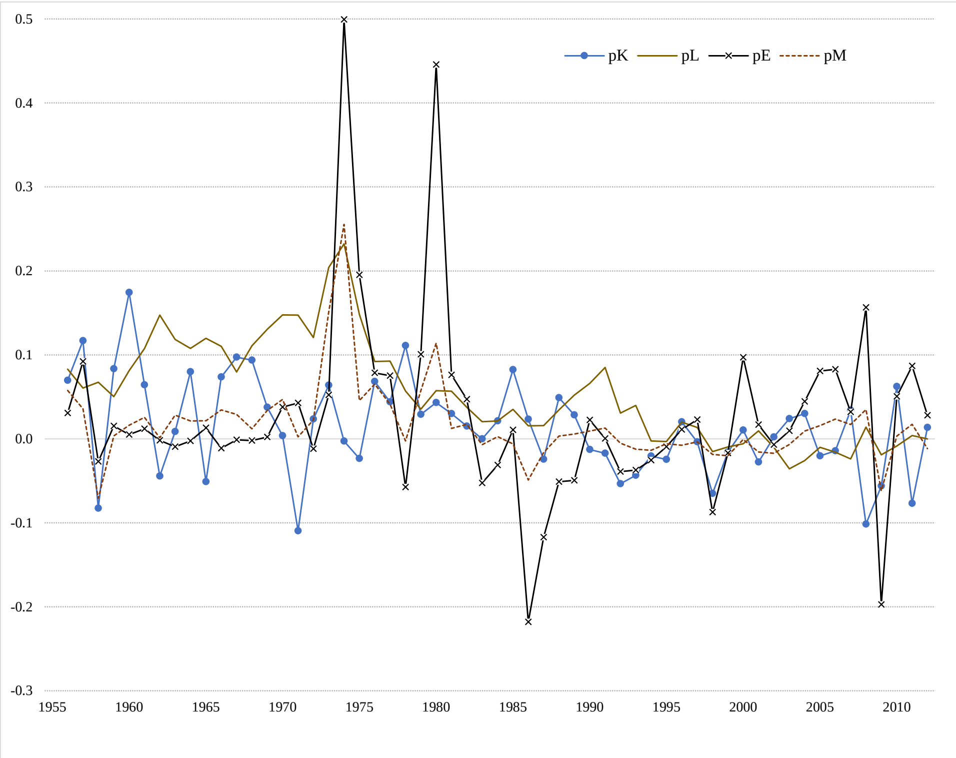

Figure 2: Changes in Aggregated KLEM Input Prices

As another observation at the industry level, Table 4 describes the energy cost shares and energy price changes relative to the price of capital inputs by industry. In the first period (1955–73), the energy price decreased relative to capital price in 26 of 35 industries. Reflecting the relative decline of energy to capital prices (2.6 percent decline per year on average) at the aggregate level, the energy cost share increased from 2.5 to 2.7 percent. In the second period (1973–91), the energy price increased by 2.8 percent on average per annum relative to capital prices at the aggregate level. A notable property is that the energy cost share declined from 2.7 percent in 1973 to 2.5 percent in 1991 at the aggregate level in this period, although 26 of 35 industries has increased energy cost shares. Figure 3 presents the annual changes in average energy intensities (AEIs) by industry in each of three sub-periods. As shown in the central figure for the period 1973–91, the energy efficiencies were improved (i.e., the AEIs were decreased) in most industries in this period. This second period is the golden age from the point of the view of the improvement in energy efficiency. In the final period of Japan's Lost Decade, the relative increase of energy prices with 3.0 percent per year has pushed up the energy cost share to 3.4 percent at the aggregate level.

Table 4: Energy Cost Shares and Price Changes Relative to Capital

	Energy cost share (vE)				Relative prices (pE/pK)		
	1955	1973	1991	2012	1955-73	1973-91	91-2012
1.Agriculture, Forestry, Fishery	0.007	0.014	0.019	0.044	-0.024	0.040	0.054
2.Mining	0.100	0.099	0.108	0.133	-0.070	0.060	0.084
3.Construction	0.012	0.016	0.019	0.028	0.006	0.015	0.113
4.Foods	0.002	0.009	0.018	0.024	0.001	0.030	0.007
5.Textile	0.010	0.011	0.023	0.044	0.031	0.006	0.043
6.Apparel	0.004	0.006	0.011	0.016	-0.047	0.014	0.115
7.Woods and Related Products	0.006	0.011	0.020	0.028	-0.047	0.045	0.014
8.Furniture and Fixture	0.008	0.010	0.011	0.017	-0.046	0.037	0.212
9.Paper and Pulp	0.048	0.034	0.042	0.048	-0.055	0.020	0.022
10.Printing and Publishing	0.006	0.007	0.011	0.012	0.029	0.001	0.028
11.Chemical Products	0.059	0.072	0.068	0.107	-0.006	0.012	0.047
12.Petroleum Refining	0.036	0.037	0.040	0.035	-0.025	0.017	0.040
13.Coal Products	0.065	0.073	0.174	0.108	-0.079	0.022	0.025
14.Rubber Products	0.007	0.019	0.024	0.020	0.021	0.001	0.015
15.Leather Products	0.006	0.008	0.011	0.018	-0.054	0.020	0.080
16.Stone, Clay, Glass	0.059	0.065	0.049	0.072	-0.061	0.051	0.032
17.Iron and Steel	0.062	0.076	0.076	0.071	-0.039	0.020	0.025
18.Non-ferrous Metal	0.034	0.042	0.029	0.026	-0.003	0.044	0.037
19.Metal Products	0.015	0.019	0.020	0.024	-0.078	0.041	0.042
20.Machinery	0.016	0.010	0.009	0.014	-0.095	0.022	0.036
21.Electric Machinery	0.012	0.010	0.011	0.017	-0.123	0.044	0.050
22.Motor Vehicles	0.013	0.008	0.010	0.013	-0.069	0.064	0.030
23.Other Transportation Equipment	0.014	0.008	0.011	0.024	-0.104	0.025	0.005
24.Precision Instruments	0.013	0.008	0.010	0.013	-0.002	0.058	0.020
25.Misc Manufacturing	0.016	0.018	0.020	0.025	-0.038	0.028	0.056
26.Transportation	0.101	0.067	0.059	0.088	0.027	-0.010	0.025
27.Communication	0.009	0.005	0.011	0.019	-0.046	0.015	0.013
28.Electricity	0.016	0.249	0.088	0.138	-0.016	-0.002	0.072
29.Gas and Water	0.126	0.101	0.097	0.051	0.003	0.010	0.004
30.Wholesale and Retail	0.025	0.025	0.021	0.039	-0.046	0.026	0.011
31.Finance and Insurance	0.006	0.005	0.003	0.007	-0.061	0.022	0.046
32.Real Estate	0.003	0.002	0.003	0.007	-0.068	0.033	0.025
33.Education and Research	0.009	0.013	0.020	0.026	-0.058	0.002	-0.001
34.Medical Care	0.028	0.016	0.028	0.020	0.030	0.101	-0.054
35.Other Service	0.017	0.016	0.022	0.024	0.011	0.010	0.015
aggregate	0.025	0.027	0.025	0.034	-0.026	0.028	0.030

Note: The aggregated estimate of the energy cost shares are measured as the ratio to the industry-sum of gross outputs. The estimates of the energy prices relative to capital prices at the whole economy are based on the translog indices from the industry-level price changes.

The structural properties of those observations can be illuminated by our estimation of the price function. Figure 4 presents the decomposition of the changes in energy efficiencies to two parts of technical change effect (defined by the contributions of the bias of technical change for energy inputs) and price change effect (defined by the substitution effects induced by price changes of KLEM inputs), as defined in equation (8), every five years and during three sub-periods by industry. Our observation of the industry-level energy intensities shown in Figure 3 indicates that the energy efficiencies were worsened at most industries during the period of Japan's rapid growth. However, our estimates of the bias of technical change for energy input indicate that most Japanese industries could benefit considerably from involving energy-saving technical change and somewhat offset the deterioration in energy efficiency induced by the price substitution effects in the period of the relative decrease of energy price. In particular, 11.Chemical Products, 14.Rubber Products, 16.Stone, Clay, and Glass, 19.Metal Products, 24.Precision Instruments took a large bonus of energy-saving technical changes. This may indicate that the energy-saving technologies were available with zero or minor costs as the advantages of backwardness of the Japanese economy and that they have been autonomously involved along with the rapid capital deepening of the Japanese economy in this period.

