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Contents

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Policy Simulations with an Integrated Model for Japan and Northeast Asia

Shuntaro Shishido*, Akira Kawakami**, Motohiro Kurokawa***, Alexander Movshuk**** & Kiyoshi Tamashiro*****

Abstract

In view of the growing importance of Northeast Asia, an integrated model was constructed, with the support of the National Institute for Research Advancement, covering Japan and seven Northeast Asian countries, including China, Hong Kong, Taiwan, the ROK, the DPRK, Mongolia, and Russia, and with two sub-regions. The models of these countries and subregions were linked to one another, and their production structures were each divided into five sectors, except for Japan's model (DEMIOS) which had 81 sectors in the framework of a Leontief-Keynesian system. Various types of policy simulations were conducted, with special reference to growth acceleration in China and Japan, and also under conditions of world economic recession.

Keywords: *DEMIOS, demographic variables, forward effect, Leontief-Keynesian model, NAMIOS, Northeast Asia, trade matrix, V-RAS*

1. Introduction

In view of the growing importance of Northeast Asia in the 21st century world economy, an empirical study was conducted within a Leontief-Keynes framework with the support of the National Institute for Research Advancement (NIRA).

The study covers Japan, the seven Northeast Asian countries or territories of China, Hong Kong, Taiwan, South Korea (ROK), North Korea (DPRK), Mongolia, and Russia, plus the two sub-regions of Northeast China and the Russian Far East. These sub-models [sub-regions] are added to the main system, because of their growing mutual interdependence with Japan. The above countries' models are linked with each other as shown below by means of a trade matrix specifically designed for this region.

Regarding the specifications of the country-models, Japan's model (DEMIOS) is exceptionally large in terms of sector divisions, with 81 sectors, and in the number of behavioral equations, covering detailed fiscal and monetary variables. The total number of endogenous variables is about four thousand. For other countries, the specifications of each model are fairly standardized, having five common sectors for output, employment, and capital stock, etc., and common aggregate expenditure variables such as private consumption, investment, and exports, etc. Prices and wage rates are also endogenized. Total population, fertility and death rates, age components, and emigration, etc., are all endogenized in each country-model, in view of the recent changes in demographic trends. Particular attention is paid with respect to the interdependence between economic growth and demographic changes. The original version of these country-models, with a trade linkage (NAMIOS), was developed by the Economic Research Institute of Northeast Asia (ERINA) in Niigata in 1998 [2] and the present version has been expanded and updated.

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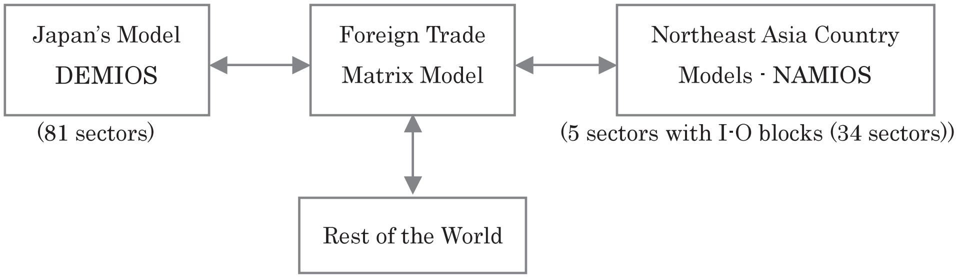
International Model Flow Chart



2. Japan's Model (DEMIOS)

The original version of this multi-sector model was constructed in 1997 in a project which was carried out with the collaboration of the LINK Project of the University of Pennsylvania on a 64-sector basis, covering sectoral output, employment, and investment, etc., with a market adjustment mechanism for prices and wage rates, as well as ordinary macroeconomic variables related to fiscal and monetary policy. [1]

The model is known as the NIRA-LINK Model because of its historical background. The present version is an expanded one with a larger sectional breakdown, i.e., 81 sectors and more elaborate fiscal and monetary sectors, such as in the public sector (including central, local and social insurance), and in the monetary sector (including securities and stock markets). The demographic variable block, though slightly simplified compared with its predecessor, covers all major demographic variables. The basic characteristics of the previous NIRA-LINK Model—in particular the V-RAS system representing flexible input-output coefficients including primary factors—are retained and are further elaborated on in DEMIOS. Detailed analysis was conducted with special reference to sectoral changes in total factor productivity (TFP) within a framework of the V-RAS system. [4] [5] [6]

An essential feature of this V-RAS system is to integrate input-output coefficients, including primary factors, in a framework of a rectangular matrix, as shown below, and analyze both individual coefficients and TFP in each column, at the same time tracing the output price repercussions in each row from the upper to the lower stream. The system is summarized as below, and unlike the ordinary input-output matrix of intermediate input, the V-RAS matrix is rectangular with more rows than columns, since it also covers primary factors such as labor services, capital, and land, etc.

$$a^*_{kj} = \begin{bmatrix} a_{11} \cdots a_{1n} \\ \vdots \ddots \\ a_{n1} \cdots a_{nm} \\ v_{11} \cdots v_{1n} \\ \vdots \qquad \vdots \\ v_{m1} \ldots v_{mn} \end{bmatrix} \qquad (1)$$

The total value of inputs represents a reciprocal of TFP (τ_j) as shown below:

$$\tau_j = \frac{1}{\sum_k a^*_{kj}} \qquad \begin{matrix} (k = 1,2,\ldots,n+m) \\ (j = 1,2,\ldots,n) \end{matrix} \qquad (2)$$

All values are shown in terms of the constant prices of the base year, implying $\tau_j = 1$. The V-RAS formula and parameters for inter-factor substitution r, total savings s, and cost-price relations are specified below in equations (3) to (10).

$$a^*_{kj} = r_k \hat{a}_{kj} s_j \quad (3)$$

$$S_j = f\left(\frac{1}{\tau_j}, \cdots\right) \quad (4)$$

$$r_k = [r_i \, ; \, r_s] \; (i = 1, \ldots, n) \; (s = 1, \ldots, m) \quad (5)$$

$$r_i = f(\hat{p}_i, \cdots) \quad (6)$$

$$\hat{p}_i = \frac{(p_i / \bar{p}_i)}{(\tilde{p}_i / \bar{\tilde{p}}_i)} \quad (7)$$

$$p_i = (1 - \mu_i) \, p_{x,i} + \mu_i p_{m,i} \quad (8)$$

$$p_{x,j} = \sum_i a_{ij} p_i + p_{v,j} \quad (9)$$

$$p_{v,j} = \sum_s v_{k,j} p_{f,s} + \pi_j \quad (10)$$

Where a^*_{kj} = the input-output coefficient of a rectangular matrix including primary factors (v) for the base year, $\hat{a}_{kj}$ = the base year I-O coefficient, τ_j = the total factor productivity of the jth sector, r_k = the substitution parameter of the kth sector, s_m = the efficiency parameter of the jth sector, p_x = the output price, p_m = the input price, p = the average of p_x and p_m, μ= import dependency, $\hat{P}$ = the average import price, and $\bar{P}$ = the base year price.

While equations (3) to (5) are related to total input, including primary inputs, equations (6) and (7) are related only to intermediate inputs. S_i and r_i are derived from the annual I-O table in constant prices and calculated by using equations (4) and (6) by ordinary least squares analysis, where τ_i and $\hat{P}_i$ play significant roles respectively. The r_s substitution parameter for primary inputs, also derived from the V-RAS formula, was used for important indicators for the demand functions of primary inputs. A direct sectoral approach to primary factor demand, however, was taken by using conventional methods for factor demand functions on a sectional basis, as described later.

Regarding the production side, derived as a dual price-cost relationship, the following system is formulated on the basis of the conventional Leontief model.

$$U_i = \Sigma a_{ij} \cdot X_j \quad (11)$$
$$D_i = U_i + F_i + E_i \quad (12)$$
$$X_i = D_i - M_i \quad (13)$$
$$M_i = f(D_i, p_{mi} / p_n) \quad (14)$$
$$U_{rj} = \sum_i a_{ij} X_j \quad (15)$$
$$Z_j = U_{rj} + \bar{w}_j \cdot L_j + \bar{p}_{kj} \cdot K_j + \bar{p}_{aj} \cdot A_j \quad (16)$$
$$\tau_j = X_j / Z_j \quad (17)$$

Where U_i = intermediate demand, U_r = intermediate input, D_i = demand total, F_i = final demand, E_i = exports, M_i = imports, K_i = capital stock, A_i = land, and Z_j = total input.

All the equations related to supply and demand variables are price sensitive, thus being affected by sectional changes in TFP and foreign prices, as well as market conditions. Unlike conventional specifications for business investment, one of the features of the present model is government investment in social overheads which is significant, with a two- or three-year time-lag, for important private sectors such as agriculture, basic manufacturing, and public utilities, etc. Private housing investment is also partly dependent on government investment such as highway access, and renewal of urban facilities, etc. This explicit consideration of the forward linkages of the I-O model for the public sector contribution to the external economy is one of the important features of the present Japanese model.

Regarding labor demand, the log-linear functions are inherited from the preceding model (where they were a special feature) along with output and relative wage rates as explanatory variables.

These factor demand equations are summarized as below.

$$L_j = f\,[X_j, W_j \,/\, PX_j,\ L_{j-1}] \qquad (18)$$
$$KP_j = Ip_j - DP_j + KP_{j-1} \qquad (19)$$
$$IP_j = f\,[X_j,\ KP_{j-1},\ INTGB_{-1},\ PX_j \,/\, PZ_j,\ IG_{-1}\ ] \qquad (20)$$

Where L_j = employment, W_j = wage rate, PX_j = producer price, PZ_j = input price, KP_j = capital stock, IP_j = business investment, DP_j = depreciation, $INTGB$ = long-term interest rate, and IG = government investment by type.

Finally, producer prices, as shown below, are determined by the total input price, a proxy rate of capacity utilization, the unemployment rate, and exchange rates, etc.

$$l_n PX_j = f\,[l_n PZ_j,\ l_n(KP_{j-1}/X_{j-1}),\ l_n URATE,\ l_n EXR_{-1},\ l_n PX_{j-1}] \quad (21)$$

Where PX_j = producer price, PZ_j = input price of all factors, $URATE$ = unemployment rate, and EXR = exchange rate (¥/$).

At an aggregate level the potential GDP^C was estimated in order to evaluate the rate of operation, i.e., ζ (=GDP/GDP^C). The aggregate production function, which includes a scale effect and technical progress represented by TFP, was estimated. The Cobb-Douglas function was calculated by using private fixed-capital stock, labor inputs, the unemployment rate, and time trends, and the result was normalized in terms of working hours and the unemployment rate to obtain the value of capacity of GDP.

In the macroeconomic block detailed improvements were carried out for the fiscal and monetary sub-blocks. The public sector is divided into central government, local government and social insurance, and financial assets and liabilities, as well as various types of expenditure and transfer payments, are specified and endogenized. For the monetary block, the stock price index and exchange rates are newly endogenized and the relationship between fiscal and monetary blocks is much more detailed, with the monetary policy of the central bank and the management of the national debt by the central government.

In view of the growing importance of the changes in demographic structure, especially regarding the issue of the aging population, the equations on demographic variables such as fertility and mortality rates, the proportion of elderly people, and the rates of international migration, etc., are reinforced through an improved body of data and through improved specifications. As noted later, one of the important findings is that demographic trends are closely related to economic growth.

3. Northeast Asian Country-Models (NAMIOS):

The coverage of NAMIOS has been expanded with new members, namely Hong Kong and Taiwan, and thus now includes nine countries, sub-regions or territories.

As in the previous model, common specifications are applied in each country-model. Production and employment are divided into five sectors, i.e., agriculture, mining, manufacturing, construction, and services, as previously noted. As exceptions, however, some sectors are aggregated due to limited data availability.

Regarding investment and capital stock, all countries have investment functions by sector, but capital stock by sector is only available for China where production functions are also calculated by sector from the labor and capital stock data-series. Output capacity and the rate of utilization of total production at the aggregate level is also available for China, but not for other countries. The rate of unemployment, however, is available for all country-models and is used as a proxy variable for supply-side constraints.

As noted earlier, the interdependence between economic growth and demographic trends is explicitly endogenized in each country-model. Particularly important are the rates of fertility and net migration, which are sensitive to employment opportunities and the expectation of income growth over a longer period than would ordinarily be expected.

Common categories are also used on the expenditure side, which are linked to the input-output system within a Leontief framework. This I-O counterpart of NAMIOS is divided into 34 sectors for output and foreign trade. Although the above two new additions, Hong Kong and Taiwan, are still excluded, China and Russia are divided respectively into Northeast China and the rest of China, and the Russian Far East and the rest of Russia. This multiregional I-O model (7×7), covering most of Northeast Asia, is originally based on a 1995 table calculated by ERINA in 1998 [3] and is structured as a Chenery-Moses model with 34 sectors for each country and sub-region. Structural changes are analyzed for the period from 1995 to 2010, as shown in Table 4.

4. Long-Term Simulations

In the following we present two types of policy simulations. The first is related to long-term simulation for the period 2000-2020 using NAMIOS, while the second concentrates on medium-term simulation by using an integrated DEMIOS-NAMIOS model for the period 2002-2010.

In both cases, the same policy assumptions are used: a) baseline, b) China's growth acceleration, c) Japan's growth acceleration, and d) world chronic recession.

A word of caution is needed in that Japan's model (DEMIOS) is used only for the medium-term analysis and that only Japan's imports are assumed exogenous in the case of the NAMIOS forecast in the long-term simulations.

This idea is derived from the assumption in DEMIOS of GDP growth of about 4%, with a more liberal import policy.

In Table 1 and Table 2 four alternative long-term scenarios are presented. The first scenario relates to the result of forecasts based on the simple extrapolation of exogenous variables. The results of this baseline scenario are indicated in terms of population, real GDP growth, foreign trade, and price levels, etc., during the 20 years between 2000 and 2020. Showing a relatively faster growth in GDP and foreign trade, China continues to be ahead in terms of its annual rate of increase, while Japan still remains in a mild deflationary trend. The degree of disparity remains almost unchanged in terms of the growth rate of GDP among China, Japan, South Korea, and other countries in the region. China would gradually overtake Japan in terms of exports by around 2015.

The second scenario is for a Chinese accelerated rate of growth, with a more active fiscal policy and foreign direct investment. The actual performance over recent years seems to be nearer to this scenario, since the growth rate of real GDP has further accelerated by nearly 1% and a similar trend is observed in foreign trade, overtaking Japan significantly. The expansionary impact on South Korea, Taiwan, Russia and other neighboring countries is also noticeable. Regarding price-trends in China, its inflationary impact still remains modest without any indication of further acceleration. Similarly, no indication of excessiveness is observed in terms of the GDP-gap and the foreign trade balance despite the acceleration of growth. The impact on Japan is also noticeable in terms of its exports, rising to 3.1% from 2.9% in the baseline scenario.

The third scenario is one where the Japanese economy accelerates in growth to about 4%, recovering from the chronic deflationary trend which has continued for more than ten years. Real imports are also assumed to rise by 5.5%. The impact is significant, though not as high as in the second case, having a strong effect on every region of Northeast Asia. Particularly noteworthy is the impact on two regions, Northeast China and the Russian Far East, the effects being greater than in the second scenario, as shown in Table 2. It is also noteworthy that China would accelerate in growth due to the financial and technical collaboration from Japan which is assumed in this scenario. [5]

The last scenario is less optimistic, assuming a reduction in world trade caused by chronic stagnation in the United States, Japan, and the rest of the world. A deceleration in terms of growth in the United States is assumed to continue due to twin deficits in its fiscal and trade balances. A negative economic impact is widely observed in this scenario in almost all of the regions in Northeast Asia. Population also tends to decrease in many regions, which further accelerates a downward trend in aggregate demand. It is noted, however, that the reduction-effect on Chinese growth remains modest, despite strong downward trends in other regions. This is mostly accounted for by the fact that Chinese dependence on foreign trade is relatively modest.

In the export performance shown in Table 3-1, China overtakes Japan, taking second place behind the United States—by 2010 in both the scenarios of China's growth acceleration and of Japan's growth acceleration, and by 2015 and 2020 in the baseline and the world recession scenarios, respectively. With respect to imports in Table 3-2, however, Japan keeps its current second place until 2020 in the Japanese growth acceleration scenario, while China takes second place by 2010 for all the other scenarios.

As for the demographic trends shown in Table 3-3, it is generally observed that the issue of the aging of the population tends to slow population growth in almost all the countries in the region. Economic growth, however, tends to affect demographic trends positively in most countries, such as China, Hong Kong, South Korea, and Mongolia, etc., through the improvement of employment opportunities and living conditions, as typified in the scenario of China's growth acceleration. Also noteworthy is the impact of migration, which negatively affected the demographic trend in Taiwan.

Turning to the more sectoral aspects (after the macroeconomic side shown above), various findings are observed from the multi-sectoral input-output model for the Northeast Asian region as shown in Table 4. After tentatively updating the multi-regional input-output table for 1995 prepared by ERINA, a Leontief-type model based on the table is used in the forecasting for 2010. The model has 34 sectors for each of the seven countries or regions together comprising five of the countries, but not for Hong Kong and Taiwan. The model enables structural analysis of the Northeast Asian region for the fifteen years from 1995 to 2010, as shown in the table. It can be generally observed that the share of agriculture, forestry and fisheries, and light manufacturing tends to decline and there is a marked shift to heavy industry, particularly machinery industries with higher value-added ratios. Also noteworthy is a rising trend, showing a more than four-fold increase, for steel, non-ferrous metals, electrical machinery and transport equipment. Even among light manufacturing industries a significant rising trend is observed for textiles, apparel, household utensils, and sundry goods, etc. What is especially notable is the role of foreign direct investment, which contributes to the promotion of productivity, thus accelerating exports. This rapid increase in terms of the share of Chinese exports is already mentioned above in the context of the trade matrix.

Northeast China is no exception, showing a similar trend, particularly for steel, electrical machinery and transport equipment. A rising trend is also noticeable for crude oil and natural gas, which tend to grow faster than in other regions of China. A long-term dynamic growth in industrial structure is also noteworthy in South Korea, though its pace is slightly behind that of China. Particularly noteworthy is the high pace of growth in IT industries accompanied by rapid technological progress. Rising shares are observed in transport equipment and precision industries. Russia is relatively far behind in economic growth though showing relative advantages in forestry, coal, crude oil and natural gas, metal mining, and steel and non-ferrous metals, etc. This trend is particularly notable in the Russian Far East where there are signs of remarkable progress, especially in agriculture, forestry, crude oil and natural gas, food, lumber, household utensils, paper and pulp, non-ferrous metals, and construction, etc.

Although the above trend is generally observed in each scenario, there are subtle, interesting differences that deserve attention. In the second scenario of Chinese growth acceleration, sectors related to investment such as construction steel and non-ferrous metals, tend to propagate all kinds of growth in machinery, impacting involved countries such as Japan, Southeast Asian countries, the United States, and the EU countries, in terms of the demand for steel, and construction machinery, etc.