Figure 3: Changes in Energy Intensities by Industry

The second period, especially from the middle 1970s to the middle 1980s, is the golden age, in which the energy efficiency has been considerably improved. However, our estimates in Figure 4 indicate the difference in the sources of energy efficiency improvement in each of the first and latter periods of this golden age. A notable property in the first period of the golden age is that the energy efficiency improvement was mainly realized not by involving the energy-saving technical changes, but by the price substitution effect induced by the rapid increases in energy prices, in particular in 1. Agriculture, many light manufacturing industries (e.g. 4. Foods, 5.Textile, 6.Apparel, 7.Wood and Related Products, 8.Furniture, 15.Leather) and some service industries. Only in heavy manufacturing industries like 11.Chemical products and 17.Iron and Steel, the energy-saving technical change effect still contributes to improving energy efficiency, although less than in the first period 1955–

73.[25] We can conclude that the energy-saving technologies with zero or minor costs, as the advantages of backwardness, were almost diminished until the early 1970s and that price substitution effect from energy to capital could realize the improvement in energy efficiencies in the first period of the golden age.

Many industries, in which the technical changes were energy-using and the price substitution effect realized an improvement in energy efficiency in the former period of the golden age, could benefit again by involving the energy-saving technical change with zero or minor costs in the latter period of the golden age of the 1980s, as shown in Figure 4. A possible explanation is the diffusion effect within those industries. The energy-saving technologies, which were developed by the leading companies in the 1970s induced by the rapid increase in oil prices, were autonomously involved by the following companies which could not invest in the 1970s, with a time lag of a decade. It is of note that, however, the opportunities of involving the energy-saving technical changes were diminished again until the late 1990s, and the bias of technology has changed to energy-using in the 2000s in most industries.

As presented in Table 4, the relative price of energy to capital inputs increases by 3.0 percent in the third period 1991–2012, which is higher than 2.8 percent in the second period 1973–91. However the price substitution effect in this recent two decades is much smaller than that in the golden age, especially in 18.Non-ferrous 19. Metal, 20.Machinery, 21.Electric Machinery, 22.Motor Vehicle, 23.Other Transportation Equipment, and 24.Precision Instruments. This may reflect higher costs for substitutions from energy to other inputs.[26]

Finally, Figure 5 projects the bias of technical change for energy input until 2030. Our projection shows the technical change will be energy-using in many industries for the future in Japan. Our estimates for the recent two decades and the future projection indicate that it is much harder for the Japanese industries to improve their energy efficiencies in the future, compared to the past experiences in the golden age, not only from higher costs for substitutions from energy to other inputs, but also from the projected bias of technical change for energy until 2030.

5 Conclusion

This paper analyzed the sources of energy efficiency improvement in Japanese industries over the period 1955–2012, based on the new estimates of substitutions of KLEM (capital, labor, energy, and materials) inputs and the biases of technical changes in the framework of the translog price function. Compared to the previous literatures, the application of the considerably flexible framework of econometric modeling in Jin and Jorgenson (2010) enables us to illuminate some notable features in the relationship between energy efficiency improvement and technical change, in the different development stages of the Japanese economy since 1955 to present.

Our estimates can decompose the sources of the observed improvement in energy efficiency.

[25] The technical change in 28.Electricity is energy-saving in the 1980s. This reflects the increases in nuclear power plant to generate electricity. The nuclear fuel is not counted as energy input here.

[26] An exception is 11.Chemical Products industry. This can be an effect by substitution from domestic production to imports of materials and parts to use a lot of energy in the production process. The distinction of imports requires the further research with a careful examination of the industry data.

The main findings are:

1) During 1955–73 with a very stable price of energy, the energy efficiencies were worsened at most industries. However, our estimates indicate that most Japanese industries could benefit considerably from involving energy-saving technical change and somewhat offset the deterioration in energy efficiency. This may indicate that the energy-saving technologies were available with zero or minor costs as the advantages of backwardness of the Japanese economy and that they have been autonomously involved along with the rapid capital deepening of the Japanese economy in this period.
2) The period 1973–1991 is the golden age, in which the energy efficiency has been considerably improved. During the first period of the golden age (the mid-1970s) the energy efficiency improvement was mainly realized not by involving the energy-saving technical changes but by the price substitution effect induced by the energy price spikes. The energy-saving technologies, which has been involved during 1955–73, were almost diminished until the early 1970s. The energy-saving technologies, which were developed by the leading companies in the 1970s, seemed to be autonomously involved by the following companies in the latter period of the golden age (the mid-1980s), with a time lag of a decade.
3) The opportunities of involving the energy-saving technical changes with minor costs were diminished again until the late 1990s. A notable feature is that the bias of technology has changed to energy-using in the 2000s in most industries. Although the relative price of energy to capital inputs increases by 3.0 percent during 1991–2012, which is higher than 2.8 percent during 1973–91, the price substitution effect is much smaller than that in the golden age. This may reflect higher costs for substitutions from energy to other inputs.
4) Our projection shows the technical change will be energy-using in many industries until 2030 in Japan.

In Japan, the discussion to determine the energy mix for the period 2030 has started in METI as of the end of January 2015, in the situation that all nuclear power plants are not being operated. The starting point to examine the future energy mix is to project the electricity demand until 2030. However, the recent energy policy tends to underestimate the electricity demand in the future, by expecting radical improvements in energy efficiency, which are almost equivalent to the levels with that had been achieved during the golden age (Nomura, 2015). Our estimates of the price function and decomposition of the sources in energy efficiency improvement indicate that it will be much harder for Japanese industries to improve their energy efficiencies in the future, compared to the experiences in the golden age, not only from the higher costs for substitutions from energy to other inputs, but also from our projected bias of technical change for energy input until 2030. The Japanese government should avoid implementing too restrictive policies on energy use, as these may impose larger costs on domestic producers and hasten the de-industrialization of the Japanese economy.