In the third scenario of Japan's growth acceleration, of particular note are consumption goods in the rest of China such as textiles, apparel, sundry goods, and household utensils, etc. Also showing remarkable increases are pulp and paper, and printing and publishing in Northeast China, in addition to the general expansion observed in the rest of China. For other areas where there is a similar impact to that in China, particularly noteworthy are the increases in crude oil, natural gas, petroleum products, and steel, etc., in the Russian Far East.

The fourth scenario of world trade decline due to chronic recession indicates a general falling tendency, in particular in export-related industries such as textiles and apparel (clothing) in South Korea and China. Construction industries are generally the least affected due to dependence on domestic demand.

5. Medium-Term Simulation

Now we turn to the more detailed annual changes up to 2010 by using our integrated model, in which Japan is completely endogenized, to analyze the mutual interdependence between Northeast Asia and Japan. Particularly important is the feedback effect from Northeast Asia to Japan, which is not fully endogenized in the long-term simulations discussed above.

Tables 5-1, 5-2, and 5-3 indicate the levels of real GDP, real exports, and real imports for Northeast Asian countries, including Japan (for GDP).

A similar pattern of sensitivity to that in the long-term simulations can be generally observed for the period between 2002 and 2010. Since the simulations for Japan using DEMIOS have a starting point of 2003, unlike 2001 for the other countries, to allow comparison some adjustment needs to be made. In Table 6 the results of this adjustment are indicated, in which Japanese figures relate to 2010, while those for other countries relate to 2008. Thus the imports become comparable in the seventh year.

A major difference becomes noticeable in this table as compared with the long-term simulations.

As compared with the baseline simulation, imports under Japan's growth acceleration have significantly higher values than those under China's growth acceleration—the reverse of what is seen in the long term simulations where imports are generally higher under China's growth acceleration. This tendency can be seen particularly in GDP and imports.

The results of the DEMIOS simulation for Japan's growth acceleration are summarized in Table 7-1. In contrast to the baseline simulation with GDP growth of approximately 0.7%, the "acceleration" simulation assumes an approximately 10-15% growth rate in public investment, strong financial support to business investment, and housing investment of approximately 2% of GDP, resulting in higher growth from 2003 to 2010. The unemployment rate declines significantly from about 5% to 3.8%, while the capacity utilization rate rises from 92% to 100%, 15% higher than in the baseline scenario in 2010. Total imports also keep rising, reaching a level 13% higher than in the baseline scenario. This rather optimistic policy assumption is based on the widening opportunity of obtaining public investment stimulated by the introduction of the Private Finance Initiative (PFI) system, where the increased social infrastructure is jointly financed by the public and private sectors. The table also shows a significant increase in tax revenues, and the ratio of net government debt against nominal GDP also improves from 1.32 to 1.14.

An additional remark is needed regarding the increase in government financial deficits in the area of primary balances. As noted above, these augmented deficits include a significant component from PFI, indicating much less pressure upon official government deficits.

In Table 7-2, sectoral changes in output and imports are summarized for major sectors. Particularly noteworthy are the sectors closely related to public and private investment in output terms. As compared with the baseline scenario, raw materials sectors such as forestry, lumber, non-metallic mineral products, cement, glass, plastic products, and metal products are also significantly affected. General machinery and electrical machinery also strongly increase, but the most noticeable impacts are found in construction sectors, such as public works, residential and non-residential construction, etc. Sectors related to private consumption such as foods, and textiles and apparel (clothing), etc., are positively affected. Particularly noteworthy are information-related service sectors which contribute to Japan's general growth acceleration.

Regarding imports which tend to stimulate exports from Northeast Asia, energy and raw materials are the most important items, as seen in the table. Particularly noteworthy are: crude oil, most significantly from the Russian Far East; non-ferrous metallic ores, including those from Mongolia; non-metal ores; ceramic products; steel, mostly from South Korea; and metal products. Capital goods including IT-related products, mostly from Taiwan, South Korea and China, show an upward trend.

In conclusion, the above scenario of Japan's growth acceleration suggests that the horizontal trade linkage as observed during the 1980s is no more, that a more hybrid relationship of horizontal and vertical divisions of labor is beginning to predominate, and this new trend has been strengthened by the movement of capital globally, especially foreign direct investment since the start of the post-Cold War period in the 1990s.

6. Concluding Remarks

As suggested in the above scenarios, the growing interdependence in Northeast Asia indicates the relative advantages of mutual collaboration in the promotion of infrastructure, environmental protection, the introduction of energy-saving technology by foreign direct investment, FTA agreements and trade liberalization, etc., and while these areas for collaboration seem to be rapidly expanding, it should also be emphasized that the Northeast Asian contribution to the world economy is steadily growing through its being one of the engines for global development. This fact should not be under-emphasized, as also the growing need for international collaboration both within and without Northeast Asia.[7]

References

Shishido, S. & N. Nakamura (1992) "Induced Technical Progress and Structural Adjustment: A Multi-Sectoral Approach to Japan's Growth Alternatives", *Journal of Applied Input-Output Analysis*, Vol. 1, pp. 1-23.

Shishido, S., et al. (1999) "A Multiregional Econometric Model for Northeast Asia (NAMIOS I): Estimation and Policy Analysis", *The Journal of Econometric Study of Northeast Asia (JESNA)*, Vol. 1, No. 1, pp. 13-31

Shishido, S., et al. (2000) "A Multiregional Input-Output Table for Northeast Asia 1995: Compilation and Analysis", *The Journal of Econometric Study of Northeast Asia (JESNA)*, Vol. 2, No. 1, pp.3-39

Shishido, S., et al. (2002) *A Study of Inter-industry Dynamic Model for Medium- and Long-Term Forecasting*, Japan Industrial Policy Research Institute, Tokyo (in Japanese)

Shishido, S., O. Nakamura, N. Minato, M. Kurokawa & A. Kawakami (2003) "Japanese ODA to China and Indonesia in the Context of FDI - A Comparative Multisectoral Approach", *The Journal of Econometric Study of Northeast Asia (JESNA)* , Vol. 4, No. 2, pp.1-29

Shishido, S. (2004) "Searching for Best Policy Scenarios", *Economist* (August 24), Mainichi Newspapers Co., Ltd. (in Japanese)

Wu, G., J. Nemoto & S. Kinoshita (2004) "Effects of International Trade, FDI and Environmental Regulation on Sustainable Development: China Data", *The Journal of Econometric Study of Northeast Asia (JESNA)*, Vol. 5, No. 1, pp. 1-26

Table 1 Alternative Scenarios : GDP

Baseline

		2000	2005	2010	2015	2020	20-year average
China	level	5,248	7,228	8,931	11,487	15,402	9,659
	annual rate (%)		6.6	4.3	5.2	6.0	5.5
Hong Kong	level	998	1,612	1,580	1,924	2,333	1,689
	annual rate (%)		10.1	-0.4	4.0	3.9	4.3
South Korea (ROK)	level	486,745	685,900	892,600	1,138,070	1,438,155	928,294
	annual rate (%)		7.1	5.4	5.0	4.8	5.6
Mongolia	level	585,874	802,695	840,447	1,024,082	940,466	838,713
	annual rate (%)		6.5	0.9	4.0	-1.7	2.4
North Korea (DPRK)	level	1,620	1,972	2,363	2,907	2,820	2,336
	annual rate (%)		4.0	3.7	4.2	-0.6	2.8
Taiwan	level	9,199	11,964	14,027	17,095	20,878	14,633
	annual rate (%)		5.4	3.2	4.0	4.1	4.2
Russia	level	461	464	482	506	534	489
	annual rate (%)		0.1	0.8	1.0	1.1	0.7

China's Growth Acceleration

		2000	2005	2010	2015	2020	20-year average
China	level	5,248	7,805	10,673	13,931	18,913	11,314
	annual rate (%)		8.3	6.5	5.5	6.3	6.6
Hong Kong	level	998	1,643	1,670	2,002	2,447	1,752
	annual rate (%)		10.5	0.3	3.7	4.1	4.6
South Korea (ROK)	level	486,745	693,007	932,605	1,217,330	1,566,506	979,239
	annual rate (%)		7.3	6.1	5.5	5.2	6.0
Mongolia	level	585,874	803,591	851,446	1,055,393	990,521	857,365
	annual rate (%)		6.5	1.2	4.4	-1.3	2.7
North Korea (DPRK)	level	1,620	1,972	2,374	2,936	2,874	2,355
	annual rate (%)		4.0	3.8	4.3	-0.4	2.9
Taiwan	level	9,199	12,120	14,710	18,275	22,747	15,410
	annual rate (%)		5.7	3.9	4.4	4.5	4.6
Russia	level	461	465	485	512	545	494
	annual rate (%)		0.2	0.9	1.1	1.2	0.8

Japan's Growth Acceleration

		2000	2005	2010	2015	2020	20-year average
China	level	5,248	7,272	9,195	12,080	16,480	10,055
	annual rate (%)		6.7	4.8	5.6	6.4	5.9
Hong Kong	level	998	1,616	1,606	1,959	2,390	1,714
	annual rate (%)		10.1	-0.1	4.0	4.1	4.5
South Korea (ROK)	level	486,745	687,594	911,260	1,183,227	1,521,518	958,069
	annual rate (%)		7.2	5.8	5.4	5.2	5.9
Mongolia	level	585,874	802,752	843,842	1,036,841	965,675	846,997
	annual rate (%)		6.5	1.0	4.2	-1.4	2.6
North Korea (DPRK)	level	1,620	1,972	2,371	2,929	2,864	2,351
	annual rate (%)		4.0	3.8	4.3	-0.4	2.9
Taiwan	level	9,199	11,992	14,288	17,673	21,939	15,018
	annual rate (%)		5.4	3.6	4.3	4.4	4.4
Russia	level	461	464	483	509	541	492
	annual rate (%)		0.1	0.8	1.0	1.2	0.8

World Recession

		2000	2005	2010	2015	2020	20-year average
China	level	5,248	6,948	8,337	10,564	13,999	9,019
	annual rate (%)		5.8	3.7	4.8	5.8	5.0
Hong Kong	level	998	1,480	1,359	1,644	1,910	1,478
	annual rate (%)		8.2	-1.7	3.9	3.0	3.4
South Korea (ROK)	level	486,745	662,118	826,680	1,017,679	1,248,651	848,375
	annual rate (%)		6.3	4.5	4.2	4.2	4.8
Mongolia	level	585,874	801,306	832,614	1,005,556	912,484	827,567
	annual rate (%)		6.5	0.8	3.8	-1.9	2.3
North Korea (DPRK)	level	1,620	1,969	2,350	2,880	2,774	2,319
	annual rate (%)		4.0	3.6	4.2	-0.7	2.7
Taiwan	level	9,199	11,580	13,141	15,538	18,420	13,576
	annual rate (%)		4.7	2.6	3.4	3.5	3.5
Russia	level	461	461	474	491	512	480
	annual rate (%)		0.0	0.5	0.7	0.8	0.5

Note on currency units: **China**: 1990 billion yuan, **Hong Kong**: 1990 million HK$, **South Korea**: 1995 billion won, **Mongolia**: 1990 million togrog, **North Korea**: 1995 billion won, **Russia**: 1997 billion rubles, **Taiwan**: 1996 billion NT$

Table 2
China's Three Northeastern Provinces and the Russian Far East: Four Scenarios

China's Three Northeastern Provinces

	2000	2005	2010	2015	2020	Average
Baseline	463.8	652.2	913.7	1,260.5	1,739.3	
		7.1	7.0	6.6	6.7	6.83
China's Growth Acceleration	463.8	664.7	945.4	1,298.0	1,780.9	
		7.5	7.3	6.5	6.5	6.96
Japan's Growth Acceleration	463.8	666.2	950.6	1,302.5	1,784.6	
		7.5	7.4	6.5	6.5	6.97
World Recession	463.8	653.1	916.2	1,264.8	1,745.4	
		7.1	7.0	6.7	6.7	6.85

The Russian Far East

	2000	2005	2010	2015	2020	Average
Baseline	16.8	32.9	36.7	41.3	46.8	
		14.4	2.2	2.4	2.5	1.78
China's Growth Acceleration	16.8	33.1	37.2	42.1	47.9	
		14.5	2.4	2.5	2.6	1.87
Japan's Growth Acceleration	16.8	33	37.1	42.2	48.4	
		14.5	2.4	2.6	2.8	1.93
World Recession	16.8	32.1	34.7	37.7	41.3	
		13.8	1.6	1.7	1.8	1.27

Note on currency units: **China**: 1990 billion yuan
Russia: 1997 billion rubles
annual rate (%)

Table 3-1 Exports 2000-2020

(1995 million US$)

Baseline

		2000	2005	2010	2015	2020	20-year average
China	level	306,861	565,592	674,755	858,054	1,076,429	696,338
	annual rate (%)		13.0	3.6	4.9	4.6	6.5
Hong Kong	level	239,257	379,779	466,203	572,125	700,519	471,577
	annual rate (%)		9.7	4.2	4.2	4.1	5.5
South Korea (ROK)	level	202,453	252,363	309,081	383,947	476,569	324,883
	annual rate (%)		4.5	4.1	4.4	4.4	4.4
Mongolia	level	538	719	889	1,119	1,425	938
	annual rate (%)		6.0	4.3	4.7	5.0	5.0
North Korea (DPRK)	level	1,009	1,211	1,414	1,672	1,988	1,459
	annual rate (%)		3.7	3.2	3.4	3.5	3.5
Taiwan	level	167,050	212,599	252,485	306,826	374,560	262,704
	annual rate (%)		4.9	3.5	4.0	4.1	4.1
Russia	level	110,281	125,658	140,438	158,470	180,058	142,981
	annual rate (%)		2.6	2.2	2.4	2.6	2.5
U.S.A.	level	912,538	1,098,394	1,385,996	1,726,108	2,134,826	1,451,572
	annual rate (%)		3.8	4.8	4.5	4.3	4.3
Japan	level	533,740	617,860	686,022	803,809	949,012	718,089
	annual rate (%)		3.0	2.1	3.2	3.4	2.9
Rest of World	level	5,121,232	5,382,839	7,029,183	8,778,740	11,011,670	7,464,733
	annual rate (%)		1.0	5.5	4.5	4.6	3.9

China's Growth Acceleration

		2000	2005	2010	2015	2020	20-year average
China	level	306,861	573,253	714,980	934,475	1,208,801	747,674
	annual rate (%)		13.3	4.5	5.5	5.3	7.2
Hong Kong	level	239,257	383,352	480,836	597,438	738,363	487,849
	annual rate (%)		9.9	4.6	4.4	4.3	5.8
South Korea (ROK)	level	202,453	256,252	327,226	417,610	530,617	346,832
	annual rate (%)		4.8	5.0	5.0	4.9	4.9
Mongolia	level	538	747	1,010	1,339	1,768	1,080
	annual rate (%)		6.8	6.2	5.8	5.7	6.1
North Korea (DPRK)	level	1,009	1,235	1,548	1,945	2,449	1,637
	annual rate (%)		4.1	4.6	4.7	4.7	4.5
Taiwan	level	167,050	215,664	265,895	330,738	412,030	278,275
	annual rate (%)		5.2	4.3	4.5	4.5	4.6
Russia	level	110,281	126,418	143,967	165,042	190,461	147,234
	annual rate (%)		2.8	2.6	2.8	2.9	2.8
U.S.A.	level	912,538	1,113,400	1,468,066	1,890,394	2,409,945	1,558,869
	annual rate (%)		4.1	5.7	5.2	5.0	5.0
Japan	level	533,740	622,019	702,927	832,305	991,722	736,543
	annual rate (%)		3.1	2.5	3.4	3.6	3.1
Rest of World	level	5,121,232	5,382,839	7,029,183	8,778,740	11,011,670	7,464,733
	annual rate (%)		1.0	5.5	4.5	4.6	3.9

Japan's Growth Acceleration

		2000	2005	2010	2015	2020	20-year average
China	level	306,861	569,102	702,445	919,146	1,186,510	736,813
	annual rate (%)		13.1	4.3	5.5	5.2	7.1
Hong Kong	level	239,257	380,177	469,793	580,784	716,612	477,325
	annual rate (%)		9.7	4.3	4.3	4.3	5.7
South Korea (ROK)	level	202,453	253,455	317,698	403,583	512,106	337,859
	annual rate (%)		4.6	4.6	4.9	4.9	4.7
Mongolia	level	538	725	934	1,224	1,618	1,008
	annual rate (%)		6.1	5.2	5.6	5.7	5.7
North Korea (DPRK)	level	1,009	1,224	1,511	1,890	2,377	1,602
	annual rate (%)		3.9	4.3	4.6	4.7	4.4
Taiwan	level	167,050	213,206	257,518	318,419	395,748	270,388
	annual rate (%)		5.0	3.8	4.3	4.4	4.4
Russia	level	110,281	125,848	141,969	162,022	186,510	145,326
	annual rate (%)		2.7	2.4	2.7	2.9	2.7
U.S.A.	level	912,538	1,105,315	1,439,812	1,848,156	2,354,121	1,531,988
	annual rate (%)		3.9	5.4	5.1	5.0	4.9
Japan	level	533,740	618,173	689,624	812,555	965,613	723,941
	annual rate (%)		3.0	2.2	3.3	3.5	3.0
Rest of World	level	5,121,232	5,382,839	7,029,183	8,778,740	11,011,670	7,464,733
	annual rate (%)		1.0	5.5	4.5	4.6	3.9

World Recession

		2000	2005	2010	2015	2020	20-year average
China	level	306,861	529,826	592,852	719,396	856,311	601,049
	annual rate (%)		11.5	2.3	3.9	3.5	5.3
Hong Kong	level	239,257	361,988	420,590	491,194	575,427	417,691
	annual rate (%)		8.6	3.0	3.2	3.2	4.5
South Korea (ROK)	level	202,453	240,713	280,069	332,926	397,032	290,639
	annual rate (%)		3.5	3.1	3.5	3.6	3.4
Mongolia	level	538	692	818	994	1,233	855
	annual rate (%)		5.1	3.4	4.0	4.4	4.2
North Korea (DPRK)	level	1,009	1,157	1,279	1,438	1,633	1,303
	annual rate (%)		2.8	2.0	2.4	2.6	2.4
Taiwan	level	167,050	205,332	234,587	275,420	325,213	241,520
	annual rate (%)		4.2	2.7	3.3	3.4	3.4
Russia	level	110,281	122,518	132,428	144,358	158,388	133,595
	annual rate (%)		2.1	1.6	1.7	1.9	1.8
U.S.A.	level	912,538	1,034,891	1,226,170	1,446,332	1,705,097	1,265,006
	annual rate (%)		2.5	3.5	3.4	3.3	3.2
Japan	level	533,740	601,216	643,625	727,976	829,201	667,152
	annual rate (%)		2.4	1.4	2.5	2.6	2.2
Rest of World	level	5,121,232	5,382,839	7,029,183	8,778,740	11,011,670	7,464,733
	annual rate (%)		1.0	5.5	4.5	4.6	3.9

Table 3-2 Imports 2000-2020

(1995 million US$)