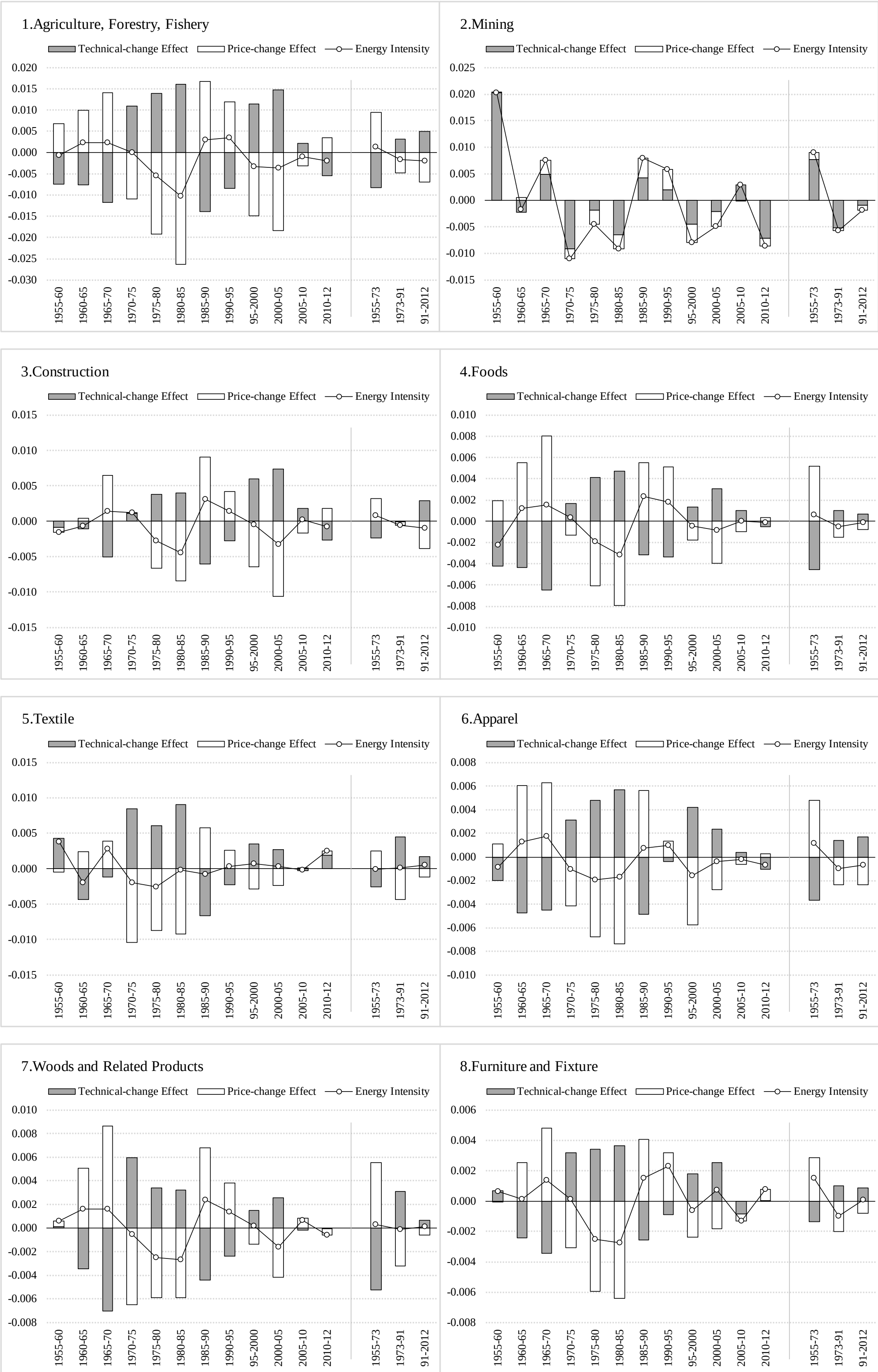

Figure 4: Decomposition of Changes in Energy Intensities by Industry (1–8)

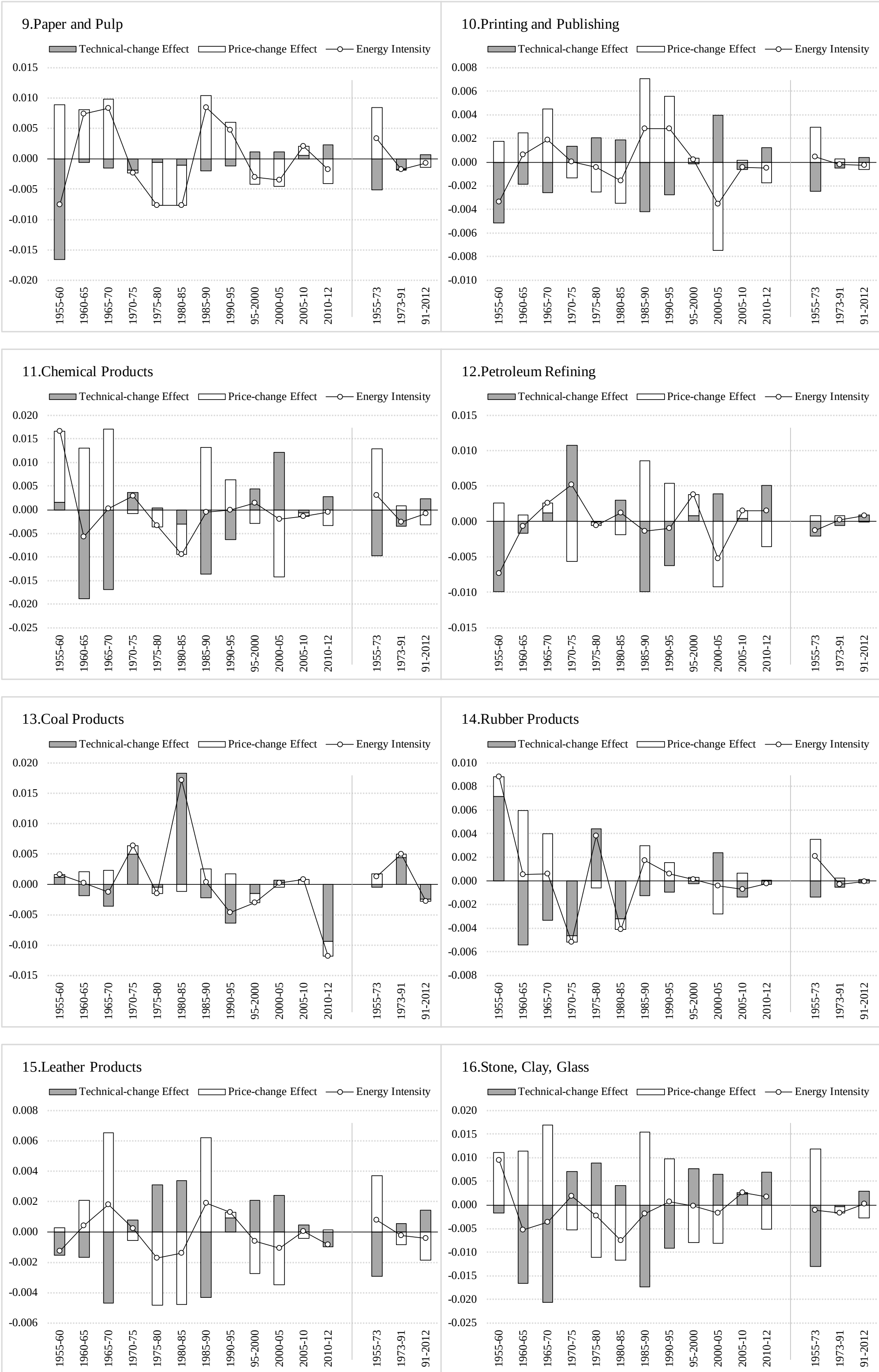

Figure 4: Decomposition of Changes in Energy Intensities by Industry (9–16)