Baseline

		2000	2005	2010	2015	2020	20-year average
China	level	242,360	388,390	503,249	670,420	904,357	541,755
	annual rate (%)		9.9	5.3	5.9	6.2	6.8
Hong Kong	level	254,025	474,570	524,091	648,382	803,481	540,910
	annual rate (%)		13.3	2.0	4.3	4.4	5.9
South Korea (ROK)	level	157,513	231,480	309,462	401,957	513,433	322,769
	annual rate (%)		8.0	6.0	5.4	5.0	6.1
Mongolia	level	797	934	1,318	1,464	1,729	1,248
	annual rate (%)		3.2	7.1	2.1	3.4	3.9
North Korea (DPRK)	level	4,625	11,849	16,554	23,086	22,045	15,632
	annual rate (%)		20.7	6.9	6.9	-0.9	8.1
Taiwan	level	131,198	178,800	214,975	268,242	333,920	225,427
	annual rate (%)		6.4	3.8	4.5	4.5	4.8
Russia	level	42,155	42,169	42,219	42,330	42,481	42,271
	annual rate (%)		0.0	0.0	0.1	0.1	0.0
U.S.A.	level	1,389,580	1,585,279	1,934,580	2,359,559	2,876,610	2,029,122
	annual rate (%)		2.7	4.1	4.1	4.0	3.7
Japan	level	392,227	431,050	490,788	558,377	634,847	501,458
	annual rate (%)		1.9	2.6	2.6	2.6	2.4
Rest of World	level	3,859,591	4,196,455	4,864,841	5,639,684	6,537,939	5,019,702
	annual rate (%)		1.7	3.0	3.0	3.0	2.7

China's Growth Acceleration

		2000	2005	2010	2015	2020	20-year average
China	level	242,360	411,922	593,524	819,892	1,119,213	637,382
	annual rate (%)		11.2	7.6	6.7	6.4	8.0
Hong Kong	level	254,025	479,808	543,235	674,808	847,025	559,780
	annual rate (%)		13.6	2.5	4.4	4.7	6.3
South Korea (ROK)	level	157,513	233,634	323,334	430,676	560,292	341,090
	annual rate (%)		8.2	6.7	5.9	5.4	6.6
Mongolia	level	797	950	1,395	1,610	1,957	1,342
	annual rate (%)		3.6	8.0	2.9	4.0	4.6
North Korea (DPRK)	level	4,625	11,860	16,693	23,444	22,707	15,866
	annual rate (%)		20.7	7.1	7.0	-0.6	8.5
Taiwan	level	131,198	181,490	226,791	288,686	366,268	238,887
	annual rate (%)		6.7	4.6	4.9	4.9	5.3
Russia	level	42,155	42,270	42,696	43,168	43,745	42,807
	annual rate (%)		0.1	0.2	0.2	0.3	0.2
U.S.A.	level	1,389,580	1,585,279	1,934,580	2,359,559	2,876,610	2,029,122
	annual rate (%)		2.7	4.1	4.1	4.0	3.7
Japan	level	392,227	444,356	587,984	775,700	1,021,038	644,261
	annual rate (%)		2.5	5.8	5.7	5.7	4.9
Rest of World	level	3,859,591	4,196,455	4,864,841	5,639,684	6,537,939	5,019,702
	annual rate (%)		1.7	3.0	3.0	3.0	2.7

Japan's Growth Acceleration

		2000	2005	2010	2015	2020	20-year average
China	level	242,360	389,465	515,466	702,145	965,563	563,000
	annual rate (%)		10.0	5.8	6.4	6.6	7.2
Hong Kong	level	254,025	474,982	529,096	658,196	822,516	547,763
	annual rate (%)		13.3	2.2	4.5	4.6	6.1
South Korea (ROK)	level	157,513	231,925	315,850	418,072	543,610	333,394
	annual rate (%)		8.0	6.4	5.8	5.4	6.4
Mongolia	level	797	937	1,346	1,533	1,856	1,294
	annual rate (%)		3.3	7.5	2.6	3.9	4.3
North Korea (DPRK)	level	4,625	11,854	16,651	23,361	22,589	15,816
	annual rate (%)		20.7	7.0	7.0	-0.7	8.5
Taiwan	level	131,198	179,281	219,472	278,249	352,276	232,095
	annual rate (%)		6.4	4.1	4.9	4.8	5.1
Russia	level	42,155	42,170	42,232	42,359	42,535	42,290
	annual rate (%)		0.0	0.0	0.1	0.1	0.0
U.S.A.	level	1,389,580	1,585,279	1,934,580	2,359,559	2,876,610	2,029,122
	annual rate (%)		2.7	4.1	4.1	4.0	3.7
Japan	level	392,227	444,356	587,984	775,700	1,021,038	644,261
	annual rate (%)		2.5	5.8	5.7	5.7	4.9
Rest of World	level	3,859,591	4,196,455	4,864,841	5,639,684	6,537,939	5,019,702
	annual rate (%)		1.7	3.0	3.0	3.0	2.7

World Recession

		2000	2005	2010	2015	2020	20-year average
China	level	242,360	376,806	472,786	615,064	818,551	505,113
	annual rate (%)		9.2	4.6	5.4	5.9	6.3
Hong Kong	level	254,025	447,162	467,062	556,745	656,432	476,285
	annual rate (%)		12.0	0.9	3.6	3.3	4.9
South Korea (ROK)	level	157,513	223,681	286,114	358,211	444,073	293,918
	annual rate (%)		7.3	5.0	4.6	4.4	5.3
Mongolia	level	797	917	1,272	1,382	1,601	1,194
	annual rate (%)		2.9	6.8	1.7	3.0	3.6
North Korea (DPRK)	level	4,625	11,810	16,388	22,761	21,492	15,415
	annual rate (%)		20.6	6.8	6.8	-1.1	8.3
Taiwan	level	131,198	172,180	199,606	241,245	291,347	207,115
	annual rate (%)		5.6	3.0	3.9	3.8	4.1
Russia	level	42,155	42,142	42,153	42,215	42,305	42,194
	annual rate (%)		-0.0	0.0	0.0	0.0	0.0
U.S.A.	level	1,389,580	1,524,158	1,771,214	2,057,620	2,389,643	1,826,443
	annual rate (%)		1.9	3.1	3.0	3.0	2.7
Japan	level	392,227	405,018	426,879	449,856	474,004	429,597
	annual rate (%)		0.6	1.1	1.1	1.1	1.0
Rest of World	level	3,859,591	4,196,455	4,864,841	5,639,684	6,537,939	5,019,702
	annual rate (%)		1.7	3.0	3.0	3.0	2.7

Table 3-3 Population 2000-2020

Baseline

		2000	2005	2010	2015	2020	20-year average
China	level	1,273,000,000	1,333,500,000	1,375,000,000	1,396,300,000	1,418,400,000	1,359,240,000
	annual rate (%)		0.9	0.6	0.3	0.3	0.5
Hong Kong	level	6,661,255	6,956,310	7,792,094	8,115,304	8,530,366	7,611,066
	annual rate (%)		0.9	2.3	0.8	1.0	1.2
South Korea (ROK)	level	47,179,000	48,888,000	50,633,000	52,624,000	54,822,000	50,829,200
	annual rate (%)		0.7	0.7	0.8	0.8	0.8
Mongolia	level	2,411,402	2,531,252	2,647,720	2,759,158	2,839,834	2,637,873
	annual rate (%)		1.0	0.9	0.8	0.6	0.8
North Korea (DPRK)	level	22,311,550	22,764,860	24,437,450	25,914,390	23,579,570	23,801,564
	annual rate (%)		0.4	1.4	1.2	-1.9	0.3
Taiwan	level	21,518,000	21,526,000	21,594,000	21,594,000	21,649,000	21,576,200
	annual rate (%)		0.0	0.1	0.0	0.1	0.0
Russia*	level	145,560,000	143,825,026	142,005,882	140,209,747	138,436,330	142,007,397
	annual rate (%)		-0.2	-0.3	-0.3	-0.3	-0.3

China's Growth Acceleration

		2000	2005	2010	2015	2020	20-year average
China	level	1,273,000,000	1,333,900,000	1,379,400,000	1,406,100,000	1,428,100,000	1,364,100,000
	annual rate (%)		0.9	0.7	0.4	0.3	0.6
Hong Kong	level	6,661,255	6,956,856	7,850,009	8,278,725	8,674,723	7,684,314
	annual rate (%)		0.9	2.4	1.1	0.9	1.3
South Korea (ROK)	level	47,179,000	48,888,000	50,643,000	52,728,000	55,123,000	50,912,200
	annual rate (%)		0.7	0.7	0.8	0.9	0.8
Mongolia	level	2,411,402	2,531,257	2,648,044	2,761,114	2,845,292	2,639,422
	annual rate (%)		1.0	0.9	0.8	0.6	0.8
North Korea (DPRK)	level	22,311,550	22,764,860	24,437,090	25,912,050	23,590,310	23,803,172
	annual rate (%)		0.4	1.4	1.2	-1.9	0.3
Taiwan	level	21,518,000	21,526,000	21,597,000	21,597,000	21,651,000	21,577,800
	annual rate (%)		0.0	0.1	0.0	0.0	0.0

Japan's Growth Acceleration

		2000	2005	2010	2015	2020	20-year average
China	level	1,273,000,000	1,333,500,000	1,375,400,000	1,398,000,000	1,420,700,000	1,360,120,000
	annual rate (%)		0.9	0.6	0.3	0.3	0.6
Hong Kong	level	6,661,255	6,956,315	7,799,982	8,163,422	8,597,186	7,635,632
	annual rate (%)		0.9	2.3	0.9	1.0	1.3
South Korea (ROK)	level	47,179,000	48,888,000	50,635,000	52,667,000	54,973,000	50,868,400
	annual rate (%)		0.7	0.7	0.8	0.9	0.8
Mongolia	level	2,411,402	2,531,252	2,647,778	2,759,782	2,842,074	2,638,458
	annual rate (%)		1.0	0.9	0.8	0.6	0.8
North Korea (DPRK)	level	22,311,550	22,764,860	24,437,330	25,912,410	23,586,120	23,802,454
	annual rate (%)		0.4	1.4	1.2	-1.9	0.3
Taiwan	level	21,518,000	21,526,000	21,595,000	21,595,000	21,650,000	21,576,800
	annual rate (%)		0.0	0.1	0.0	0.1	0.0

World Recession

		2000	2005	2010	2015	2020	20-year average
China	level	1,273,000,000	1,333,200,000	1,372,900,000	1,393,300,000	1,416,700,000	1,357,820,000
	annual rate (%)		0.9	0.6	0.3	0.3	0.5
Hong Kong	level	6,661,255	6,953,277	7,551,975	7,711,083	8,047,761	7,385,070
	annual rate (%)		0.9	1.7	0.4	0.9	0.9
South Korea (ROK)	level	47,179,000	48,888,000	50,592,000	52,410,000	54,318,000	50,677,400
	annual rate (%)		0.7	0.7	0.7	0.7	0.7
Mongolia	level	2,411,402	2,531,242	2,647,364	2,757,745	2,836,540	2,636,859
	annual rate (%)		1.0	0.9	0.8	0.6	0.8
North Korea (DPRK)	level	22,311,550	22,764,830	24,438,970	25,914,300	23,561,180	23,798,166
	annual rate (%)		0.4	1.4	1.2	-1.9	0.3
Taiwan	level	21,518,000	21,526,000	21,590,000	21,589,000	21,644,000	21,573,400
	annual rate (%)		0.0	0.1	-0.0	0.1	0.0

Note:
* Figures for Russia are only available for the Baseline scenario due to suitability of data.

Table 4
Output: Northeast Asia in 2010
Four Scenarios

(1995, 100 million US$)

Northeast China	Baseline	China Acceleration	Japan Acceleration	World Recession
110 Agriculture	18,996	18,809	18,966	19,078
120 Forestry	1,318	1,303	1,315	1,324
130 Fishing	2,200	2,177	2,195	2,209
210 Coal	443	439	442	445
220 Crude oil & gas	906	906	906	906
230 Metal mining	6	6	6	6
290 Non-metal mining	680	680	680	681
301 Food, tobacco	11,437	11,549	11,646	11,487
302 Textiles, apparel	3,978	3,944	3,979	3,997
303 Wood products	577	570	576	579
304 Furniture	568	561	566	570
305 Pulp, paper products	1,021	1,077	1,082	1,024
306 Printing, publishing	155	164	165	155
307 Chemicals	3,495	3,463	3,492	3,511
308 Petroleum, coal products	2,122	2,117	2,121	2,123
309 Rubber products	168	167	168	169
310 Leather products	330	327	330	331
311 Non-metallic products	948	941	947	952
312 Iron & steel	705	705	705	705
313 Non-ferrous metals	107	106	107	107
314 Metal products	952	942	950	956
315 General machinery	11,573	11,515	11,570	11,602
316 Electrical machinery	7,225	7,152	7,215	7,258
317 Motor vehicles, aircraft	4,450	4,422	4,444	4,461
319 Other transport	990	985	990	993
320 Precision instruments	136	135	136	136
321 Other manufacturing	898	891	897	901
400 Construction	40,544	40,311	40,505	40,648
500 Electricity, gas	1,643	1,622	1,639	1,652
600 Wholesale & retail trade	21,243	22,228	22,381	21,322
700 Transportation	3,206	3,176	3,207	3,222
800 Communication	121	120	121	122
910 Finance, real estate	4,738	4,889	4,931	4,760
920 Other services	29,969	36,023	36,112	30,015

South Korea	Baseline	China Acceleration	Japan Acceleration	World Recession
110 Agriculture	13,624	14,185	13,887	12,693
120 Forestry	373	388	380	347
130 Fishing	7,412	7,768	7,579	6,826
210 Coal	13	13	13	13
220 Crude oil & gas	0	0	0	0
230 Metal mining	0	0	0	0
290 Non-metal mining	320	340	329	287
301 Food, tobacco	57,511	60,025	58,686	53,336
302 Textiles, apparel	66,047	69,839	67,847	59,920
303 Wood products	430	452	441	394
304 Furniture	8,106	8,435	8,257	7,544
305 Pulp, paper products	3,850	4,062	3,950	3,509
306 Printing, publishing	5,234	5,457	5,338	4,862
307 Chemicals	31,086	32,776	31,886	28,346
308 Petroleum, coal products	14,720	15,442	15,060	13,536
309 Rubber products	5,944	6,297	6,112	5,376
310 Leather products	7,989	8,420	8,193	7,289
311 Non-metallic products	2,946	3,111	3,024	2,679
312 Iron & steel	14,100	14,985	14,522	12,681
313 Non-ferrous metals	1,942	2,062	2,000	1,749
314 Metal products	19,603	20,601	20,070	17,956
315 General machinery	63,660	66,340	64,885	59,074
316 Electrical machinery	159,820	168,636	163,982	145,460
317 Motor vehicles, aircraft	96,490	101,009	98,591	88,951
319 Other transport	25,363	26,641	25,959	23,245
320 Precision instruments	10,871	11,337	11,085	10,076
321 Other manufacturing	24,479	25,892	25,150	22,195
400 Construction	255,037	264,439	259,249	238,485
500 Electricity, gas	11,809	12,305	12,040	10,979
600 Wholesale & retail trade	104,873	109,155	106,853	97,645
700 Transportation	26,618	27,728	27,134	24,762
800 Communication	9,058	9,438	9,235	8,421
910 Finance, real estate	115,411	120,196	117,632	107,376
920 Other services	188,370	192,765	190,418	181,029

Other China	Baseline	China Acceleration	Japan Acceleration	World Recession
110 Agriculture	165,072	191,346	169,224	155,557
120 Forestry	13,425	15,424	13,778	12,586
130 Fishing	20,083	23,095	20,604	18,842
210 Coal	7,645	8,390	7,866	7,046
220 Crude oil & gas	6,708	7,075	6,958	5,969
230 Metal mining	248	261	257	221
290 Non-metal mining	4,987	5,359	5,182	4,423
301 Food, tobacco	163,553	187,289	167,911	152,505
302 Textiles, apparel	259,592	279,291	269,238	231,738
303 Wood products	3,959	4,200	4,124	3,473
304 Furniture	15,359	16,981	15,887	13,916
305 Pulp, paper products	15,796	18,574	16,089	15,053
306 Printing, publishing	4,559	5,375	4,641	4,354
307 Chemicals	65,577	71,760	67,749	59,528
308 Petroleum, coal products	4,579	5,170	4,713	4,236
309 Rubber products	6,318	6,956	6,515	5,778
310 Leather products	23,104	25,087	23,929	20,758
311 Non-metallic products	20,610	22,253	21,314	18,604
312 Iron & steel	17,507	18,596	18,229	15,373
313 Non-ferrous metals	8,100	8,602	8,435	7,111
314 Metal products	36,641	40,284	37,900	33,177
315 General machinery	122,793	152,001	126,215	117,064
316 Electrical machinery	175,400	194,281	181,353	159,279
317 Motor vehicles, aircraft	46,666	56,062	48,031	43,957
319 Other transport	14,046	16,849	14,465	13,203
320 Precision instruments	19,550	21,474	20,317	17,426
321 Other manufacturing	78,113	83,122	81,250	68,877
400 Construction	349,700	453,496	359,210	338,152
500 Electricity, gas	10,801	12,307	11,094	10,070
600 Wholesale & retail trade	155,704	190,828	158,570	149,878
700 Transportation	25,831	30,295	26,447	24,488
800 Communication	1,087	1,308	1,113	1,036
910 Finance, real estate	19,027	23,411	19,347	18,296
920 Other services	242,227	322,615	243,928	238,370

North Korea	Baseline	China Acceleration	Japan Acceleration	World Recession
110 Agriculture	1,641	1,649	1,646	1,632
120 Forestry	26	27	27	26
130 Fishing	604	607	606	601
210 Coal	18	18	18	18
220 Crude oil & gas	0	0	0	0
230 Metal mining	0	0	0	0
290 Non-metal mining	13	14	14	13
301 Food, tobacco	1,924	1,934	1,930	1,914
302 Textiles, apparel	1,011	1,018	1,016	1,004
303 Wood products	12	12	12	12
304 Furniture	240	242	241	239
305 Pulp, paper products	59	60	60	59
306 Printing, publishing	187	188	188	187
307 Chemicals	533	536	535	530
308 Petroleum, coal products	198	199	199	197
309 Rubber products	33	33	33	33
310 Leather products	145	146	146	144
311 Non-metallic products	41	42	42	41
312 Iron & steel	13	13	13	13
313 Non-ferrous metals	20	21	21	20
314 Metal products	306	308	307	304
315 General machinery	1,704	1,715	1,712	1,690
316 Electrical machinery	1,692	1,703	1,700	1,678
317 Motor vehicles, aircraft	558	562	560	554
319 Other transport	277	279	278	274
320 Precision instruments	533	537	536	529
321 Other manufacturing	249	251	250	248
400 Construction	7,355	7,405	7,392	7,296
500 Electricity, gas	347	349	348	345
600 Wholesale & retail trade	3,674	3,694	3,687	3,654
700 Transportation	928	933	931	924
800 Communication	137	138	138	137
910 Finance, real estate	2,903	2,918	2,913	2,887
920 Other services	5,506	5,519	5,514	5,493

Table 4
Output: Northeast Asia in 2010 Four Scenarios

(1995, 100 million US$)