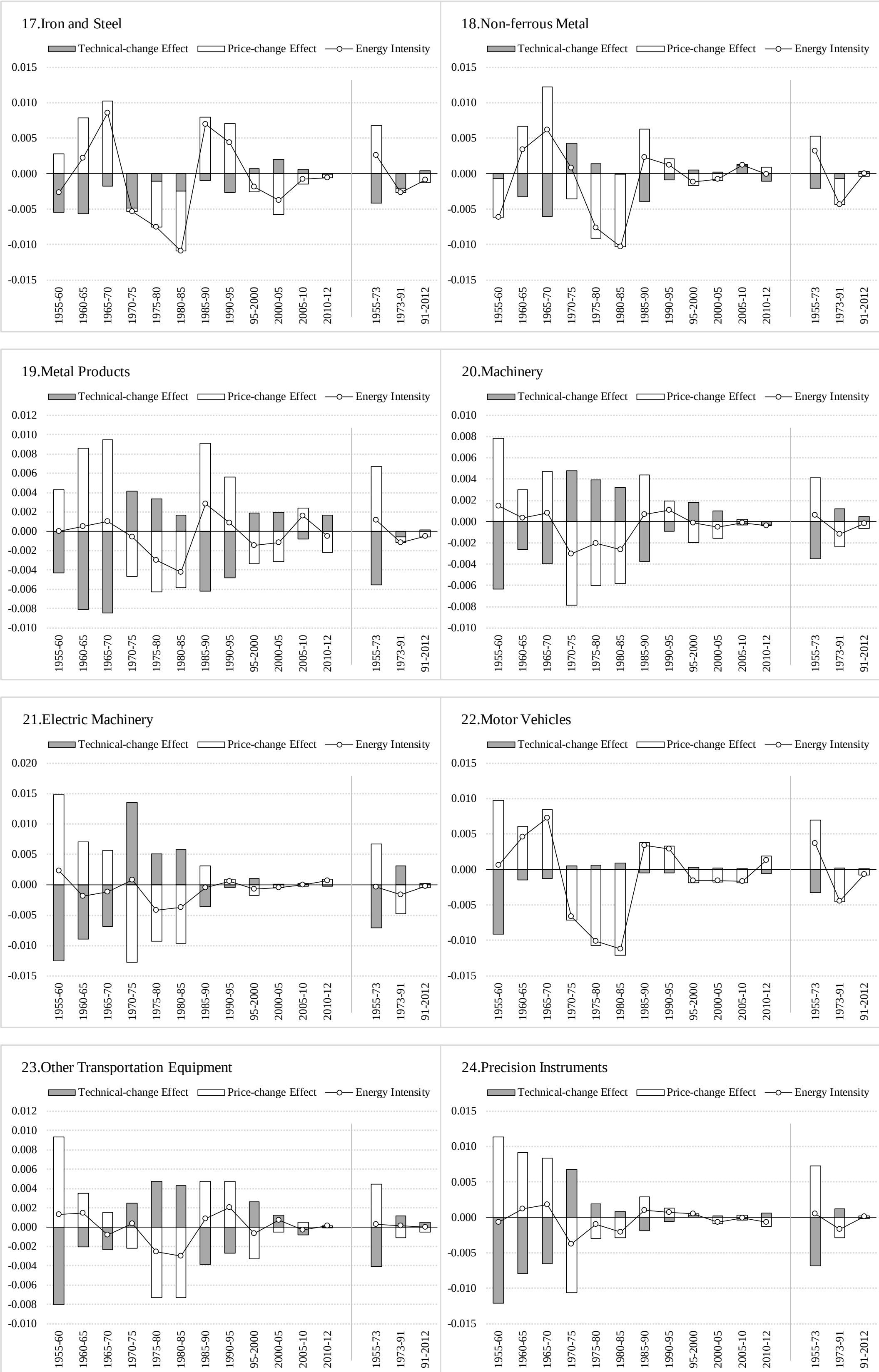

Figure 4: Decomposition of Changes in Energy Efficiency by Industry (17–24)

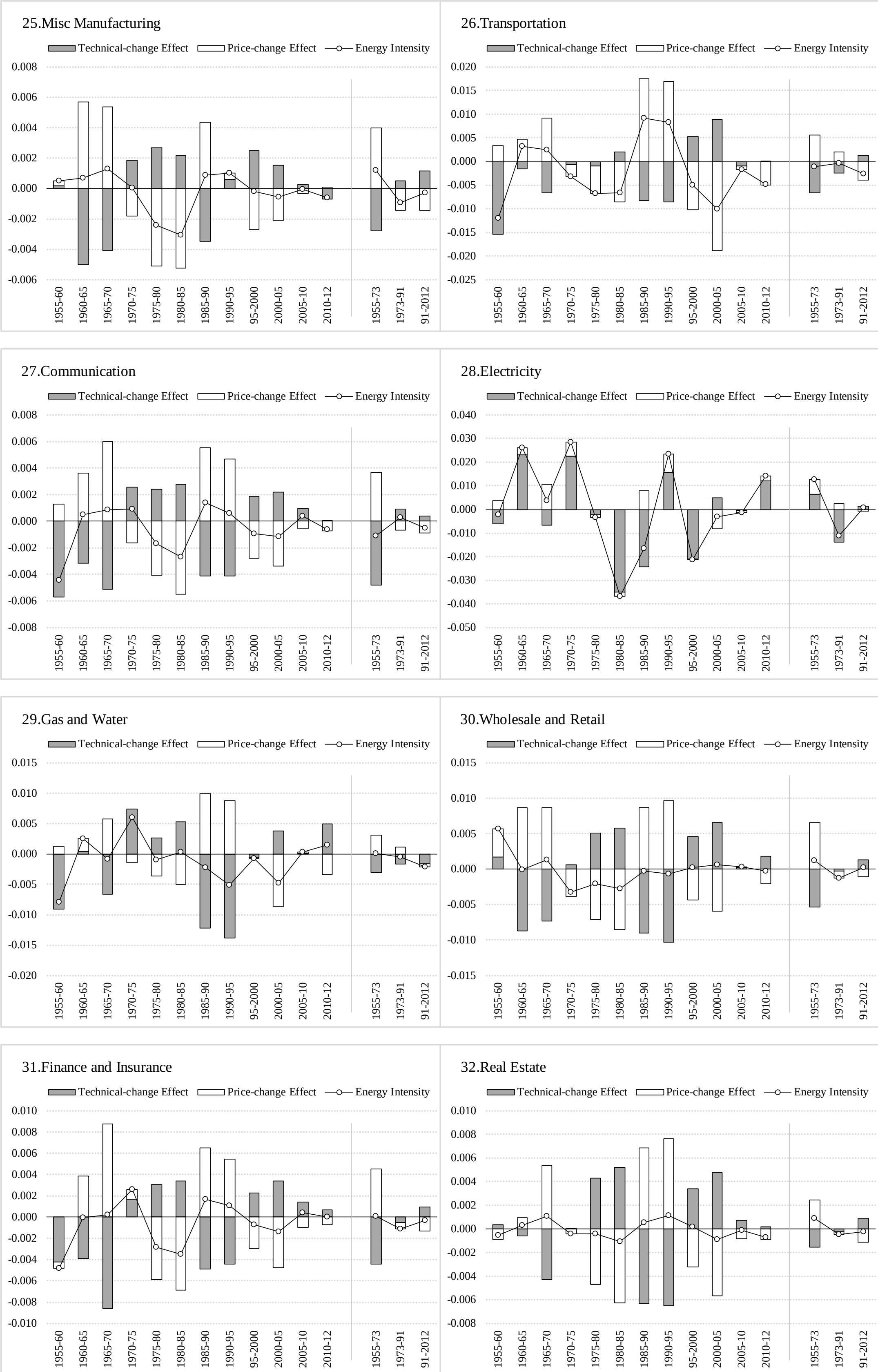

Figure 4: Decomposition of Changes in Energy Intensities by Industry (25–32)

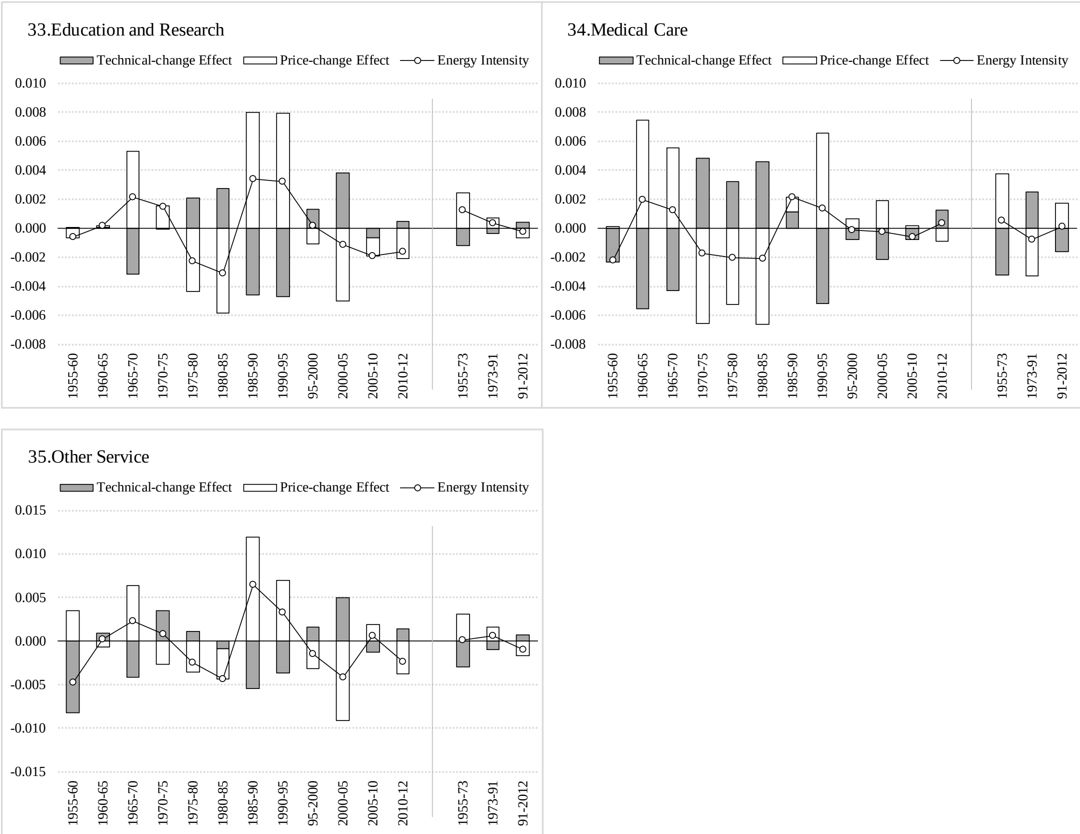

Figure 4: Decomposition of Changes in Energy Intensities by Industry (33–35)