Russian Far East	Baseline	China Acceleration	Japan Acceleration	World Recession
110 Agriculture	1,746	1,754	1,754	1,705
120 Forestry	695	707	703	645
130 Fishing	980	988	987	942
210 Coal	394	401	399	366
220 Crude oil & gas	368	374	373	342
230 Metal mining	111	112	112	104
290 Non-metal mining	0	0	0	0
301 Food, tobacco	3,019	3,055	3,047	2,860
302 Textiles, apparel	110	110	110	107
303 Wood products	934	950	945	869
304 Furniture	68	69	69	66
305 Pulp, paper products	84	85	84	81
306 Printing, publishing	68	69	68	65
307 Chemicals	323	325	324	313
308 Petroleum, coal products	217	221	219	201
309 Rubber products	26	26	26	25
310 Leather products	135	136	136	132
311 Non-metallic products	92	92	92	90
312 Iron & steel	94	95	95	88
313 Non-ferrous metals	690	701	698	643
314 Metal products	96	98	98	90
315 General machinery	680	695	690	636
316 Electrical machinery	77	78	78	72
317 Motor vehicles, aircraft	227	232	230	212
319 Other transport	62	63	63	58
320 Precision instruments	46	47	47	43
321 Other manufacturing	659	669	666	617
400 Construction	10,548	10,857	10,753	9,620
500 Electricity, gas	53	53	53	51
600 Wholesale & retail trade	4,004	4,035	4,032	3,854
700 Transportation	779	784	784	751
800 Communication	101	102	102	98
910 Finance, real estate	1,855	1,857	1,857	1,846
920 Other services	3,239	3,252	3,249	3,183

Mongolia	Baseline	China Acceleration	Japan Acceleration	World Recession
110 Agriculture	263	268	264	259
120 Forestry	0	0	0	0
130 Fishing	0	0	0	0
210 Coal	8	8	8	8
220 Crude oil & gas	0	0	0	0
230 Metal mining	40	44	42	38
290 Non-metal mining	0	0	0	0
301 Food, tobacco	138	139	138	137
302 Textiles, apparel	71	75	73	70
303 Wood products	20	21	20	20
304 Furniture	0	0	0	0
305 Pulp, paper products	0	0	0	0
306 Printing, publishing	2	2	2	2
307 Chemicals	6	6	6	6
308 Petroleum, coal products	0	0	0	0
309 Rubber products	0	0	0	0
310 Leather products	17	17	17	17
311 Non-metallic products	13	14	13	13
312 Iron & steel	0	0	0	0
313 Non-ferrous metals	2	2	2	2
314 Metal products	2	2	2	2
315 General machinery	0	0	0	0
316 Electrical machinery	1	1	1	1
317 Motor vehicles, aircraft	2	2	2	2
319 Other transport	0	0	0	0
320 Precision instruments	2	2	2	2
321 Other manufacturing	52	55	53	49
400 Construction	120	125	122	117
500 Electricity, gas	88	88	88	88
600 Wholesale & retail trade	0	0	0	0
700 Transportation	56	56	56	55
800 Communication	29	29	29	29
910 Finance, real estate	0	0	0	0
920 Other services	210	213	211	209

Other Russia	Baseline	China Acceleration	Japan Acceleration	World Recession
110 Agriculture	23,171	23,308	23,229	22,822
120 Forestry	1,320	1,337	1,328	1,280
130 Fishing	702	707	704	690
210 Coal	624	632	628	607
220 Crude oil & gas	13,391	13,593	13,479	12,924
230 Metal mining	4,013	4,072	4,039	3,877
290 Non-metal mining	0	0	0	0
301 Food, tobacco	27,494	27,673	27,571	27,040
302 Textiles, apparel	4,067	4,095	4,079	3,997
303 Wood products	1,724	1,743	1,733	1,679
304 Furniture	1,415	1,433	1,423	1,375
305 Pulp, paper products	1,632	1,652	1,641	1,586
306 Printing, publishing	1,619	1,639	1,628	1,573
307 Chemicals	8,502	8,614	8,550	8,241
308 Petroleum, coal products	6,635	6,734	6,679	6,405
309 Rubber products	742	752	747	720
310 Leather products	1,372	1,381	1,376	1,348
311 Non-metallic products	1,023	1,031	1,026	1,003
312 Iron & steel	7,642	7,759	7,693	7,370
313 Non-ferrous metals	8,322	8,442	8,374	8,043
314 Metal products	1,540	1,555	1,547	1,505
315 General machinery	11,825	11,937	11,876	11,557
316 Electrical machinery	2,027	2,047	2,036	1,981
317 Motor vehicles, aircraft	5,280	5,330	5,303	5,160
319 Other transport	931	940	935	911
320 Precision instruments	788	796	792	771
321 Other manufacturing	2,395	2,413	2,402	2,354
400 Construction	36,629	36,941	36,784	35,848
500 Electricity, gas	645	650	647	636
600 Wholesale & retail trade	47,571	47,879	47,704	46,781
700 Transportation	10,155	10,221	10,183	9,985
800 Communication	1,320	1,328	1,324	1,297
910 Finance, real estate	45,253	45,279	45,264	45,186
920 Other services	75,134	75,283	75,198	74,752

Total	Baseline	China Acceleration	Japan Acceleration	World Recession
Northeast China	177,847	184,421	185,493	178,406
Other China	2,124,370	2,519,419	2,181,884	1,990,342
South Korea	1,353,109	1,410,538	1,379,786	1,257,044
North Korea	32,884	33,067	33,011	32,693
Russian Far East	32,580	33,092	32,943	30,775
Other Russia	356,905	359,200	357,924	351,303
Mongolia	1,142	1,169	1,151	1,125

Medium-Term Simulation
Table 5-1 GDP

Baseline

		2002	2003	2004	2005	2006	2007	2008	2009	2010
Japan	GDP	528,465	542,503	552,967	556,522	555,105	547,990	543,975	550,879	568,448
China	V_C	6,032	6,596	7,127	7,561	7,667	7,600	7,809	8,450	9,030
Hong Kong	V_H	1,080	1,537	1,724	1,635	1,364	1,191	1,374	1,469	1,576
S. Korea	V_K	570,610	620,964	671,144	720,201	759,940	788,958	825,905	869,445	917,401
Mongolia	V_M	547,760	591,382	713,455	812,826	913,306	929,596	924,295	867,373	854,320
N. Korea	V_NK	1,824	1,890	1,941	1,990	2,038	2,106	2,181	2,277	2,382
Russia Far E.	V_RF	31.76	32.39	35.23	33.59	34.40	34.75	35.52	36.28	37.15
Taiwan	V_T	9,938,510	10,650,890	11,612,830	12,352,100	12,731,050	12,900,170	13,118,430	13,655,880	14,270,030
China N.E.	VDF_NE	527.5	564.7	615.1	663.4	706.4	743.9	788.0	845.5	908.9
Russia	VD_RU	457.9	460.3	463.2	466.6	469.6	472.5	475.4	479.3	483.5

China's Acceleration

		2002	2003	2004	2005	2006	2007	2008	2009	2010
Japan	GDP	528,499	542,660	553,341	557,197	556,185	549,510	545,961	553,275	571,322
China	V_C	6,117	6,809	7,491	8,107	8,423	8,528	8,907	9,752	10,583
Hong Kong	V_H	1,082	1,545	1,742	1,664	1,398	1,219	1,401	1,520	1,645
S. Korea	V_K	570,950	622,403	674,359	725,861	768,655	801,061	841,384	888,574	940,871
Mongolia	V_M	547,778	591,464	713,753	813,680	915,159	932,879	929,232	873,914	862,356
N. Korea	V_NK	1,824	1,890	1,941	1,991	2,039	2,108	2,183	2,280	2,386
Russia Far E.	V_RF	31.77	32.44	35.32	33.74	34.62	35.05	35.90	36.74	37.70
Taiwan	V_T	9,947,271	10,686,950	11,690,900	12,484,620	12,926,870	13,161,020	13,438,080	14,036,460	14,727,900
China N.E.	VDF_NE	528.1	566.4	618.4	668.6	713.6	752.7	798.0	857.5	924.0
Russia	VD_RU	457.9	460.5	463.6	467.2	470.5	473.8	477.0	481.2	485.7

Japan's Acceleration

		2002	2003	2004	2005	2006	2007	2008	2009	2010
Japan	GDP	528,464	542,502	565,244	590,224	610,328	623,062	638,701	664,059	697,359
China	V_C	6,032	6,596	7,157	7,641	7,776	7,725	7,937	8,581	9,189
Hong Kong	V_H	1,080	1,537	1,727	1,645	1,378	1,201	1,380	1,482	1,592
S. Korea	V_K	570,610	620,964	672,485	724,695	767,690	799,424	838,356	883,390	933,374
Mongolia	V_M	547,760	591,382	713,500	812,996	913,900	931,039	926,796	870,856	858,547
N. Korea	V_NK	1,824	1,890	1,941	1,991	2,040	2,110	2,186	2,284	2,391
Russia Far E.	V_RF	31.76	32.39	35.26	33.70	34.58	34.97	35.77	36.55	37.45
Taiwan	V_T	9,938,510	10,650,890	11,634,530	12,423,430	12,851,190	13,054,860	13,288,490	13,833,330	14,468,730
China N.E.	VDF_NE	527.5	564.7	615.3	664.1	707.4	745.0	789.0	846.6	910.3
Russia	VD_RU	457.9	460.3	463.3	467.1	470.3	473.5	476.5	480.4	484.7

World Recession

		2002	2003	2004	2005	2006	2007	2008	2009	2010
Japan	GDP	528,092	541,447	550,995	553,544	550,973	542,839	537,770	543,755	560,248
China	V_C	5,983	6,483	6,955	7,323	7,386	7,300	7,493	8,052	8,515
Hong Kong	V_H	1,051	1,474	1,623	1,508	1,251	1,114	1,278	1,304	1,362
S. Korea	V_K	567,640	613,266	657,577	699,933	732,771	755,026	785,418	821,158	859,756
Mongolia	V_M	547,732	591,291	713,112	811,963	911,576	926,778	920,374	862,558	848,782
N. Korea	V_NK	1,824	1,889	1,940	1,988	2,035	2,102	2,175	2,269	2,373
Russia Far E.	V_RF	31.62	32.07	34.70	32.86	33.47	33.60	34.17	34.69	35.29
Taiwan	V_T	9,886,929	10,516,780	11,380,620	12,018,700	12,307,580	12,400,070	12,555,590	13,001,130	13,484,390
China N.E.	VDF_NE	527.2	563.7	613.5	661.2	703.8	741.2	785.3	842.3	904.6
Russia	VD_RU	457.3	459.0	461.1	463.6	465.8	467.8	469.9	472.7	475.9

Note on currency units: **Japan**: 1990 billion yen, **China**: 1990 billion yuan, **Hong Kong**: 1990 million HK$, **South Korea**: 1995 billion won, **Mongolia**: 1990 million togrog, **North Korea**: 1995 billion won, **Russia**: 1997 billion rubles, **Taiwan**: 1996 million NT$

Table 5-2 Exports (1995 million US$)

Baseline

		2002	2003	2004	2005	2006	2007	2008	2009	2010
China	E$_C	412,492	493,136	563,814	612,879	615,408	599,985	604,179	658,966	705,482
Hong Kong	E$_H	273,447	337,697	365,892	385,707	402,018	417,406	432,787	450,848	470,109
S. Korea	E$_K	214,650	235,101	251,410	266,977	275,495	282,058	289,264	304,111	318,694
Mongolia	E$_M	660.8	700.7	744.9	796.1	824.5	847.0	861.1	898.8	939.5
N. Korea	E$_NK	1,205.4	1,255.7	1,308.6	1,377.8	1,398.2	1,422.2	1,427.5	1,479.8	1,525.7
Taiwan	E$_T	179,061	195,005	211,373	221,078	226,997	230,606	235,708	246,975	258,027
Russia	E$_R	118,825	121,815	124,916	128,285	130,912	133,384	135,716	138,906	142,201

China's Acceleration

		2002	2003	2004	2005	2006	2007	2008	2009	2010
China	E$_C	412,726	494,229	566,363	617,451	622,211	608,664	613,759	670,069	720,724
Hong Kong	E$_H	273,704	338,684	367,879	388,952	406,792	423,808	440,794	460,582	481,794
S. Korea	E$_K	214,870	235,963	253,181	269,913	279,824	287,837	296,388	312,742	329,225
Mongolia	E$_M	662.6	707.6	758.7	818.7	857.8	891.8	917.3	967.2	1,021.7
N. Korea	E$_NK	1,206.3	1,259.1	1,315.8	1,390.0	1,416.2	1,446.6	1,458.0	1,517.5	1,571.4
Taiwan	E$_T	179,252	195,754	212,910	223,623	230,746	235,595	241,833	254,375	267,084
Russia	E$_R	118,871	121,992	125,277	128,881	131,791	134,569	137,199	140,716	144,385

Japan's Acceleration

		2002	2003	2004	2005	2006	2007	2008	2009	2010
China	E$_C	412,492	493,136	566,656	621,618	628,935	616,618	622,224	677,905	727,757
Hong Kong	E$_H	273,447	337,697	366,186	386,635	403,502	419,308	434,979	453,256	472,870
S. Korea	E$_K	214,650	235,101	252,277	269,613	279,528	287,030	294,813	310,084	325,576
Mongolia	E$_M	660.8	700.7	749.2	809.3	844.9	872.3	889.9	930.2	975.5
N. Korea	E$_NK	1,205.4	1,255.7	1,319.1	1,409.2	1,444.9	1,479.0	1,491.1	1,548.7	1,604.5
Taiwan	E$_T	179,061	195,005	211,846	222,542	229,283	233,460	238,890	250,389	261,993
Russia	E$_R	118,825	121,815	125,065	128,740	131,610	134,252	136,700	139,980	143,433

World Recession

		2002	2003	2004	2005	2006	2007	2008	2009	2010
China	E$_C	407,751	480,419	542,765	582,614	577,886	557,794	558,595	603,708	635,010
Hong Kong	E$_H	269,681	329,770	353,499	368,559	379,929	390,237	400,404	412,812	425,919
S. Korea	E$_K	212,730	230,719	244,352	256,997	262,708	266,630	271,310	282,782	293,213
Mongolia	E$_M	658.0	693.5	732.3	777.3	799.6	816.2	825.2	855.8	887.7
N. Korea	E$_NK	1,199.1	1,240.9	1,284.3	1,342.7	1,352.6	1,365.8	1,361.1	1,400.3	1,430.9
Taiwan	E$_T	177,936	192,299	206,952	214,765	218,942	221,052	224,784	233,936	242,168
Russia	E$_R	118,219	120,519	122,873	125,438	127,238	128,866	130,343	132,579	134,824

Table 5-3 Imports

(1995 million US$)

Baseline

		2002	2003	2004	2005	2006	2007	2008	2009	2010
China	M$_C	312,529	342,026	374,821	407,448	432,077	446,806	460,955	485,128	515,433
Hong Kong	M$_H	284,948	371,505	443,828	481,990	474,253	440,538	438,156	487,208	527,613
S. Korea	M$_K	189,008	206,694	225,302	243,899	260,051	272,639	286,205	301,801	319,181
Mongolia	M$_M	987.3	993.3	930.1	984.5	1,120.1	1,184.9	1,310.3	1,332.3	1,356.9
N. Korea	M$_NK	10,084	10,868	11,480	12,081	12,639	13,462	14,351	15,516	16,784
Taiwan	M$_T	143,838	156,254	172,329	185,526	192,000	194,768	199,090	208,395	219,216
Russia	M$_R	42,196	42,187	42,185	42,190	42,193	42,197	42,202	42,215	42,231

China's Acceleration

		2002	2003	2004	2005	2006	2007	2008	2009	2010
China	M$_C	314,360	349,015	388,820	430,220	465,530	491,593	516,949	553,113	596,977
Hong Kong	M$_H	285,208	372,717	446,617	486,926	481,519	449,546	447,700	497,892	542,728
S. Korea	M$_K	189,097	207,099	226,269	245,681	262,884	276,685	291,510	308,451	327,383
Mongolia	M$_M	988.4	997.4	938.4	998.1	1,140.2	1,212.3	1,345.3	1,375.8	1,409.8
N. Korea	M$_NK	10,085	10,870	11,483	12,088	12,652	13,482	14,380	15,555	16,835
Taiwan	M$_T	143,989	156,876	173,674	187,810	195,374	199,267	204,612	214,977	227,140
Russia	M$_R	42,196	42,189	42,188	42,195	42,201	42,207	42,214	42,230	42,250

Japan's Acceleration

		2002	2003	2004	2005	2006	2007	2008	2009	2010
China	M$_C	312,529	342,026	375,474	409,716	436,125	452,389	467,649	492,611	524,074
Hong Kong	M$_H	284,948	371,505	444,124	483,209	476,696	443,745	440,985	489,458	530,998
S. Korea	M$_K	189,008	206,694	225,653	245,185	262,479	276,131	290,546	306,795	324,907
Mongolia	M$_M	987.3	993.3	932.7	992.5	1,132.3	1,200.1	1,327.9	1,352.3	1,380.4
N. Korea	M$_NK	10,084	10,868	11,484	12,095	12,664	13,503	14,416	15,603	16,889
Taiwan	M$_T	143,838	156,254	172,703	186,756	194,070	197,434	202,020	211,460	222,662
Russia	M$_R	42,196	42,187	42,186	42,194	42,199	42,205	42,210	42,224	42,242

World Recession

		2002	2003	2004	2005	2006	2007	2008	2009	2010
China	M$_C	311,426	338,622	368,519	397,744	419,085	431,141	443,142	464,042	489,467
Hong Kong	M$_H	281,137	360,362	425,348	455,501	442,339	406,867	404,299	445,963	472,351
S. Korea	M$_K	188,230	204,437	221,050	237,276	250,888	260,920	271,979	284,758	298,816
Mongolia	M$_M	985.7	989	922.6	973.2	1,105	1,165.8	1,287.3	1,304.4	1,322.9
N. Korea	M$_NK	10,082	10,862	11,467	12,057	12,600	13,407	14,277	15,423	16,671
Taiwan	M$_T	142,949	153,944	168,328	179,782	184,703	186,129	189,341	197,047	205,594
Russia	M$_R	42,191	42,177	42,168	42,166	42,162	42,159	42,157	42,162	42,171

Table 6 Comparison of Scenarios in the Seventh Year
GDP, Exports, and Imports

			Baseline 2008	China Acc. 2008	Japan Acc. 2010	World Rec. 2008
China						
	GDP	V_C	7,809	8,907	9,189	7,493
	Exports	E$	604,179	613,759	727,757	558,595
	Imports	M$	460,955	516,949	524,074	443,142
Hong Kong						
	GDP	V_H	1,374	1,401	1,592	1,278
	Exports	E$	432,787	440,794	472,870	400,404
	Imports	M$	438,156	447,700	530,998	404,299
S. Korea						
	GDP	V_K	826	841	933	785
	Exports	E$	289,264	296,388	325,576	271,310
	Imports	M$	286,205	291,510	324,907	271,979
Mongolia						
	GDP	V_M	924	929	859	920
	Exports	E$	861	917	976	825
	Imports	M$	1,310	1,345	1,380	1,287
N. Korea						
	GDP	V_NK	2,181	2,183	2,391	2,175
	Exports	E$	1,428	1,458	1,604	1,361
	Imports	M$	14,351	14,380	16,889	14,277
Taiwan						
	GDP	V_T	13,118	13,438	14,469	12,556
	Exports	E$	235,708	241,833	261,993	224,784
	Imports	M$	199,090	204,612	222,662	189,341
Russia						
	GDP	VD_RU	475	477	485	470
	Exports	E$	135,716	137,199	143,433	130,343
	Imports	M$	42,202	42,214	42,242	42,157
Northeast China						
	GDP	VDF_NE	788.0	798.0	910.3	785.3
	Exports	ED_NE	146.2	165.3	168.5	140.4
	Imports	ID_NE	296.2	294.6	347.7	296.9
Russian Far East						
	GDP	V_RF	35.5	35.9	37.5	34.2
	Exports	E_RF	36.0	36.5	38.7	34.2
	Imports	M_RF	27.7	28.1	29.9	26.2

Note: Exports and imports: 1995 million US$,
except for Northeast China and the Russian Far East where the local currencies are used
(1990 billion yuan and 1997 billion rubles, respectively).