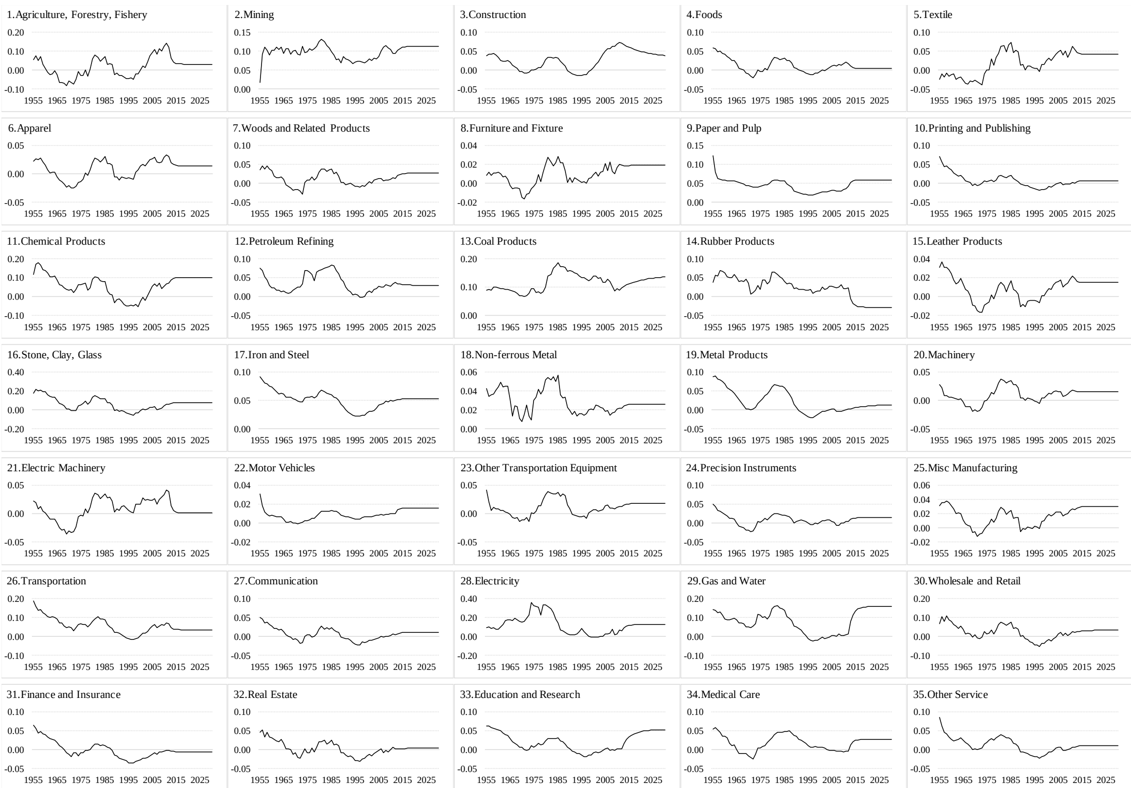

Figure 5: Projection of Bias of Technical Change for Energy until 2030

Table 5: Estimated Parameters

	1.Agriculture, Forestry, Fishery		2.Mining		3.Construction		4.Foods		5.Textile		6.Apparel		7.Woods and Related Products		8.Furniture and Fixture		9.Paper and Pulp	
α_K	0.155	(0.040)	0.046	(0.767)	0.003	(0.015)	0.003	(0.044)	0.003	(0.020)	0.031	(0.270)	0.034	(0.004)	0.024	(0.113)	0.072	(0.197)
α_L	0.108	(0.005)	0.078	(0.849)	0.006	(0.124)	0.007	(0.105)	0.103	(0.009)	0.104	(0.138)	0.104	(0.223)	0.141	(0.123)	0.077	(1.541)
α_E	0.011	(0.053)	0.030	(0.255)	0.002	(0.081)	0.003	(0.012)	0.016	(0.019)	0.005	(0.093)	0.010	(0.093)	0.007	(0.010)	0.027	(0.969)
α_T	-0.002	(0.182)	0.009	(2.529)	-0.002	(0.833)	0.004	(0.172)	0.002	(2.160)	0.000	(0.165)	0.001	(0.749)	0.001	(0.291)	0.004	(4.377)
β_{KK}	-0.002	(0.061)	0.000	(2.050)	-0.029	(0.047)	-0.005	(0.320)	-0.045	(0.602)	-0.034	(0.003)	-0.035	(0.169)	-0.036	(0.006)	-0.005	(2.267)
β_{KL}	-0.010	(0.012)	0.001	(1.494)	0.003	(0.002)	0.074	(0.137)	0.001	(0.072)	0.002	(0.257)	0.002	(0.055)	-0.002	(0.116)	-0.003	(0.430)
β_{KE}	0.107	(0.050)	-0.002	(0.553)	0.021	(0.093)	0.017	(0.104)	0.015	(0.319)	0.025	(0.211)	0.022	(0.071)	0.002	(0.003)	0.070	(1.008)
β_{LL}	0.001	(0.040)	-0.001	(1.022)	-0.001	(0.019)	-0.058	(0.011)	-0.001	(1.318)	0.000	(0.315)	0.000	(0.265)	0.002	(0.261)	-0.003	(1.567)
β_{LE}	0.072	(0.191)	0.011	(0.556)	0.035	(0.097)	0.038	(0.026)	0.017	(0.210)	0.031	(0.033)	0.026	(0.025)	0.008	(0.003)	0.060	(1.536)
β_{EE}	-0.197	(0.164)	-0.019	(0.321)	-0.093	(0.013)	-0.099	(0.171)	-0.083	(0.449)	-0.091	(0.168)	-0.083	(0.115)	-0.087	(0.066)	-0.084	(0.057)
χ_K	0.245	(0.144)	0.074	(1.770)	0.007	(0.038)	-0.010	(0.084)	0.004	(0.638)	0.049	(0.229)	0.056	(0.004)	0.039	(0.024)	0.110	(1.958)
χ_L	0.173	(0.317)	0.136	(1.859)	0.031	(0.041)	0.019	(0.152)	0.169	(1.091)	0.170	(0.217)	0.167	(0.109)	0.226	(0.141)	0.117	(3.000)
χ_E	0.018	(0.038)	0.053	(0.807)	0.003	(0.153)	0.003	(0.022)	0.024	(0.131)	0.008	(0.165)	0.015	(0.095)	0.010	(0.048)	0.038	(1.585)
χ_D	0.002	(0.628)	-0.012	(0.371)	0.001	(0.368)	-0.001	(0.016)	-0.006	(0.728)	0.001	(0.570)	-0.002	(0.446)	-0.002	(0.115)	-0.007	(0.054)
δ_{KK}	0.435	(0.160)	0.506	(5.987)	0.888	(0.043)	0.469	(0.164)	0.403	(4.739)	0.401	(0.828)	0.401	(0.347)	0.407	(0.634)	0.350	(10.844)
δ_{KL}	0.039	(0.181)	0.015	(0.389)	0.000	(0.157)	-0.009	(0.033)	-0.002	(4.753)	0.009	(0.056)	0.009	(0.135)	0.004	(0.004)	0.006	(25.648)
δ_{KE}	0.003	(0.765)	0.007	(3.981)	0.000	(0.124)	0.001	(0.064)	-0.001	(15.648)	0.000	(0.161)	0.001	(1.115)	0.000	(0.161)	0.002	(4.942)
δ_{KD}	0.000	(1.956)	-0.004	(3.478)	0.000	(0.068)	0.000	(0.129)	0.000	(2.699)	0.000	(1.710)	0.000	(0.389)	-0.001	(1.321)	0.000	(1.060)
δ_{LK}	0.040	(0.496)	0.022	(6.645)	0.002	(0.007)	-0.003	(3.536)	0.008	(8.893)	0.009	(4.774)	0.009	(9.879)	0.011	(1.505)	0.006	(12.189)
δ_{LL}	0.406	(0.138)	0.517	(0.177)	0.898	(0.156)	0.480	(0.023)	0.428	(1.240)	0.431	(2.972)	0.426	(2.601)	0.449	(0.604)	0.351	(15.413)
δ_{LE}	0.003	(1.107)	0.013	(3.618)	0.001	(0.104)	-0.002	(0.317)	0.003	(13.043)	0.002	(20.932)	0.002	(18.437)	0.002	(1.009)	0.002	(17.245)
δ_{LD}	0.000	(0.177)	0.003	(4.473)	0.000	(0.029)	-0.001	(1.027)	-0.001	(10.338)	0.000	(12.148)	0.000	(4.542)	0.000	(2.392)	0.000	(19.040)
δ_{EK}	0.003	(0.127)	0.010	(2.725)	0.000	(0.562)	0.001	(0.014)	-0.001	(0.720)	0.000	(2.609)	0.001	(0.875)	0.000	(0.638)	0.001	(1.548)
δ_{EL}	0.003	(0.271)	0.011	(0.462)	0.002	(0.398)	-0.002	(0.052)	0.005	(2.147)	0.002	(0.370)	0.003	(0.304)	0.003	(0.097)	0.001	(12.705)
δ_{EE}	0.373	(0.387)	0.486	(0.516)	0.886	(0.904)	0.467	(0.280)	0.400	(11.677)	0.399	(2.732)	0.398	(2.072)	0.398	(0.412)	0.346	(23.615)
δ_{ED}	0.000	(0.105)	0.000	(2.146)	0.000	(0.843)	0.000	(0.174)	0.000	(1.399)	0.000	(0.029)	0.000	(0.429)	0.000	(0.137)	0.000	(16.724)
δ_{DK}	0.001	(2.892)	-0.001	(1.833)	0.001	(2.311)	-0.002	(1.454)	0.000	(4.178)	0.000	(9.351)	0.000	(2.865)	0.000	(0.006)	0.000	(2.644)
δ_{DL}	0.002	(2.084)	-0.005	(1.339)	0.000	(0.445)	0.003	(0.734)	0.000	(4.820)	0.000	(0.879)	0.000	(1.133)	0.000	(0.551)	0.000	(1.104)
δ_{DE}	0.000	(1.117)	-0.001	(3.823)	0.000	(1.353)	-0.001	(1.548)	0.000	(1.698)	0.000	(12.760)	0.000	(7.304)	0.000	(0.586)	0.000	(10.886)
δ_{DD}	0.331	(1.265)	0.461	(1.262)	0.881	(0.173)	0.433	(1.199)	0.396	(9.275)	0.396	(3.948)	0.396	(3.409)	0.396	(0.265)	0.332	(8.350)