Table 7-1 Japan Acceleration Scenario vs. Baseline Scenario

			2003	2004	2005	2006	2007	2008	2009	2010
Nominal GDP, billions	GDP_N	Japan Acc.	514,062	518,186	536,962	557,220	585,160	609,659	634,755	667,525
		Baseline	514,062	516,027	524,575	526,976	532,297	528,503	522,040	521,358
		% Deviation	0.00	0.42	2.36	5.74	9.93	15.36	21.59	28.04
GDP, real (90p.), billions	GDP	Japan Acc.	542,502	565,244	590,224	610,328	623,062	638,701	664,059	697,359
		Baseline	542,503	552,967	556,522	555,105	547,990	543,975	550,879	568,448
		% Deviation	0.00	2.22	6.06	9.95	13.70	17.41	20.55	22.68
Private consumption, real	CX82	Japan Acc.	324,682	331,825	347,092	353,761	359,470	360,333	370,022	380,668
		Baseline	324,682	331,826	339,902	339,204	339,252	335,550	340,849	347,277
		% Deviation	0.00	0.00	2.12	4.29	5.96	7.39	8.56	9.62
Private residential investment, real	IH	Japan Acc.	25,256	24,863	28,996	30,556	31,997	29,133	30,511	35,455
		Baseline	25,256	24,863	25,099	21,284	18,358	12,758	13,202	17,905
		% Deviation	0.00	0.00	15.52	43.56	74.29	128.34	131.11	98.02
Business investment, real	IPXSUM	Japan Acc.	102,648,100	109,338,100	115,847,000	119,390,600	116,358,500	118,607,500	122,008,900	126,977,100
		Baseline	102,648,300	101,085,800	101,074,600	101,829,500	96,358,880	93,625,650	91,820,690	92,118,040
		% Deviation	0.00	8.16	14.62	17.25	20.76	26.68	32.88	37.84
Government investment, real	IG	Japan Acc.	33218.40	38201.16	43931.33	50521.03	58099.19	65652.08	73530.33	80883.36
		Baseline	33218.40	33218.40	33218.40	33218.40	33218.40	33218.40	33218.40	33218.40
		% Deviation	0.00	15.00	32.25	52.09	74.90	97.64	121.35	143.49
Government consumption, real	CG	Japan Acc.	48,472	49,927	51,424	52,967	54,556	56,193	57,879	59,615
		Baseline	48,472	49,200	49,937	50,687	51,447	52,219	53,002	53,797
		% Deviation	0.00	1.48	2.98	4.50	6.04	7.61	9.20	10.81
Exports, G&S, real	E82	Japan Acc.	82,167,040	89,835,840	94,636,320	97,871,620	100,797,200	105,644,300	111,691,800	118,163,700
		Baseline	82,167,040	89,808,450	94,536,820	97,686,480	100,538,200	105,340,400	111,356,000	117,758,600
		% Deviation	0.00	0.03	0.11	0.19	0.26	0.29	0.30	0.34
Imports, G&S, real	M82	Japan Acc.	78,353,210	81,861,470	89,730,390	90,852,220	92,771,570	90,932,580	94,186,520	96,773,760
		Baseline	78,353,280	80,368,980	85,302,730	84,293,950	84,845,500	82,082,690	84,604,050	85,829,790
		% Deviation	0.00	1.86	5.19	7.78	9.34	10.78	11.33	12.75
Current balance, million $	BLCURNT	Japan Acc.	129,929	196,918	209,620	194,294	190,510	205,592	257,004	303,772
		Baseline	129,929	205,768	242,019	264,010	306,582	366,709	492,191	593,890
		% Deviation	0.00	-4.30	-13.39	-26.41	-37.86	-43.94	-47.78	-48.85
Rate of utilization of GDP, %	ROUSP	Japan Acc.	92.0	93.7	95.8	96.8	96.3	96.3	97.9	100.6
		Baseline	92.0	91.7	90.4	88.4	85.8	83.7	83.7	85.4
		% Deviation	0.00	2.22	6.02	9.40	12.28	14.99	16.98	17.75
Unemployment rate, %	URATE	Japan Acc.	4.74	4.67	4.48	4.25	4.10	4.06	4.00	3.82
		Baseline	4.74	4.67	4.66	4.76	4.94	5.22	5.47	5.57
		% Deviation	0.00	0.00	-3.88	-10.54	-16.95	-22.22	-26.93	-31.36
GDP deflator	P	Japan Acc.	94.8	92.7	91.0	91.3	93.9	95.5	95.6	95.7
		Baseline	94.8	94.3	94.3	94.9	97.1	97.2	94.8	91.7
		% Deviation	0.00	-1.74	-3.48	-3.83	-3.31	-1.75	0.87	4.37
Wage rate (¥1000)	W	Japan Acc.	5,608	5,602	5,685	5,833	6,043	6,206	6,332	6,461
		Baseline	5,608	5,624	5,683	5,731	5,793	5,781	5,717	5,655
		% Deviation	0.00	-0.39	0.03	1.76	4.32	7.36	10.75	14.26
Private consumption deflator	PC	Japan Acc.	101.4	98.9	99.4	100.7	104.3	105.5	105.6	105.3
		Baseline	101.4	99.9	100.7	101.3	103.4	102.7	100.6	98.0
		% Deviation	0.00	-1.02	-1.35	-0.54	0.91	2.77	4.97	7.49
Exchange rate, ¥/$	EXR	Japan Acc.	112.7	105.0	98.9	104.6	108.1	115.4	110.5	108.3
		Baseline	112.7	106.5	100.6	102.5	99.7	100.1	89.0	83.9
		% Deviation	0.00	-1.38	-1.75	2.13	8.45	15.22	24.19	29.03
Stock price (TOPIX)	STOCKPR	Japan Acc.	1,197	1,542	1,696	1,604	1,849	2,068	2,024	2,041
		Baseline	1,197	1,397	1,277	1,036	1,205	1,444	1,463	1,567
		% Deviation	0.00	10.39	32.80	54.83	53.48	43.22	38.41	30.25
Long-term interest rate, %	INTGB	Japan Acc.	1.11	1.34	2.08	1.90	2.45	2.47	3.03	3.74
		Baseline	1.11	1.19	1.68	1.29	1.87	1.68	1.93	2.43
		% Deviation	0.00	13.09	23.90	46.73	31.09	47.48	57.08	54.32
Government debt ratio, net	GGFDNRA	Japan Acc.	0.560	0.692	0.832	0.937	1.028	1.104	1.185	1.137
		Baseline	0.560	0.688	0.836	0.968	1.095	1.217	1.347	1.317
		% Deviation	0.00	0.60	-0.41	-3.13	-6.11	-9.27	-12.02	-13.67
Primary balance	PBR	Japan Acc.	-0.042	-0.052	-0.058	-0.064	-0.077	-0.083	-0.085	-0.086
		Baseline	-0.042	-0.045	-0.048	-0.051	-0.058	-0.056	-0.050	-0.043
		% Deviation	0.00	16.11	19.84	25.20	34.44	48.50	68.83	98.72
Primary balance, central government	PBRC	Japan Acc.	-0.033	-0.035	-0.035	-0.035	-0.039	-0.037	-0.035	-0.031
		Baseline	-0.033	-0.033	-0.036	-0.039	-0.042	-0.038	-0.035	-0.028
		% Deviation	0.00	5.67	-2.72	-9.41	-6.13	-3.31	0.70	11.59
Primary balance, local government	PBRL	Japan Acc.	-0.009	-0.017	-0.023	-0.029	-0.038	-0.046	-0.050	-0.054
		Baseline	-0.009	-0.012	-0.012	-0.013	-0.016	-0.017	-0.016	-0.015
		% Deviation	0.00	45.16	87.65	130.61	140.03	163.93	216.19	261.10
Tax & social insurance revenue	TSUM	Japan Acc.	146,227	149,221	155,253	163,156	168,932	178,303	188,941	199,388
		Baseline	146,227	147,031	148,027	149,067	148,247	150,870	154,339	157,679
		% Deviation	0.00	1.49	4.88	9.45	13.95	18.18	22.42	26.45
Total population, thousands	POPT	Japan Acc.	127,253	127,302	127,411	127,531	127,672	127,817	127,968	128,149
		Baseline	127,253	127,302	127,367	127,380	127,394	127,383	127,324	127,246
		% Deviation	0.00	0.00	0.03	0.12	0.22	0.34	0.51	0.71

Table 7-2 Japan: Sectoral Output and Imports

A. Output, 2010

	Annual rate BS	Annual rate Japan Accel.	% Deviation
X06 Forestry	-3.38%	2.04%	46.52
X13 Other mining	-0.91%	10.38%	112.79
X21 Textiles	-0.02%	2.79%	21.48
X23 Apparel	-2.86%	1.90%	39.85
X25 Wood products	-3.21%	4.21%	67.77
X26 Utensils	-1.26%	3.54%	39.41
X29 Coal products	0.25%	6.24%	50.12
X34 Plastic products	-0.17%	3.76%	31.00
X35 Cement	-1.43%	8.92%	101.16
X41 Metal products	-0.47%	3.93%	35.33
X42 Office equipment	1.28%	4.56%	24.95
X44 Industrial electric machinery	1.81%	4.54%	20.35
X53 Residential building	-4.10%	5.01%	88.75
X54 Non-residential building	-0.76%	4.46%	43.22
X55 Public works	-0.02%	13.47%	142.49
X56 Other construction	0.00%	-1.23%	59.97
X71 Real estate	0.00%	3.88%	7.65
X72 Information services	0.00%	-0.30%	31.93
X73 Other office services	0.12%	3.84%	29.09
X82 Total output	0.52%	3.62%	23.74

B. Imports, 2010

	Annual rate BS	Annual rate Japan Accel.	% Deviation
M04 Livestock for textiles	-1.00%	2.38%	26.48
M09 Crude oil	2.28%	4.28%	14.51
M12 Non-ferrous metal mining	0.19%	4.24%	31.94
M13 Other mining	0.08%	6.13%	50.88
M36 Other ceramic products	-1.53%	7.30%	82.47
M37 Iron	8.87%	5.82%	-18.01
M38 Steel	2.05%	12.83%	102.00
M41 Metallic products	-0.66%	7.33%	71.87
M44 Industrial electric machinery	2.33%	4.72%	17.49
M46 Precision Instruments	2.20%	5.52%	25.09
M82 Total Imports	1.31%	3.06%	12.75

The Interdependence among Economy, Energy, and Environment in China: An Econometric Analysis 2000-2020

Mitsuo Yamada*

Abstract

In this paper, we construct a multi-sectoral econometric model of China, and discuss the economic impacts of the improvement of energy efficiency and shift of energy demand in our model. We analyze scenarios for the pipeline project of the Chinese government and the natural-gas thermal power plant project. According to our simulation, China will continue to grow at a relatively high rate, though the rate will fall back gradually to less than 5% per year. The amount of real GDP in 2020 will increase to 2.78 times the amount in 2000. The overall energy demand in 2020 will increase to 1.95 times the amount in 2000. Also, CO_2 emissions will grow in volume 1.91 times from 2000 to 2020. Investment in the projects expands total demand in the economy, which requires more energy and increases CO_2 emissions. However, the shift in demand from coal to natural gas brought about by the projects has the effect of reducing CO_2 emissions. Though these two effects offset one another, the CO_2 reduction is large enough for the simulation periods throughout. The CO_2 reduction cost for the economy as a whole is estimated at US$30.39 per ton of CO_2 for the pipeline project, and at US$21.48 per ton of CO_2 for the power plant.

Keywords: *multi-sectoral econometric model, China, economy-energy-environmental model, energy-demand shift, natural gas*

1. Introduction

After introducing market mechanisms into the economy, China has managed to grow as rapidly as it has by actively accepting an inflow of foreign direct investment. In the 1990s the growth rate of China became prominent among East Asian countries (see Figure 1-1). Generally, rapid development of the economy requires large consumption of energy followed by a great amount of CO_2 emissions. Actually, China's CO_2 emissions are the second largest in the world, after those of the US (see Figure 1-2). In terms of emissions by GDP, no other country exceeds China. Consequently, China, with its rapid growth, will be required to make more efficient use of energy and reduce CO_2 emissions for the sake of the global environment.

China has abundant coal resources, which have been used mainly as an energy resource. The comparison in Figure 1-3 of energy resource components among countries shows that China depends heavily on domestic coal for energy use. Continued development in China might result in serious environmental problems, thus necessitating improvements in energy efficiency, and a shift in demand from coal to natural gas, which has the lowest CO_2 emissions per calorie of the fossil fuels. Economic cooperation with the developed countries and transfer of advanced technology to China seem important recourses for such a transition.

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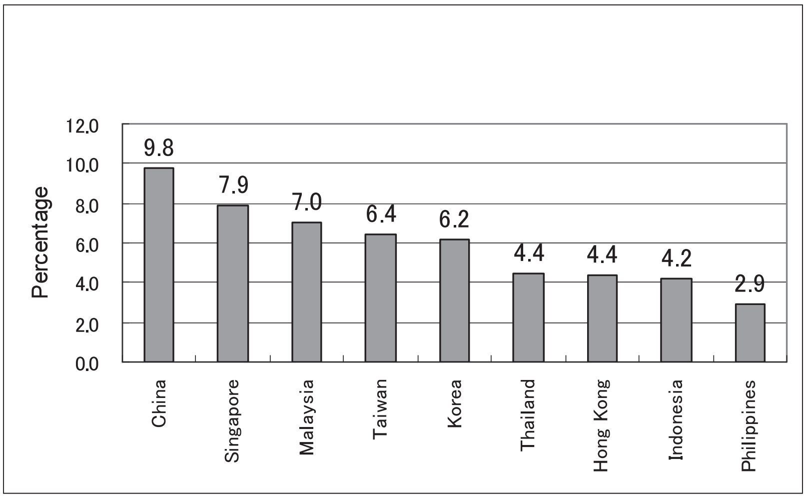
A large-scale natural gas field was recently discovered in the Tarim Basin, located in western China. Economic development in the eastern coastal area of China has been remarkable, and there appears to be a shortage of energy, and serious air pollution in the region. Therefore, the Chinese government produced a construction plan for a natural gas pipeline to connect both regions in February 2000. This plan was started in 2001 and completion was aimed at for 2004. The project involved the construction of a 4,100 km pipeline from the Tarim Basin to Shanghai. The estimated cost was 146 billion yuan. Twelve billion cubic meters of natural gas per year was to be supplied after completion. This amount is to be increased to 19 billion cubic meters after 2010. It is estimated the supply will be stable for 20 years or more, and this plan is expected to contribute to the reduction of CO_2 emissions in China.

The Clean Development Mechanism (CDM) is a system in which a developed country transfers advanced technology to a developing country, for which the developed country receives a certain amount of emission credits, called Certified Emission Reductions (CERs). CERs are authorized amounts of carbon dioxide emissions which are reduced by a given project. The CDM seems attractive to both developed and developing countries, because the developed country can gain a reduction in CO_2 emissions at a lower cost than it would be able to domestically, and because the developing country achieves environmental improvement by way of introducing advanced technology at a lower cost than it would be able to otherwise. As a rule, the CDM projects, from small- to large-scale, are considered to have a private-sector base. A natural-gas thermal power plant would be a good example of such projects because power generation with natural gas would promote the disuse of coal thermal power stations, which are of small- to medium-scale and superannuated. As a result, this type of project would shift energy usage from coal to natural gas and thus reduce CO_2 emissions.

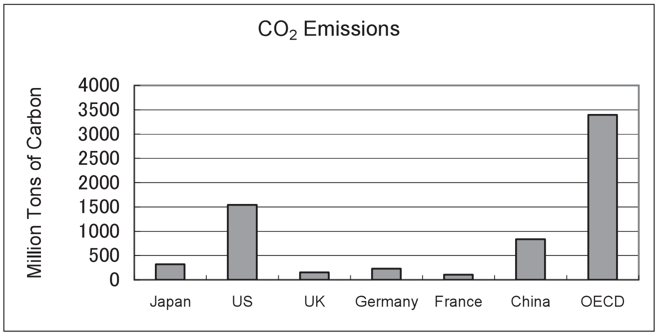
In this paper, we construct a multi-sectoral econometric model of the Chinese economy, and discuss the economic impacts of the improvement of energy efficiency and the shift of energy demand within this model. In the next section, we explain the outline of our model, and discuss the performance of the estimation model. In Section 3, we present a baseline project from 2000 to 2020, and in Section 4, we analyze scenarios for the pipeline project of the Chinese government, and the natural gas thermal power plant project, which might be a candidate for CDM.

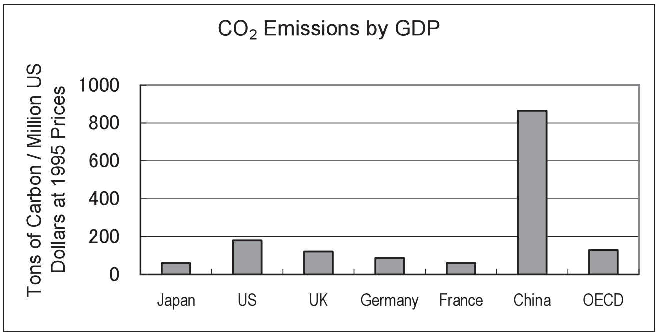
Figure 1-1 Growth Rates of East Asian Countries 1990-2000



Source: *Key Indicators of Developing Asian and Pacific Countries 2000*
Calculated from the database of the Asian Development Bank.