	10.Printing and Publishing		11.Chemical Products		12.Petroleum Refining		13.Coal Products		14.Rubber Products		15.Leather Products		16.Stone, Clay, Glass		17.Iron and Steel		18.Non-ferrous Metal	
α_K	0.044	(0.110)	0.098	(0.120)	0.039	(1.064)	0.014	(0.007)	0.036	(0.011)	0.041	(0.193)	0.036	(0.009)	0.041	(0.024)	0.008	(0.052)
α_L	0.115	(0.084)	0.046	(0.074)	-0.001	(0.066)	0.001	(0.059)	0.110	(0.080)	0.103	(0.205)	0.066	(0.070)	0.020	(0.051)	0.040	(0.058)
α_E	0.003	(0.003)	0.035	(0.011)	0.004	(0.190)	0.002	(0.012)	-0.006	(0.029)	0.005	(0.016)	0.013	(0.030)	0.024	(0.030)	0.014	(0.142)
α_T	-0.002	(0.154)	0.004	(0.332)	-0.001	(1.739)	0.000	(0.264)	0.003	(0.216)	0.000	(0.808)	0.003	(1.307)	0.002	(0.084)	0.003	(0.376)
β_{KK}	-0.003	(0.518)	-0.001	(0.545)	-0.015	(0.104)	-0.019	(0.099)	-0.004	(0.052)	-0.022	(0.143)	-0.005	(0.716)	-0.005	(0.086)	-0.006	(0.092)
β_{KL}	-0.001	(0.204)	0.118	(0.515)	0.046	(0.002)	0.049	(0.114)	-0.003	(0.043)	0.001	(0.185)	-0.002	(0.034)	0.131	(0.026)	0.036	(0.003)
β_{KE}	0.052	(0.051)	0.094	(1.146)	0.028	(0.030)	-0.006	(0.132)	0.049	(0.019)	0.021	(0.165)	0.077	(0.417)	-0.008	(0.011)	0.038	(0.027)
β_{LL}	0.001	(0.150)	-0.040	(0.242)	-0.085	(0.097)	-0.056	(0.021)	0.001	(0.038)	0.000	(0.143)	-0.007	(0.028)	-0.043	(0.096)	-0.031	(0.057)
β_{LE}	0.059	(0.012)	0.095	(0.010)	0.032	(0.128)	0.026	(0.068)	0.033	(0.137)	0.021	(0.070)	0.098	(0.041)	0.075	(0.328)	0.054	(0.070)
β_{EE}	-0.101	(0.109)	-0.079	(0.143)	-0.074	(0.122)	-0.030	(0.222)	-0.066	(0.178)	-0.090	(0.109)	-0.164	(0.809)	-0.133	(1.365)	-0.112	(0.296)
χ_K	0.071	(0.105)	0.158	(0.755)	0.079	(0.957)	0.018	(0.490)	0.049	(0.129)	0.065	(0.042)	0.079	(0.002)	0.054	(0.413)	-0.003	(0.025)
χ_L	0.182	(0.946)	0.076	(0.343)	0.011	(0.302)	0.008	(0.026)	0.180	(0.266)	0.167	(1.365)	0.158	(0.266)	0.031	(0.003)	0.059	(0.065)
χ_E	0.004	(0.020)	0.058	(0.043)	0.012	(0.153)	0.016	(0.128)	-0.012	(0.032)	0.008	(0.185)	0.031	(0.006)	0.034	(0.853)	0.017	(0.015)
χ_D	0.001	(0.227)	-0.006	(0.639)	0.000	(1.345)	-0.001	(0.085)	0.003	(0.138)	0.001	(0.605)	-0.016	(0.044)	-0.008	(0.015)	-0.003	(0.039)
δ_{KK}	0.406	(1.501)	0.426	(4.246)	0.617	(0.713)	0.888	(0.977)	0.404	(1.106)	0.403	(0.277)	0.601	(0.445)	0.349	(0.626)	0.338	(0.064)
δ_{KL}	0.016	(0.113)	0.013	(1.982)	0.000	(1.612)	0.001	(0.589)	0.010	(0.208)	0.011	(0.616)	0.009	(0.259)	0.000	(4.079)	-0.008	(0.000)
δ_{KE}	0.001	(0.331)	0.009	(1.668)	0.002	(12.358)	0.002	(2.551)	0.001	(0.143)	0.001	(1.339)	0.003	(0.477)	0.001	(3.438)	-0.001	(0.524)
δ_{KD}	0.000	(0.741)	-0.001	(3.726)	-0.001	(2.189)	-0.001	(1.784)	0.000	(0.893)	0.000	(4.037)	0.000	(0.063)	0.001	(1.576)	0.000	(0.749)
δ_{LK}	0.018	(9.433)	0.013	(0.630)	0.000	(0.777)	0.002	(0.037)	0.018	(2.941)	0.011	(9.958)	0.017	(0.670)	0.000	(0.978)	-0.001	(0.322)
δ_{LL}	0.442	(0.582)	0.405	(2.467)	0.593	(0.100)	0.887	(0.100)	0.433	(1.326)	0.429	(3.369)	0.617	(0.521)	0.347	(0.860)	0.346	(0.164)
δ_{LE}	0.001	(7.958)	0.005	(1.791)	0.001	(2.221)	0.001	(0.145)	0.002	(1.984)	0.001	(28.629)	0.006	(0.289)	0.001	(3.035)	0.000	(0.542)
δ_{LD}	0.000	(6.516)	0.000	(0.631)	0.000	(0.592)	0.000	(0.392)	-0.001	(0.504)	0.000	(0.171)	0.000	(0.094)	-0.001	(0.918)	-0.001	(0.253)
δ_{EK}	0.000	(0.014)	0.010	(0.503)	0.000	(0.108)	0.002	(0.265)	0.000	(1.026)	0.001	(0.421)	0.001	(0.112)	0.002	(0.650)	0.001	(0.912)
δ_{EL}	0.000	(0.127)	0.005	(1.576)	0.001	(0.343)	0.001	(0.258)	-0.013	(0.899)	0.002	(1.141)	0.002	(0.185)	0.001	(9.902)	-0.001	(0.088)
δ_{EE}	0.399	(0.245)	0.402	(1.246)	0.592	(2.882)	0.888	(0.555)	0.415	(1.445)	0.398	(1.960)	0.599	(0.866)	0.346	(5.607)	0.344	(0.812)
δ_{ED}	0.000	(0.072)	0.000	(0.492)	0.000	(0.246)	0.000	(0.043)	0.003	(0.773)	0.000	(0.964)	0.001	(0.368)	0.000	(3.265)	0.000	(1.505)
δ_{DK}	0.000	(2.510)	-0.001	(2.801)	0.001	(4.075)	0.001	(0.040)	0.001	(0.531)	0.000	(6.796)	-0.003	(0.154)	-0.001	(0.069)	-0.001	(0.285)
δ_{DL}	0.001	(0.134)	-0.001	(2.724)	0.000	(5.399)	0.000	(2.410)	0.001	(0.524)	0.000	(0.760)	-0.002	(0.277)	0.000	(0.179)	0.000	(0.864)
δ_{DE}	0.000	(0.249)	0.000	(2.531)	0.000	(10.863)	0.000	(0.394)	0.000	(0.295)	0.000	(7.115)	-0.004	(0.670)	-0.001	(0.450)	0.000	(4.012)
δ_{DD}	0.396	(1.118)	0.397	(1.341)	0.583	(1.015)	0.881	(0.932)	0.395	(1.174)	0.396	(0.359)	0.589	(0.589)	0.334	(0.423)	0.326	(1.179)