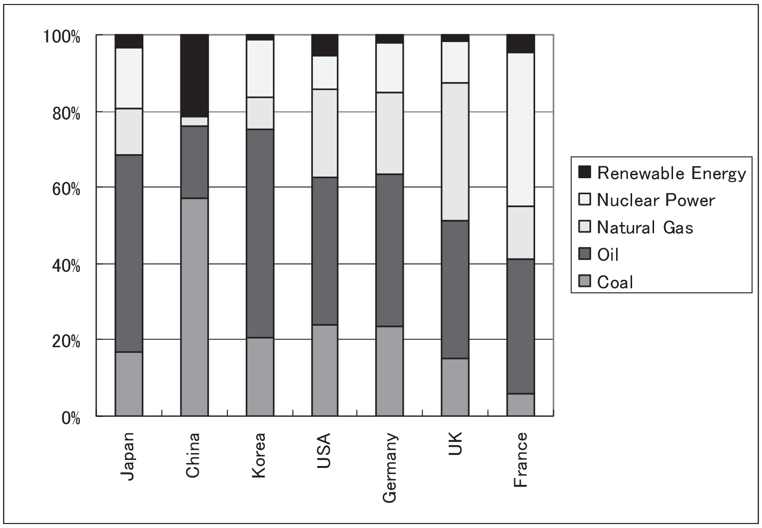
Figure 1-2 CO_2 Emissions by Country in 1999





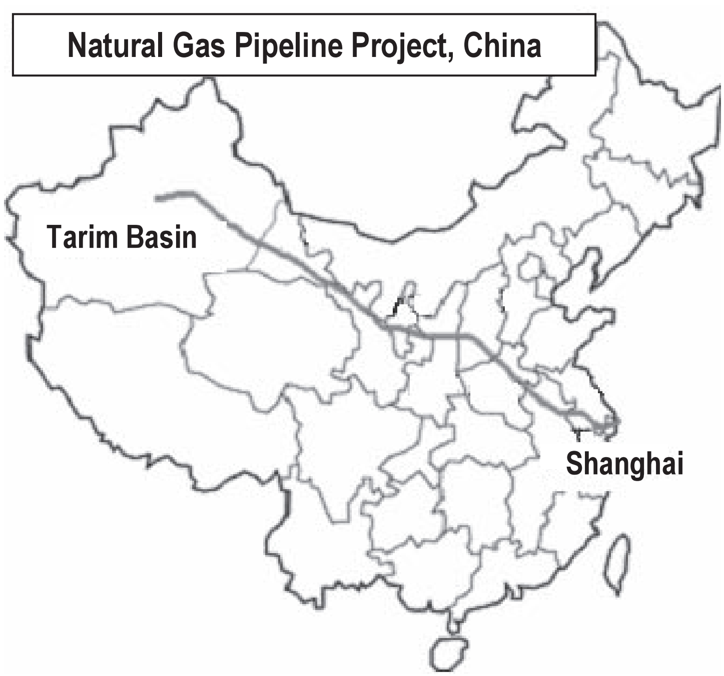
Source: IEA Energy Outlook

Figure 1-3 Primary Energy Composition by Country in 1999



Source: IEA, Energy Balance of OECD Countries,
Energy Balance of Non-OECD Countries

Figure 1-4



Source: Web site of Searchina Co., Ltd., with some modification
(http://news.searchina.ne.jp/2002/0705/general_0705_001.shtml)

2. Outline and Performance of the Model

The multi-sectoral econometric model of the Chinese economy constructed here is a demand-oriented model of the so-called Keynes-Leontief type. The sectors are categorized into the 15 sectors shown in Table 2-1, which include three energy-related sectors; (1) coal; (2) oil and natural gas; and (3) electric power and heat supply. The data for the model covers the years from 1980 to 2000. However, the period for estimation differs for each equation mainly because of data availability. The sectoral time-series are not officially-published data; therefore, they were estimated by using the Chinese input-output tables.[1]

2.1 Structure of the Model

The model structure of the macro and sectoral economy is shown in Figure 2-1. Expenditures of final demand, production by sector, wages and prices, government expenditure and revenue, current balance and capital balance in international transactions, etc., are shown in this figure. Consumption is explained by income factor and the previous consumption expenditure as a consumption function. Disposable income cannot be obtained from the Chinese official statistics, so we used total value added minus total capital consumption as a proxy variable to represent it.

The investment expenditure contains residential investment, private investment for plant and equipment, and government investment. This is explained by real GDP after subtracting government investment and foreign direct investment. Real GDP is determined as the sum of these expenditures of final demand. In our model, exports are treated as exogenous, and imports by sector are explained endogenously as an import-demand function, in which the explanatory variables are domestic demand by sector and relative price.

The average wage is explained by overall productivity. The wage rate by sector is linked to this average wage. The employment by sector is estimated as the employment-demand function, where the production by sector and real wage are the main explanatory variables. However, employment in the agriculture sector is explained in a different way. The employment in this sector is determined by subtracting the sum of non-agricultural employment from total employment.

Our model contains the fundamental structure of the input-output model. The structure of demand-production determination is expressed as:

$$\mathbf{X}=\mathbf{D}+\mathbf{E}-\mathbf{M}$$

$$\mathbf{X}=\mathbf{AX}+\mathbf{FD}+\mathbf{E}-\mathbf{M}$$

where $\mathbf{X}$ is a product vector, $\mathbf{D}$ a domestic demand vector, $\mathbf{E}$ an export vector, and $\mathbf{M}$ an import vector. Here, $\mathbf{A}$ is an input coefficient matrix, and $\mathbf{FD}$ is a domestic final-demand vector. Meanwhile, the structure of price determination is expressed as:

$$\mathbf{P}=\mathbf{AD'P}+\mathbf{AM'PM}+\mathbf{V}$$

$$\mathbf{V}=\hat{\mathbf{X}}^{-1}\hat{\mathbf{L}}\mathbf{W}+\mathbf{O}$$

where $\mathbf{P}$ is a price vector, $\mathbf{PM}$ an import price vector, $\mathbf{V}$ a value added ratio vector, $\mathbf{AD'}$ a transposition of a domestic-input coefficient matrix, and $\mathbf{AM'}$ a transposition of an import-input coefficient matrix. $\hat{\mathbf{X}}^{-1}$ signifies the inverse of the diagonal matrix, whose diagonal

[1] The input-output tables were published by the Chinese government National Bureau of Statistics, for the years 1985, 1987, 1990, 1992, 1995, and 1997. The tables were aggregated to the 15 sectors and used, with some interpolations, to estimate the time series data.

elements are from the production vector. $\hat{\mathbf{L}}$ is a diagonal matrix, whose diagonal elements are employed persons by sector. $\mathbf{W}$ is a wage-rate vector, $\hat{\mathbf{X}}^{-1}\hat{\mathbf{L}}\mathbf{W}$ is a unit-wage-cost vector, and $\mathbf{O}$ is a vector that represents other costs.

To simplify the model, however, only one input-output table is used. In the base year, the above relations are strictly maintained, though they do not hold for the other years. We therefore need some adjustment mechanism to explain the discrepancies between the actual domestic demand, $\mathbf{D}=\mathbf{AX}+\mathbf{FD}$, and the calculated domestic demand, $\mathbf{D}^0=\mathbf{A}^0\mathbf{X}+\mathbf{FD}^0$, which is obtained by assuming that the input coefficient and the distribution ratio of the domestic final-demand in the base year do not change from year to year. These discrepancies are explained by the change in relative prices in our model.

Also, the prices are determined by the sum of the intermediate input cost and unit value-added cost. However, if we apply a fixed input coefficient to this relationship, differences appear between the actual price and the price derived from the costs. In such a case we apply a regression of the actual price on the calculated price.

In our model, coal, oil, natural gas, and electricity appear in the energy sector[2], though oil and natural gas are treated as one sector in the input-output sector. Figure 2-2 shows the causality among the variables in the energy sector.

Firstly, total power generation is explained by the total demand adjusted for inventory factor and net export. The export and import of electricity are treated as exogenous variables in the model because they are small in scale. The total demand of electricity is calculated as the sum of industrial demand and household demand. Industrial demand for electricity is a function of the corresponding production or domestic demand and relative price factor. A trend factor is added in some equations. Household demand is also determined by consumption and the relative price factor. Power generation consists of hydroelectric power, thermal power, and other generation methods, mainly nuclear electric power. Nuclear generation is considered to be exogenous. Hydroelectric generation is explained as a function of total generation and a trend factor, considering that some part of the total generation consists of hydroelectric generation. The remaining part of the total generation is made up by thermal generation.

Assuming exports and imports as exogenous for coal, coal production is explained by the total demand with adjustment for inventory factor and net export. Total demand is determined by the sum of industrial demand and household demand. There is some coal demand for energy conversion. Coal demand for generation is linked to thermal generation via the coal thermal generation ratio and the fuel efficiency of coal generation.

In this equation, the data for the coal thermal ratio and the efficiency ratio of coal thermal generation were obtained from the IEA energy database. According to this data, in 2000 the coal thermal ratio in China was 90.53%, the oil thermal ratio was 8.46%, and the natural gas thermal ratio was 1.02%.The fuel efficiency of generation was 33.26% for coal,

[2] Coal, oil and natural gas are measured as tons of coal equivalent. The conversion ratios used were as follows.

Unit	Oil (10000 tons)	Coal (10000 tons)	Electricity (100 million kWh)	Natural Gas (100 million cubic meters)
Calorific Value	10000 kcal/kg	7000 kcal/kg	860 kcal/kWh	9310 kcal/m^3
Standard Coal Conversion	1.429	1.000	0.123	1.330
Conversion Ratio	0.7	1	0.814	0.075

Source: Energy Statistics of China (1997-1999 and 2001)

34.14% for oil, and 44.80% for natural gas in the same year.

Industrial demand and household demand for coal were determined as a demand function, where the explanatory variables were the production or domestic demand and the relative price. In some equations a trend factor was included.

The oil and natural gas sectors have almost the same structure as the coal sector, with the following differences. Overall energy production is explained by the summation of coal, oil, natural gas, and hydroelectric and nuclear power generation, converted to the same unit. The overall energy demand is explained by summing the sectoral and household demands. Computing the overall energy export in the same way, the overall energy import is determined as the overall demand plus the overall export minus the overall production. In our model, the overall energy import is connected to oil imports, with subtraction of coal imports, which means the shortfall in energy is filled by overseas oil.

Finally, CO_2 emissions are explained from the sum of the demands for coal, oil, and natural gas, after first being multiplied by their respective emission coefficients.[3] The activities of the physical base in the energy sector are connected to the real product in the energy-related sectors.

[3] The CO_2 emission ratios by type of energy were as follows:

	Coal	Oil	Natural Gas
Emission Coefficient	1.080 (tC / TOE)	0.837 (tC / TOE)	0.641 (tC / TOE)

Source: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories

Figure 2-1 Structure of the Model

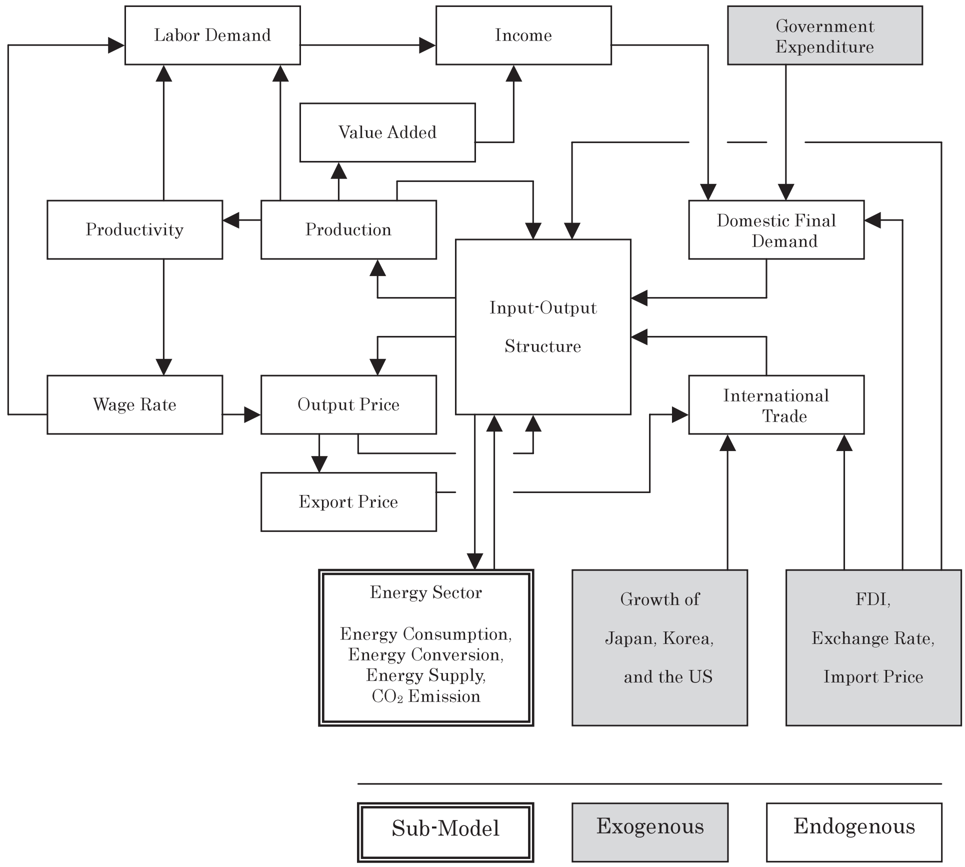
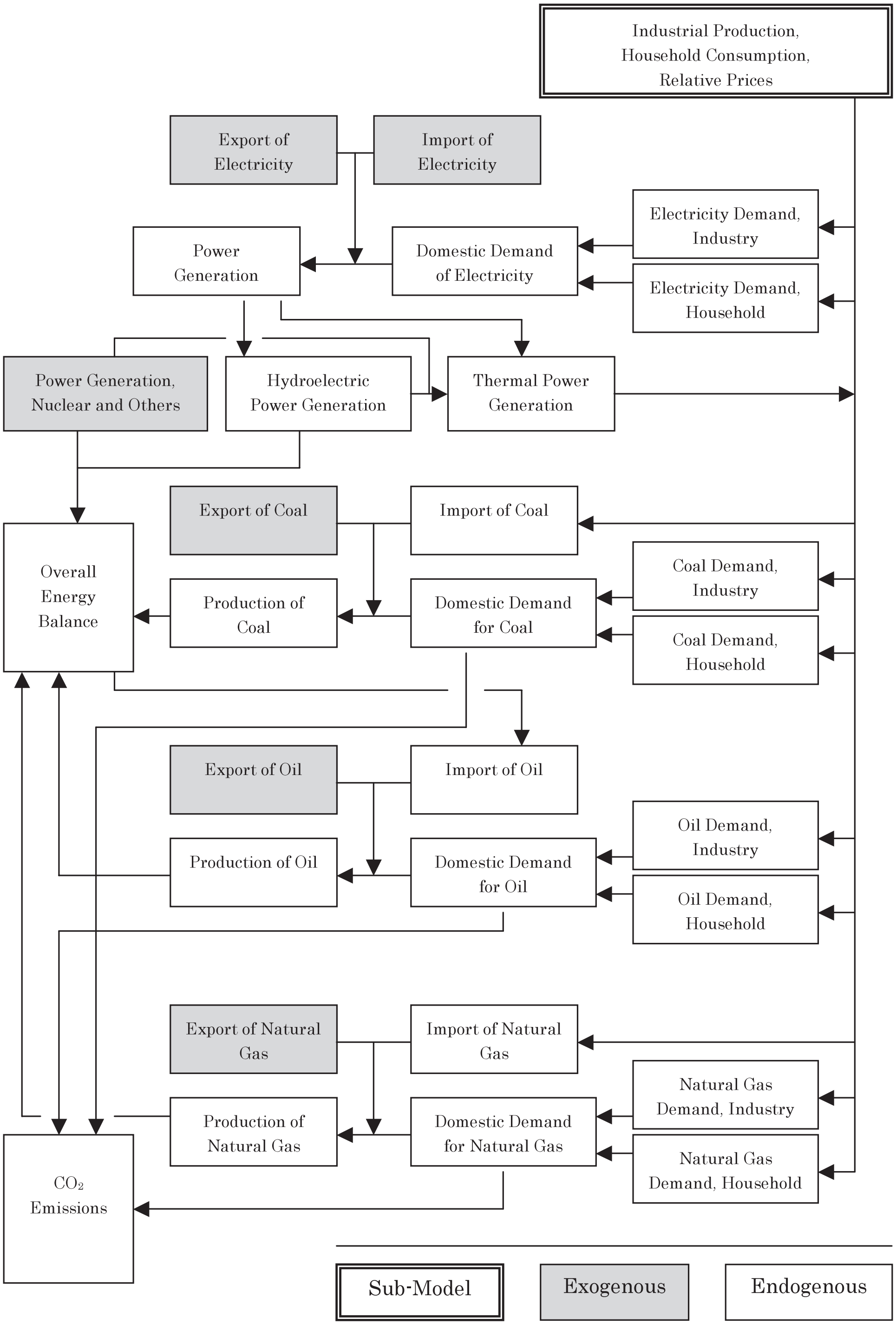


Figure 2-2 Energy Sector Flow Chart



2.2 Data, Estimation, and Performance of the Model

The main data source we used is the Statistical Yearbook of China. However, there were insufficient sectoral data, so we had to estimate sectoral time series for output, intermediate input, value added, employee income, etc. For this estimation, we used the input-output tables for China (see Footnote 1), which we first integrated according to our sectoral classification. Then we interpolated data we lacked between input-output tables, using related time series data. For value added, for example, we used GDP product by sector. We estimated the value-added-to-output ratios by linear interpolation, and obtained output series by sector by dividing the estimated value-added series by the value-added ratios. As a result, we obtained the total intermediate input by sector.

The sum of total intermediate input by sector must be equal to the sum of total intermediate demand by sector. Therefore we could estimate sectoral intermediate demand by multiplying this sum by the relevant ratio of total intermediate demand, which we had linearly interpolated in advance.

We were able to estimate sectoral export and import values from the UN trade database, with some modification for local currency. Total consumption and investment were obtained from the SNA database of China. We estimated the ratios of sectoral values to totals by linear interpolation, and multiplied them by the total value for consumption and investment. Some adjustments were necessary to stay in keeping with the definition that the sum of total intermediate demand and final demand, consumption and investment, and export minus import equals the output for each sector.

After estimating deflators for output, export, and import by sector, we got the corresponding real value by dividing the estimated nominal value by the appropriate deflator.

We ran the model using the following time series data; the period from 1981 to 2000 for the macro equation, and 1985 to 2000 for the energy sector. The estimation methods are mainly ordinal least squares. Regression with autocorrelation of error terms and estimation with coefficient restrictions were applied in some equations.

In our model, individual demand by sector is explained by the computed demand based on the base-year input-output coefficients with appropriate adjustment. This equation is important in our model. We explained it using two factors; the computed demand and the relative price. We were able to obtain statistically significant estimates for almost all sectors. For three energy sectors, we explained real output by the corresponding physical output in the energy sub-model.

Meanwhile, sectoral price was determined by intermediate input cost, labor cost, and the remaining cost. We estimated sectoral price by intermediate input price, which was computed using the base-year input-output coefficients, and wage rates. The intermediate input deflators were significant for all sectors. However, wage rates were significant only for four sectors; mining, food, construction and services. As one explanatory variable, the dependent variable of the previous period was added for each equation for two sectors; coal, and electric power and heat supply, which are expressed by a partial adjustment mechanism.

Table 2-2 shows the mean absolute percentage error (MAPE) of the main variables for the dynamic simulation for the period 1995-1999. The performance of the model can be evaluated from these values. Some variables in the table are slightly high in MAPE. However, the important variables have very low MAPE values: real GDP is 1.90%, the total for real product is 1.59%, the total for nominal value added is 2.08%, the GDP deflator is 2.15%, and total employment is 0.30%. We can thus conclude that the model is sufficient for explanation of the sample period.