Table 5: Estimated parameters (continued)

	19.Metal Products		20.Machinery		21.Electric Machinery		22.Motor Vehicles		23.Other Transportation Equipment		24.Precision Instruments		25.Misc Manufacturing		26.Transportation		27.Communication	
α_K	0.005	(0.030)	0.053	(0.051)	0.050	(0.034)	0.101	(0.074)	0.049	(0.149)	0.079	(0.114)	0.054	(0.321)	0.028	(0.067)	0.140	(0.003)
α_L	0.005	(0.050)	0.100	(0.013)	0.047	(0.089)	0.080	(0.152)	0.103	(0.315)	0.111	(0.023)	0.100	(0.018)	0.121	(0.183)	0.145	(0.057)
α_E	0.000	(0.043)	0.005	(0.017)	0.000	(0.015)	0.006	(0.083)	0.006	(0.085)	0.004	(0.027)	0.010	(0.050)	0.016	(0.192)	0.005	(0.005)
α_T	0.003	(0.161)	0.002	(0.020)	0.010	(1.345)	0.004	(0.244)	0.002	(4.405)	0.005	(0.590)	0.002	(1.452)	0.002	(0.547)	0.012	(0.205)
β_{KK}	-0.019	(0.091)	-0.009	(0.082)	-0.004	(0.166)	-0.001	(0.012)	-0.014	(0.256)	-0.002	(0.752)	-0.013	(0.487)	-0.005	(0.279)	0.000	(0.561)
β_{KL}	0.004	(0.009)	0.000	(0.083)	0.000	(0.077)	0.033	(0.050)	0.001	(0.112)	0.001	(0.342)	0.000	(0.193)	0.010	(0.122)	0.000	(0.025)
β_{KE}	0.024	(0.092)	0.016	(0.053)	0.022	(0.085)	0.039	(0.116)	0.022	(0.425)	0.054	(0.019)	0.024	(0.215)	0.042	(0.353)	0.009	(0.059)
β_{LL}	-0.003	(0.032)	0.000	(0.008)	0.000	(0.046)	-0.015	(0.014)	-0.001	(1.519)	0.000	(0.096)	0.000	(0.076)	-0.009	(0.054)	0.000	(0.038)
β_{LE}	0.057	(0.048)	0.020	(0.056)	0.020	(0.063)	0.040	(0.004)	0.020	(0.157)	0.052	(0.035)	0.026	(0.053)	0.094	(0.052)	0.008	(0.003)
β_{EE}	-0.105	(0.184)	-0.088	(0.194)	-0.087	(0.103)	-0.125	(0.129)	-0.087	(0.583)	-0.093	(0.106)	-0.081	(0.128)	-0.164	(0.415)	-0.091	(0.051)
χ_K	0.011	(0.053)	0.086	(0.093)	0.079	(0.132)	0.152	(0.042)	0.079	(0.159)	0.123	(0.137)	0.086	(0.109)	0.038	(0.030)	0.218	(0.183)
χ_L	0.028	(0.101)	0.164	(0.182)	0.073	(0.126)	0.124	(0.235)	0.167	(0.872)	0.183	(0.340)	0.163	(0.152)	0.182	(0.026)	0.226	(0.009)
χ_E	0.002	(0.106)	0.009	(0.067)	0.001	(0.050)	0.010	(0.079)	0.010	(0.383)	0.008	(0.027)	0.017	(0.085)	0.020	(0.016)	0.006	(0.108)
χ_p	-0.004	(1.322)	-0.005	(0.019)	-0.004	(0.089)	-0.010	(0.082)	-0.003	(0.514)	-0.008	(0.569)	-0.003	(0.751)	-0.008	(0.347)	-0.028	(0.002)
δ_{KK}	0.887	(0.174)	0.407	(0.230)	0.349	(0.329)	0.353	(0.319)	0.405	(3.057)	0.416	(0.514)	0.407	(0.722)	0.382	(0.069)	0.434	(0.735)
δ_{KL}	0.003	(0.128)	0.015	(0.031)	0.004	(1.411)	0.006	(0.213)	0.014	(0.410)	0.023	(0.280)	0.013	(0.300)	0.008	(0.001)	0.057	(0.544)
δ_{KE}	0.000	(0.038)	0.001	(0.398)	0.000	(1.033)	0.000	(0.379)	0.001	(0.604)	0.001	(0.679)	0.001	(3.968)	0.003	(0.090)	0.002	(0.475)
δ_{Kp}	0.000	(0.240)	0.000	(0.509)	-0.002	(0.590)	-0.001	(1.446)	0.000	(2.748)	0.000	(1.558)	0.000	(1.076)	0.000	(0.181)	-0.003	(0.551)
δ_{LK}	0.003	(0.442)	0.015	(0.303)	0.004	(1.961)	0.007	(0.034)	0.013	(11.899)	0.024	(0.833)	0.014	(6.278)	0.020	(0.019)	0.062	(0.380)
δ_{LL}	0.895	(0.143)	0.428	(0.654)	0.350	(1.514)	0.350	(1.170)	0.429	(1.588)	0.435	(0.103)	0.426	(1.446)	0.437	(0.174)	0.441	(0.290)
δ_{LE}	0.001	(0.140)	0.002	(0.624)	0.001	(1.123)	0.001	(0.408)	0.002	(14.483)	0.002	(9.195)	0.003	(22.034)	0.010	(0.779)	0.002	(0.109)
δ_{Lp}	0.000	(0.152)	0.000	(2.040)	-0.003	(1.473)	-0.001	(0.062)	0.000	(16.457)	-0.001	(1.098)	0.000	(6.246)	-0.001	(1.735)	-0.001	(0.201)
δ_{EK}	0.000	(0.669)	0.001	(0.094)	0.000	(0.013)	0.001	(0.654)	0.001	(1.973)	0.001	(0.180)	0.001	(0.169)	0.002	(0.558)	0.001	(0.009)
δ_{EL}	0.001	(0.105)	0.002	(0.214)	0.000	(0.694)	0.001	(0.343)	0.002	(1.648)	0.002	(0.085)	0.003	(0.459)	0.006	(0.059)	0.001	(0.165)
δ_{EE}	0.886	(0.232)	0.399	(0.560)	0.345	(0.369)	0.344	(0.972)	0.399	(3.467)	0.399	(0.548)	0.399	(1.427)	0.377	(0.471)	0.372	(0.309)
δ_{Ep}	0.000	(0.306)	0.000	(0.056)	0.000	(0.200)	0.000	(0.036)	0.000	(2.325)	0.000	(0.107)	0.000	(1.474)	0.000	(0.560)	0.001	(0.040)
δ_{pK}	0.000	(4.431)	-0.001	(0.651)	-0.001	(0.544)	-0.001	(0.138)	0.000	(0.128)	-0.001	(3.435)	0.000	(4.886)	-0.002	(2.938)	-0.007	(0.190)
δ_{pL}	-0.001	(2.564)	-0.001	(0.228)	0.000	(0.096)	0.000	(0.726)	0.000	(1.463)	-0.002	(0.405)	0.000	(1.543)	-0.001	(0.413)	-0.007	(0.430)
δ_{pE}	0.000	(3.784)	0.000	(1.723)	0.000	(0.037)	0.000	(0.102)	0.000	(12.566)	0.000	(1.282)	0.000	(7.403)	-0.001	(0.686)	-0.001	(0.082)
δ_{pp}	0.881	(1.279)	0.397	(0.693)	0.337	(0.573)	0.330	(0.221)	0.396	(9.224)	0.397	(0.229)	0.396	(0.722)	0.336	(2.931)	0.333	(0.176)

	28.Electricity		29.Gas and Water		30.Wholesale and Retail		31.Finance and Insurance		32.Real Estate		33.Education and Research		34.Medical Care		35.Other Service	
α_K	0.084	(0.147)	0.137	(0.011)	0.034	(0.455)	0.061	(0.104)	0.311	(1.211)	0.011	(0.030)	0.041	(0.115)	0.044	(0.047)
α_L	0.020	(0.105)	0.066	(0.037)	0.090	(0.069)	0.092	(0.019)	0.058	(0.600)	0.163	(0.274)	0.163	(0.039)	0.123	(0.065)
α_E	0.031	(0.131)	0.036	(0.091)	0.007	(0.002)	0.003	(0.009)	0.000	(0.161)	0.005	(0.431)	0.009	(0.024)	0.005	(0.026)
α_T	0.006	(0.846)	0.000	(1.018)	0.015	(1.970)	0.016	(1.438)	-0.028	(0.074)	-0.010	(23.421)	-0.001	(0.433)	-0.002	(0.009)
β_{KK}	-0.001	(0.220)	0.000	(0.001)	-0.001	(1.964)	0.000	(1.533)	-0.001	(2.768)	-0.009	(5.718)	-0.016	(0.068)	-0.003	(0.389)
β_{KL}	0.055	(0.234)	0.034	(0.031)	-0.001	(0.136)	0.001	(0.004)	0.070	(0.757)	0.006	(4.919)	0.001	(0.061)	0.001	(0.265)
β_{KE}	-0.037	(0.036)	0.046	(0.064)	0.036	(0.202)	0.014	(1.629)	0.007	(0.034)	0.001	(13.605)	0.052	(0.028)	0.037	(0.042)
β_{LL}	-0.046	(0.325)	-0.022	(0.065)	0.002	(2.873)	-0.001	(0.508)	-0.126	(0.073)	-0.004	(0.366)	0.001	(0.144)	-0.001	(0.181)
β_{LE}	0.075	(0.114)	0.044	(0.105)	0.049	(0.334)	0.017	(0.493)	0.013	(0.149)	0.030	(4.816)	0.054	(0.051)	0.058	(0.006)
β_{EE}	-0.071	(0.456)	-0.071	(0.168)	-0.107	(0.809)	-0.098	(1.291)	-0.098	(0.293)	-0.093	(5.478)	-0.089	(0.105)	-0.119	(0.061)
χ_K	0.157	(0.375)	0.260	(0.243)	0.076	(0.108)	0.129	(0.789)	0.308	(2.643)	0.007	(4.096)	0.065	(0.027)	0.067	(0.420)
χ_L	0.041	(0.112)	0.128	(0.171)	0.212	(1.380)	0.207	(0.234)	0.057	(0.133)	0.325	(29.522)	0.262	(0.017)	0.188	(1.123)
χ_E	0.059	(0.447)	0.067	(0.126)	0.011	(0.014)	-0.002	(0.121)	0.002	(0.146)	0.012	(4.052)	0.014	(0.027)	0.007	(0.094)
χ_p	-0.011	(0.494)	-0.001	(0.240)	-0.008	(4.485)	-0.011	(0.103)	0.012	(0.508)	-0.002	(1.536)	0.001	(0.257)	-0.001	(0.474)
δ_{KK}	0.534	(0.382)	0.557	(0.280)	0.603	(4.465)	0.624	(2.986)	0.391	(3.835)	0.593	(23.857)	0.405	(0.116)	0.385	(2.368)
δ_{KL}	0.013	(3.062)	0.037	(0.051)	0.028	(1.626)	0.040	(0.497)	0.026	(2.001)	0.008	(2.255)	0.021	(0.043)	0.018	(0.247)
δ_{KE}	0.015	(0.942)	0.019	(0.163)	0.001	(1.192)	0.000	(7.288)	0.001	(1.689)	-0.001	(9.177)	0.001	(0.173)	0.001	(4.011)
δ_{Kp}	-0.002	(1.269)	0.000	(1.151)	-0.001	(1.798)	-0.001	(1.658)	0.000	(6.863)	0.000	(8.571)	0.000	(1.568)	0.000	(0.423)
δ_{LK}	0.012	(0.250)	0.037	(0.148)	0.031	(25.853)	0.045	(0.917)	0.007	(0.743)	0.039	(353.640)	0.021	(3.676)	0.023	(7.709)
δ_{LL}	0.487	(0.938)	0.501	(0.384)	0.672	(11.988)	0.660	(0.556)	0.211	(0.468)	0.775	(27.202)	0.485	(0.447)	0.428	(1.044)
δ_{LE}	0.004	(0.555)	0.010	(0.066)	0.005	(18.123)	0.001	(0.412)	-0.004	(0.556)	0.005	(66.870)	0.005	(4.770)	0.003	(4.910)
δ_{Lp}	0.001	(0.305)	0.000	(0.217)	-0.001	(7.700)	-0.001	(0.308)	0.004	(0.380)	-0.001	(12.438)	0.000	(1.857)	-0.001	(1.966)
δ_{EK}	0.013	(0.898)	0.019	(0.185)	0.001	(1.235)	-0.002	(0.246)	0.002	(0.221)	0.001	(3.653)	0.001	(0.186)	0.000	(0.615)
δ_{EL}	0.006	(1.573)	0.010	(0.357)	0.003	(0.923)	0.000	(0.352)	-0.003	(0.754)	0.006	(0.199)	0.005	(0.049)	0.002	(0.108)
δ_{EE}	0.498	(0.087)	0.485	(0.311)	0.591	(1.915)	0.590	(2.440)	0.172	(1.360)	0.590	(23.087)	0.399	(0.295)	0.374	(0.866)
δ_{Ep}	0.000	(1.818)	0.000	(0.538)	0.001	(0.469)	0.001	(0.486)	-0.001	(0.588)	0.000	(5.194)	0.000	(0.057)	0.000	(0.195)
δ_{pK}	-0.003	(1.517)	0.000	(0.151)	-0.001	(15.808)	-0.002	(0.728)	0.011	(1.152)	0.000	(17.680)	0.000	(1.885)	0.000	(1.603)
δ_{pL}	0.000	(1.975)	0.001	(0.258)	-0.005	(4.108)	-0.006	(0.333)	0.002	(1.861)	0.000	(7.053)	0.001	(0.127)	0.001	(1.013)
δ_{pE}	0.001	(1.368)	0.000	(0.509)	-0.001	(16.514)	0.000	(0.875)	-0.001	(4.388)	0.000	(33.512)	0.000	(0.197)	0.000	(1.543)
δ_{pp}	0.462	(0.799)	0.459	(0.877)	0.583	(6.361)	0.583	(0.568)	0.069	(0.114)	0.582	(20.330)	0.397	(0.443)	0.335	(6.028)

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