Table 2-1 Sector Classification

	Sectors
1	Agriculture
2	Mining
3	Food
4	Textile Products
5	Chemical Products
6	Non-Metallic Mineral Products
7	Iron and Steel, and Non-Ferrous Metals
8	Metal Products and Machinery
9	Other Manufacturing
10	Construction
11	Transportation and Communications
12	Services
13	Coal
14	Oil and Natural Gas
15	Electric Power and Heat Supply

Table 2-2 Performance of the Model

Macro Variables	MAPE(%)	Real Product	MAPE(%)
Real GDP	1.90	Agriculture	2.24
Real Consumption	1.73	Mining	17.30
Real Government Consumption	4.95	Food	4.44
Real Investment	1.80	Textile Products	4.06
Real Exports	2.66	Chemical Products	4.69
Real Imports	7.63	Non-Metallic Mineral Products	9.95
Nominal GDP	2.74	Iron and Steel, and Non-Ferrous Metals	2.74
Nominal Consumption	0.93	Metal Products and Machinery	2.77
Nominal Government Consumption	5.44	Other Manufacturing	12.48
Nominal Investment	2.52	Construction	1.91
Nominal Exports	2.00	Transportation and Communication	3.04
Nominal Imports	9.13	Services	5.61
GDP Deflator	2.15	Coal	6.49
Producer Price Index	1.89	Oil and Natural Gas	3.26
Consumer Price Index	0.90	Electric Power and Heat Supply	1.85
Employment, Total	0.30	Total	1.59

Table 2-2 Performance of the Model (continued)

Value Added	MAPE(%)	Product Deflators	MAPE(%)
Agriculture	4.62	Agriculture	6.74
Mining	11.06	Mining	3.23
Food	9.22	Food	1.90
Textile Products	9.09	Textile Products	2.63
Chemical Products	5.23	Chemical Products	4.21
Non-Metallic Mineral Products	9.17	Non-Metallic Mineral Products	1.75
Iron and Steel, and Non-Ferrous Metals	14.13	Iron and Steel, and Non-Ferrous Metals	5.25
Metal Products and Machinery	2.27	Metal Products and Machinery	1.89
Other Manufacturing	18.79	Other Manufacturing	2.34
Construction	1.52	Construction	1.22
Transportation and Communications	7.22	Transportation and Communications	7.71
Services	3.51	Services	3.63
Coal	10.11	Coal	2.43
Oil and Natural Gas	9.41	Oil and Natural Gas	5.16
Electric Power and Heat Supply	6.05	Electric Power and Heat Supply	4.26
Total	2.08	Average	1.49

Employment	MAPE(%)	Energy Variables	MAPE(%)
Agriculture	3.15	Overall Energy Production	2.98
Mining	4.65	Overall Energy Exports	6.65
Food	9.02	Overall Energy Imports	8.78
Textile Products	11.04	Overall Energy Demand	2.70
Chemical Products	11.33	Coal Production	3.23
Non-Metallic Mineral Products	14.10	Coal Demand	3.12
Iron and Steel, and Non-Ferrous Metals	14.15	Coal Demand, Industry	3.61
Metal Products and Machinery	16.17	Coal Demand, Household	5.65
Other Manufacturing	15.66	Coal Demand, Power Generation	2.36
Construction	2.81	Oil Production	5.51
Transportation and Communications	2.27	Oil Demand	2.61
Services	3.34	Oil Demand, Industry	2.54
Coal	4.27	Oil Demand, Household	4.62
Oil and Natural Gas	6.02	Natural Gas Production	3.26
Electric Power and Heat Supply	3.35	CO_2 Emissions	2.66
Total	0.30		

3. Baseline Prediction

3.1 The Assumptions made for the Prediction

In this section we discuss the baseline prediction from 2000 to 2020 which was to be used in the scenario analysis. The assumed values, adopted here for the exogenous variables, are shown in Table 3-1. Basically these values were extracted with some adjustments from the recent trends from 1995 to 2000, indicated in past research by the IEA and the Institute of Energy Economics, Japan (IEEJ).

We assumed that the growth rate of real exports was about 9.4% for the first 10 years, and 6.45% for the second 10 years. The net value of foreign direct investment would grow by 9.98% and 10.0% for these periods, respectively. The import price would grow at 3%, the exchange rate was fixed at its value in 2000, and the population growth rates were assumed to be 0.79% and 0.62%.

We assumed that the export and import of energy would grow as fast as in the past or would not change in level. The unit ratio of natural gas to production, which is exogenous in the model, was set as constant, at the 2000 value.

Table 3-2 shows the composition of thermal power generation and fuel efficiency from 2000 to 2020, which were the values for China indicated in the Energy Outlook of the IEA. In this table, coal thermal generation will be predominant in the future, though natural gas thermal generation will gradually grow. The share of coal generation was assumed to be 88.13% in 2020. It was assumed that the fuel efficiencies of coal, oil, and natural gas would improve. The efficiency of natural gas was 50.0%, that of coal, 37.34%, and of oil, 34.97%.

Table 3-1 Assumed Values of the Exogenous Variables, (%)

Variables	2000-2010	2010-2020
Real Export		
Agriculture	10.00	5.00
Mining	0.50	2.00
Food	5.00	3.00
Textile Products	6.49	3.00
Chemical Products	8.00	5.00
Non-Metallic Mineral Products	1.50	1.00
Iron and Steel, and Non-Ferrous Metals	5.00	3.00
Metal Products and Machinery	11.00	8.00
Other Manufacturing	9.00	4.00
Construction	6.49	5.00
Coal	10.00	5.00
Oil and Natural Gas	0.00	0.00
Electric Power and Heat Supply	2.00	1.00
Total	9.40	6.45
Foreign Direct Investment, Net	9.98	10.00
Import Price (dollar base)	3.00	3.00
International Oil Price (dollar base)	3.00	3.00
Exchange Rate (yuan/dollar)	0.00	0.00
Government Debt from Foreign Countries	-6.01	-3.00
Government Investment	10.00	8.00
Government Income Outside Taxation	17.47	10.00
Average Tax Rate	3.44	2.26
Population	0.79	0.62

Table 3-2 Assumptions on Thermal Electricity Generation

		2000	2010	2020
Power generation composition	Coal	90.53	89.44	88.13
	Oil	8.46	7.58	6.76
	Natural Gas	1.02	2.98	5.11
Power generation efficiency	Coal	33.26	35.26	37.34
	Oil	34.14	33.65	34.97
	Natural Gas	44.80	50.00	50.00

3.2 Characteristics of the Baseline

Table 3-3 shows the results for the main variables in the baseline forecast from 2000 to 2020, as average annual growth rates for two ten-year periods. The growth rates for actual data from 1995 to 2000 are also shown.

The growth rate of real GDP is 6.11% for the first 10 years and 4.40% for the second 10 years, which is slightly low compared with the economic growth in the 1990s. Referring to the standard forecast of the IEA, the growth rate of real GDP is 6.0% for 1997-2010, and 3.7% for 2010-2020. The simulation study of the IEEJ shows 7.1% growth for 2000-2010, and 6.1% for 2010-2020 (see Table 3-4). Though comparison between them is limited because the prediction assumptions and the respective model characteristics are different, the growth rate of our model corresponds to the forecasted values of the IEA and the IEEJ.

Figure 3-1 shows the amount of real production by sector to 2020 and its composition, in which the values from 1995-1999 are actual data. Figure 3-2 shows employed persons by sector. Because we assume the expansion of exports in the metal product and machinery sector, the production in this sector is also growing faster than the other sectors. Moreover, employment in the service sector increases from 40% in 2000 to 48% in 2020, though the employment in the agriculture sector decreases, and the agricultural workers' share of total employment shrinks from 47% to 39% over 20 years. That is, a shift of employment from the agricultural sector to the service sector is expected.

Table 3-5 shows a comparison of primary energy supply. Its growth rate is 5.30% in the first ten-year period and 3.01% in the latter. The energy elasticity to GDP is 0.867 and 0.684 for the same periods, respectively. According to the IEA forecast, the primary energy supply growth rate is 3.56% for the period 1997-2010, and 3.11% for the period 2010-2020. The elasticity to GDP is about 0.59 and 0.84 for those same periods, respectively. The IEEJ simulation estimates 3.23% growth for 2000-2010, and 3.84% for 2010-2020. The elasticity to GDP is 0.45 and 0.63 for those same periods, respectively. The estimates of our model are slightly high in the growth rate for the first period, though almost the same for the latter period.

The primary energy supply is estimated to be 2.480 billion tons of coal equivalent in 2020 in our model, which is slightly lower than the estimates of the IEA and IEEJ, which were 2.767 and 2.747 billion tons of coal equivalent, respectively. The total amount of generation in our model is 3.04 trillion kWh in 2020, which is also lower than the values of the IEA and IEEJ of 3.69 and 4.22 trillion kWh, respectively. The difference may partly stem from the assumption in our prediction that the growth in household demand for electricity halves according to the data.

We estimate that the supply of natural gas is 0.069 billion tons of coal equivalent, which is much lower than the values of the IEA and IEEJ, which are 0.159 and 0.261 billion tons of coal equivalent, respectively. Our forecasts are basically dependent on past trends in demand and consumption, and we have included policy consideration of the future introduction of natural gas, which would make such differences possible.[4]

Table 3-6 shows the amount of CO_2 emissions in relation to energy production. They tally 1.597 billion tons of carbon in 2020, although only 0.835 billion tons of carbon in 2000. In the IEA forecast, the amount of CO_2 emissions in 2020 are 1.753 billion tons of carbon. The IEEJ predicts 1.668 billion tons of carbon in 2020. Our estimate is slightly low compared with the other two results, because energy production and consumption are slightly lower than for the others.

Figure 3-3 shows CO_2 emissions by real GDP in our model. This ratio decreases from 0.1 tons of carbon per thousand yuan in 2000 to 0.0688 tons of carbon per thousand yuan in 2020. The improvement in energy efficiency and the energy shift from coal to natural gas and oil make this ratio lower.

Table 3-3 Average Growth Rates of Macro Variables, (%)

	1995-2000	2000-2010	2010-2020
Real GDP	7.39	6.11	4.40
Real Consumption	7.95	6.45	3.85
Real Government Consumption	9.61	5.91	4.11
Real Investment	8.88	6.43	4.47
Real Exports	20.65	8.97	6.31
Real Imports	21.25	9.12	5.68
Nominal GDP	9.98	9.92	8.33
Nominal Consumption	10.69	10.09	8.05
Nominal Government Consumption	12.39	9.53	8.32
Nominal Investment	10.67	11.14	9.51
Nominal Exports	20.57	9.63	7.57
Nominal Imports	16.94	11.72	9.06
GDP Deflator	2.41	3.60	3.76
Producer Price Index	1.51	3.45	4.18
Consumer Price Index	2.52	3.42	4.04
Employment, Total	0.91	0.59	0.66

[4] The Energy Research Institute of China estimated the future demands of natural gas, which are shown in the following table. The volume of demand in 2020 is relatively large.

	Actual Data Unit: BCM			Growth Rate (%)	
Sector	1997	2010	2020	2010	2020
Power Generation	2.2	35.0	81.2	23.76	8.78
Chemical Industry	8.4	19.0	32.5	6.45	5.51
Other Industry	6.3	20.0	40.0	9.32	7.18
Household	2.1	22.0	50.0	19.72	8.56
Total	19.6	96.0	203.7	13.02	7.81

Table 3-4 Comparison of Real GDP

Predictions of Our Model	Average Growth Rate (%)		
Real GDP	1995-2000	2000-2010	2010-2020
	7.39	6.11	4.40
Population	2005-2010	2000-2010	2010-2020
	0.89	0.79	0.62

IEA World Energy Outlook 2000	Average Growth Rate (%)		
Real GDP	2000	1997-2010	2010-2020
	7.00	6.00	3.71
Population	1971-1997	1997-2020	
	1.50	0.70	

Institute of Energy Economics, Japan	Average Growth Rate (%)		
Real GDP	1998-2000	2000-2010	2010-2020
	7.30	7.10	6.10
Population	1998-2000	2000-2010	2010-2020
	1.00	0.75	0.62

Figure 3-1 Real Production by Sector

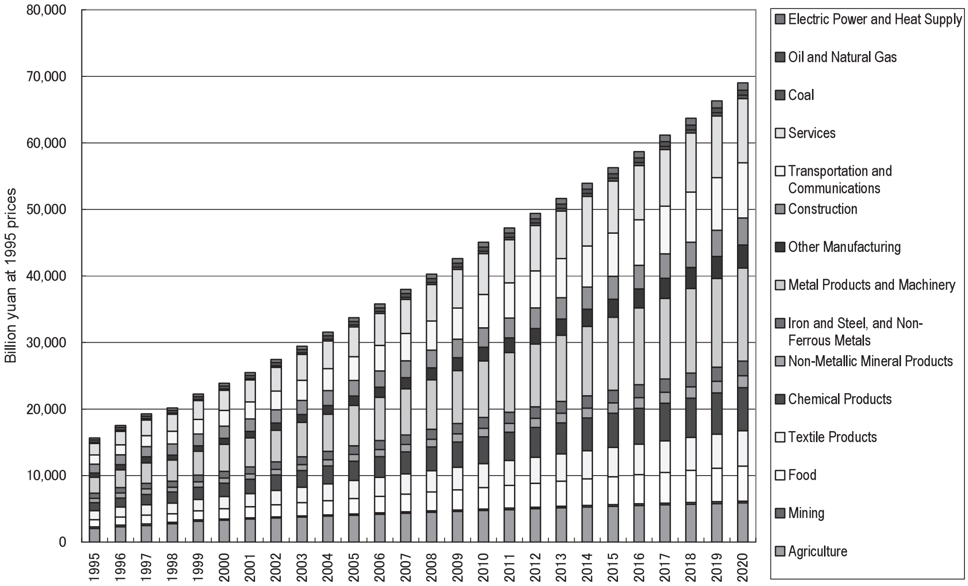


Figure 3-2 Employment by Sector

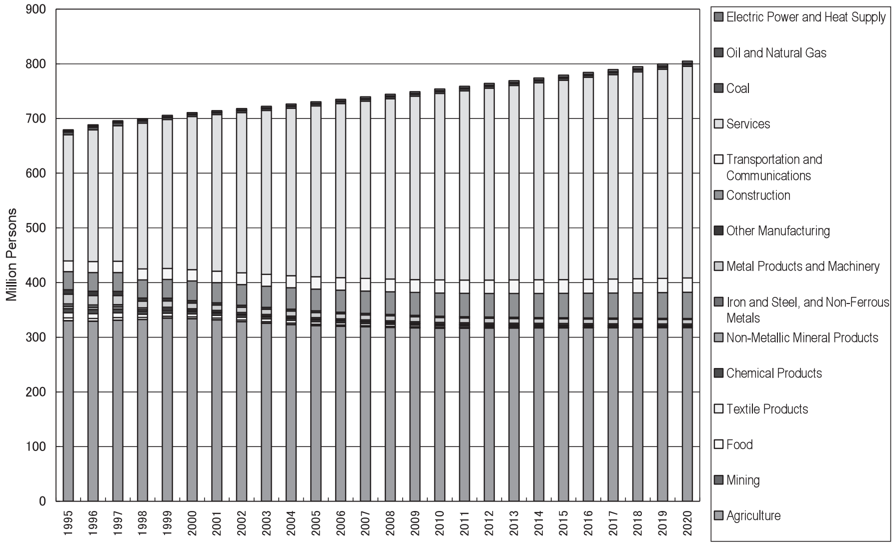


Table 3-5 Comparison of Primary Energy Supply

Predictions of Our Model

	Million Tons of Oil Equivalent			Million Tons of Coal Equivalent			Average Growth Rate (%)	
	2000	2010	2020	2000	2010	2020	2000-2010	2010-2020
Total Primary Energy	770	1,290	1,736	1,100	1,843	2,480	5.30	3.01
Coal	477	810	1,064	682	1,158	1,520	5.43	2.76
Oil	222	355	497	317	507	710	4.81	3.43
Natural Gas	22	35	49	32	49	69	4.41	3.45
Others	48	91	127	69	129	181	6.50	3.44
	(Billion Kwh)							
Electricity	13,158	21,274	30,383	162	261	373	4.92	3.63

IEA World Energy Outlook 2000

	Million Tons of Oil Equivalent			Million Tons of Coal Equivalent			Average Growth Rate (%)	
	1997	2010	2020	1997	2010	2020	1997-2010	2010-2020
Total Primary Energy	905	1,426	1,937	1,293	2,037	2,767	3.56	3.11
Coal	662	940	1,192	946	1,343	1,703	2.73	2.40
Oil	201	371	541	287	530	773	4.83	3.84
Natural Gas	21	56	111	30	80	159	7.84	7.08
Others	21	59	93	30	84	133	8.27	4.66
	(Billion Kwh)							
Electricity	11,630	24,080	36,910	143	296	453	5.76	4.36

Institute of Energy Economics, Japan

	Million Tons of Oil Equivalent			Million Tons of Coal Equivalent			Average Growth Rate (%)	
	2000	2010	2020	2000	2010	2020	2000-2010	2010-2020
Total Primary Energy	961	1,320	1,923	1,372	1,885	2,747	3.23	3.84
Coal	684	829	1,076	977	1,184	1,537	1.94	2.64
Oil	230	335	513	329	479	733	3.83	4.34
Natural Gas	23	82	183	33	117	261	13.53	8.36
Others	23	73	151	33	105	216	12.11	7.50
	(Billion Kwh)							
Electricity	12,455	22,283	42,200	153	274	518	5.99	6.59

Table 3-6 Comparison of CO_2 Emissions

Predictions of Our Model

	Million Tons of CO_2			Million Tons of Carbon			Average Growth Rate (%)	
	2000	2010	2020	2000	2010	2020	1997-2010	2010-2020
CO_2 Emissions	3,061.8	4,393.3	5,855.9	835.0	1,198.2	1,597.1	3.68	2.92
Coal	2,335.2	3,221.5	4,212.9	636.9	878.6	1,149.0	3.27	2.72
Oil	673.8	1,088.9	1,525.5	183.8	297.0	416.0	4.92	3.43
Natural Gas	52.8	82.9	117.5	14.4	22.6	32.1	4.61	3.56

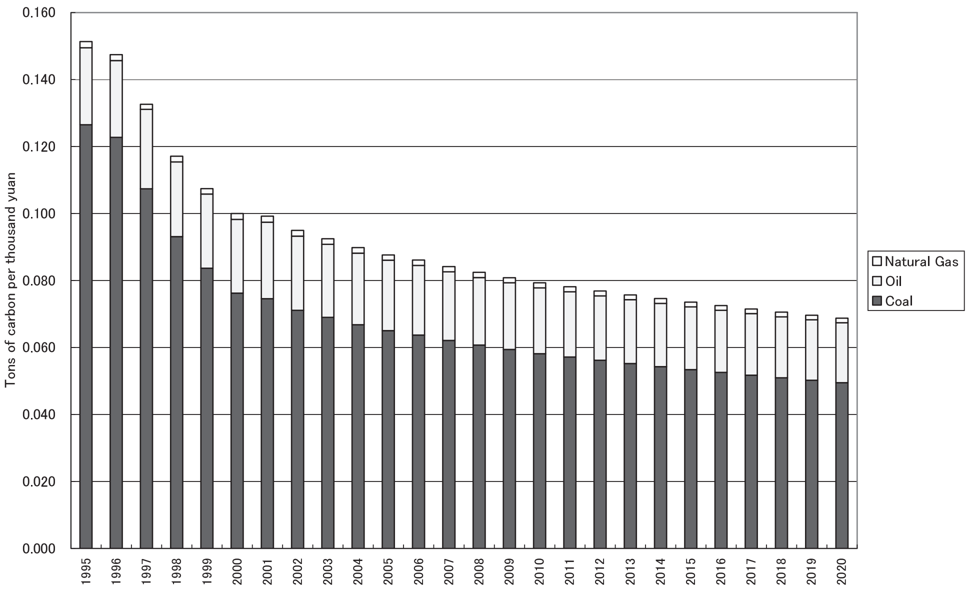
IEA World Energy Outlook 2000

	Million Tons of CO_2			Million Tons of Carbon			Average Growth Rate (%)	
	1997	2010	2020	1997	2010	2020	1997-2010	1997-2020
CO_2 Emissions	3,162.0	4,822.0	6,426.0	862.4	1,315.1	1,752.5	3.30	2.91
Coal	2,548.0	3,638.0	4,624.0	694.9	992.2	1,261.1	2.78	2.43
Oil	567.0	1,060.0	1,555.0	154.6	289.1	424.1	4.93	3.91
Natural Gas	46.0	124.0	247.0	12.5	33.8	67.4	7.93	7.13

Institute of Energy Economics, Japan

	Million Tons of CO_2			Million Tons of Carbon			Average Growth Rate (%)	
	2000	2010	2020	2000	2010	2020	2000-2010	1997-2020
CO_2 Emissions	3,361.5	4,381.3	6,114.6	916.8	1,194.9	1,667.6	2.68	3.39
Coal	2,709.7	3,281.7	4,260.7	739.0	895.0	1,162.0	1.48	2.65
Oil	597.7	905.7	1,426.3	163.0	247.0	389.0	3.25	4.65
Natural Gas	55.0	194.3	429.0	15.0	53.0	117.0	10.20	8.24

Figure 3-3 CO_2 Emissions by Real GDP



4. Scenario Analyses

In this section, we discuss the following two simulations.
Case 1: The natural gas pipeline project.
Case 2: The construction of natural gas power stations.
In these simulations, we use the baseline prediction, which is explained in the previous section, for the 20 years from 2000 to 2020.

4.1 The Natural Gas Pipeline Project

The Chinese government estimated that the cost of the pipeline project from the Tarim Basin to Shanghai of China at about 140 billion yuan, which was 136.25 billion yuan at 1995 market prices. A simulation of this project was performed.

The construction period of this project was to be four years, 2002 to 2005. We therefore divided the total cost by year, assuming that the cost each year was the same, that is, 34 billion yuan. According to the government plan, 90% of the total cost was for the purchase of equipment and materials, 65% of which was to be provided from the domestic market. Considering these circumstances, we assumed that the distribution ratios of the investment were as shown in Table 4-1. The scale of this investment, 34 billion yuan, is about 0.3% of GDP in the baseline forecast.

This project was to be completed in 2005, and natural gas supplied from that year. It is assumed that 12 billion cubic meters of natural gas were to be supplied at first, and that the supply would increase to 19 billion cubic meters after 2010. We assume that the natural gas is consumed in four sectors; electric power and heat supply, chemical products, transportation and communications, and household, as shown in Table 4-2. It is thought that coal consumption will be replaced by the same amount of natural gas in calorie terms. However, oil consumption will be reduced in the transportation sector. Moreover, the difference in power generation efficiency between natural gas thermal power generation and coal thermal power generation is considered in the electric power sector. [5]

Figure 4-1 shows the GDP changes from the baseline case. Case 1a shows the effect of increased investment, which expands GDP by 0.20-0.35% of the baseline values for the period of investment. The effect on GDP is concentrated in this period. The investment multiplier is about 1.07-1.28, because the amount of GDP is 25-30 billion yuan and domestic investment is 23.46 billion yuan per year. This effect disappears soon after the completion of the pipeline. Case 1b shows the effect after the completion of the pipeline. A slightly negative influence on GDP is seen. The overall effect is shown by Case 1. The multiplier effect of the investment works and there is a positive effect on GDP until 2005. However, the deflationary effect of the decreased coal demand becomes predominant after 2005.

Figure 4-2 shows the changes in production by sector from the baseline for the years 2005, 2010, and 2020. The primary metal, machinery, construction, transportation and communication, and service sectors receive positive effects in 2005, when investment is increased. Conversely, the natural gas supply starts in 2005, and the demand shift effect of

[5] The substitution of natural gas for coal and petroleum will require additional fixed investment in energy-consuming sectors. However, we did not consider such factors in the simulation, because we were not able to obtain sufficient data for their estimation.

the natural gas begins in 2010 and 2020. Production in the machinery, transportation and communication, and service sectors will decrease in line with the production decrease in the coal industry.

Figure 4-3 shows the difference in the amount of the CO_2 emission of each case from the baseline. When the energy demand shift from coal to natural gas occurs, Case 1b shows that the amount of CO_2 emissions decreases, though the CO_2 emissions increase in accordance with the expansion of investment demand, which can also be seen in Case 1a. When natural gas use begins, CO_2 is gradually reduced, though CO_2 increases in the project investment (construction) period, and Case 1 indicates what happens if the two effects are combined

Table 4-1 Distribution of Investment Demand, (%)

Sectors	share	domestic	imports
Agriculture	-	-	-
Mining	-	-	-
Food	-	-	-
Textile Products	-	-	-
Chemical Products	-	-	-
Non-Metallic Mineral Products	-	-	-
Iron and Steel, and Non-Ferrous Metals	70.0	45.5	24.5
Metal Products and Machinery	20.0	13.0	7.0
Other Manufacturing	-	-	-
Construction	7.0	7.0	-
Transportation and Communications	1.0	1.0	-
Services	2.0	2.0	-
Coal	-	-	-
Oil and Natural Gas	-	-	-
Electric Power and Heat Supply	-	-	-
Total	100.0	68.5	31.5

Table 4-2 Share of Natural Gas Consumption by Sector, (%)

Sectors	2005	2010	2020
Electric Power and Heat Supply	60	60	60
Chemical Products	20	20	20
Transportation and Communications	10	10	10
Household	10	10	10
Total	100	100	100

Figure 4-1 Effect on Real GDP

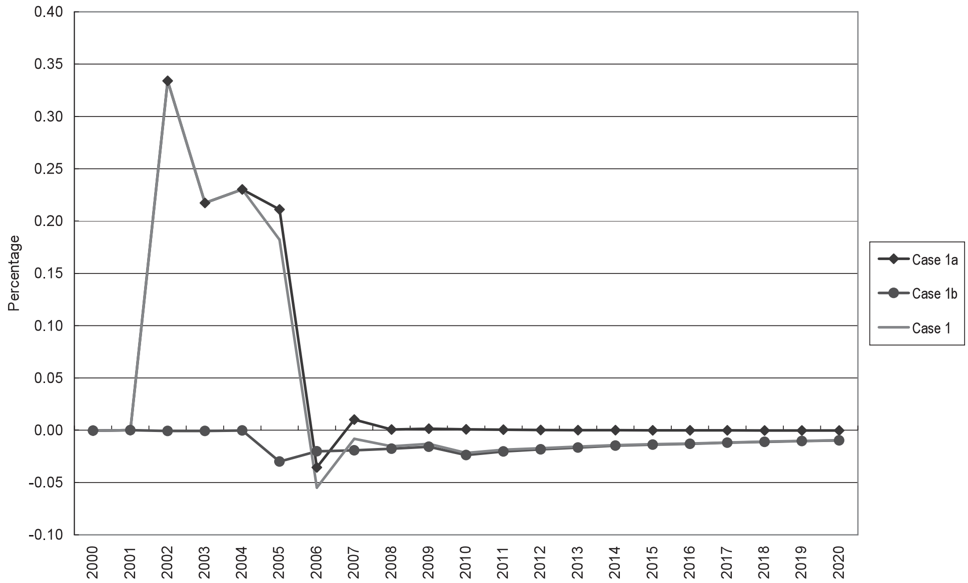


Figure 4-2 Effect on Real Production by Sector

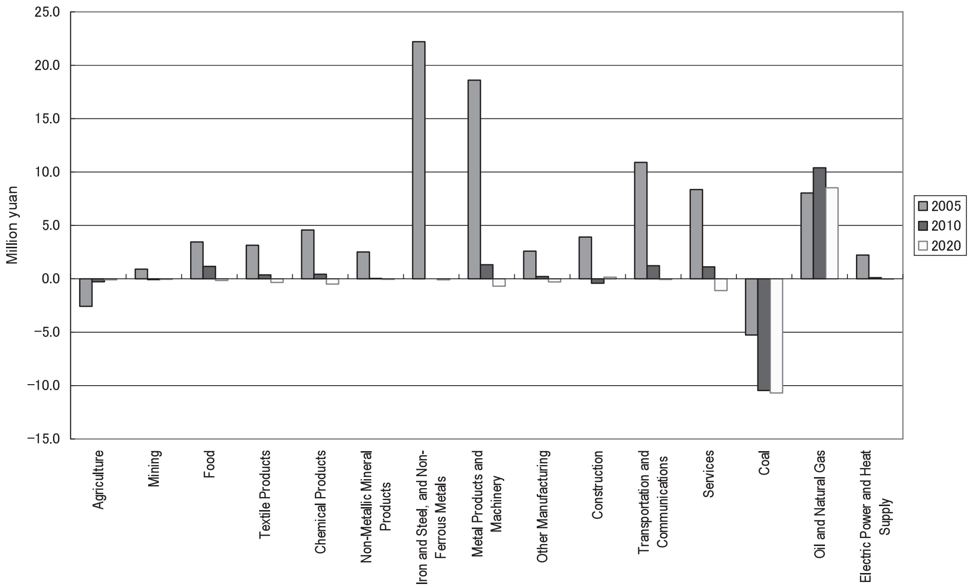
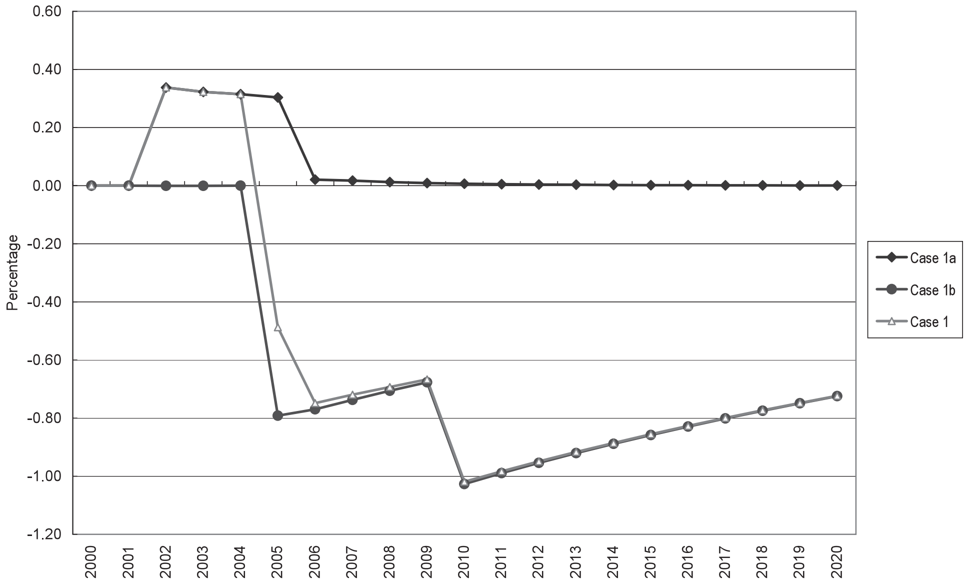


Figure 4-3 Changes in CO_2 Emissions



4.2 Construction of Natural Gas Thermal Power Plants

Here we discuss the effect of the construction of natural gas thermal power plants, a project which is widely noted as a candidate for CDM activities. The supply of electricity from the natural gas thermal power plants will reduce that from coal power generation because of the advantage in fuel efficiency. As a result, fuel shifts from coal to natural gas in the power generation process.

From the previous scenario (4.1), we find that the shift from coal to natural gas brings society an immediate reduction in CO_2. However, at the same time, investment demand causes society to experience additional CO_2 emissions. Similar results are expected in this case. The problem then becomes one of whether the effect of the CO_2 reduction is still large even if the investment effect is taken into account.

According to the Energy Research Institute of China, the construction cost of a typical natural gas thermal power plant able to supply 42 kWh per year of electricity is estimated at 4.2 billion yuan. The present scenario is based on this information.

In order to supply 1% of the amount of power generation in 2010 in our baseline, which is approximately 21 billion kWh, five thermal power plants of the type stated above will be built. The total construction cost is assumed here to be 21 billion yuan, or 20.44 billion yuan at 1995 market prices.

The construction period of the five power plants is assumed to be the five years, 2005-2009. This means that 4.088 billion yuan will be invested each year. Power generation will begin from 2010. Thus the 11 years, up to and including 2020, are evaluated here for the purposes of this analysis.

Natural gas thermal power generation will supply 21 billion kWh of electricity per year.

The amount of coal thermal power generation, however, will fall, and coal consumption is reduced as a result. The power generation efficiency of natural gas thermal power is assumed to be 50%, and the efficiency of coal thermal power generation is assumed to be the same as that set in the baseline forecast.

We assume that 80% of the investment expenditure is for machinery products, i.e., machines related to power generation, 15% for construction, 3% for transportation, and 2% for services, as shown in Table 4-3. In addition, 35% of the above-mentioned machinery demand is assumed to be covered by imported goods, and the remainder by domestic ones. It is thought that 72% of the total amount of the investment is domestic.

Figure 4-4 shows the influence on real GDP. The investment has a positive effect on GDP, though the demand shift in energy contributes a negative effect after electricity is supplied by natural gas thermal generation. This pattern is almost the same as that seen in the previous scenario, though the present scenario shows a difference in the scale of the effects.

Figure 4-5 shows the effect on production by sector. The influence on the machinery sector is the largest, followed by the construction, and transportation and communication sectors. Moreover, coal production is reduced and natural gas production increases after the natural gas generation starts. Many sectors receive a negative influence, though not so large.

Figure 4-6 shows the changes in the amount of CO_2 emissions. An increase of approximately 0.02% in tons of carbon per year is observed in the period of investment (construction), though a decrease of approximately 0.19-0.27% per year is seen after generation starts.

Table 4-3 Distribution of Investment Demand, (%)

Sectors	share	domestic	imports
Agriculture	-	-	-
Mining	-	-	-
Food	-	-	-
Textile Products	-	-	-
Chemical Products	-	-	-
Non-Metallic Mineral Products	-	-	-
Iron and Steel, and Non-Ferrous Metals	-	-	-
Metal Products and Machinery	80	52	28
Other Manufacturing	-	-	-
Construction	15	15	-
Transportation and Communications	3	3	-
Services	2	2	-
Coal	-	-	-
Oil and Natural Gas	-	-	-
Electric Power and Heat Supply	-	-	-
Total	100	72	28

Figure 4-4 Effect on Real GDP

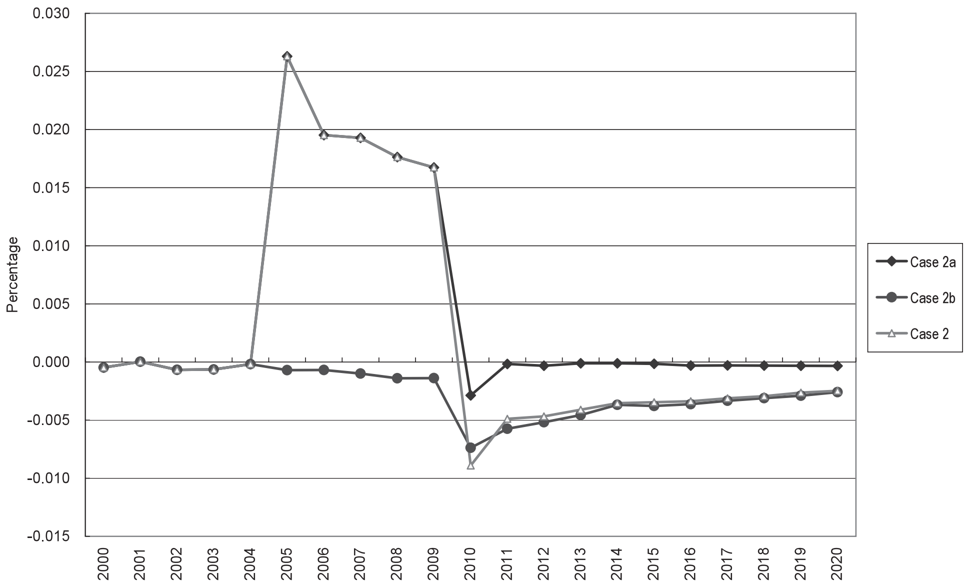


Figure 4-5 Effect on Real Production

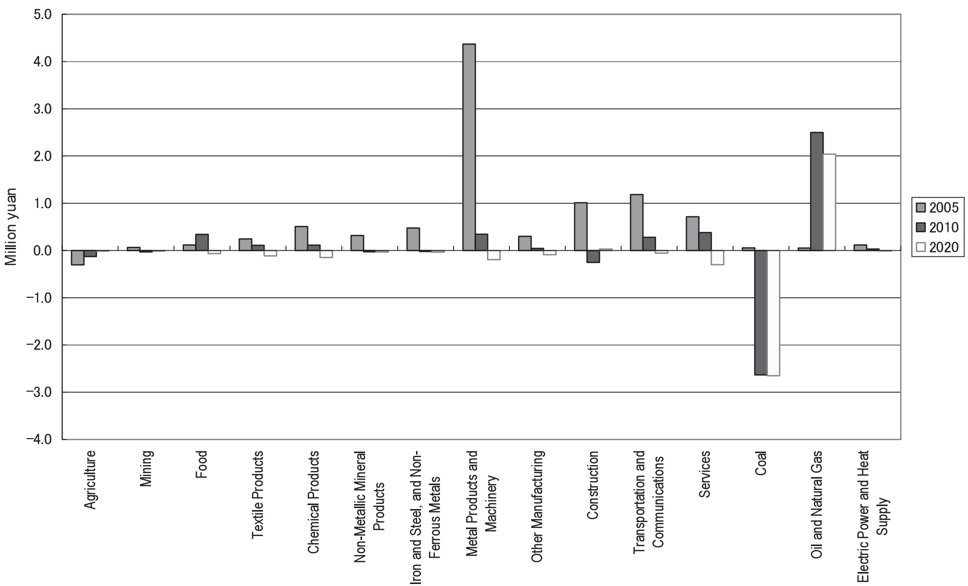
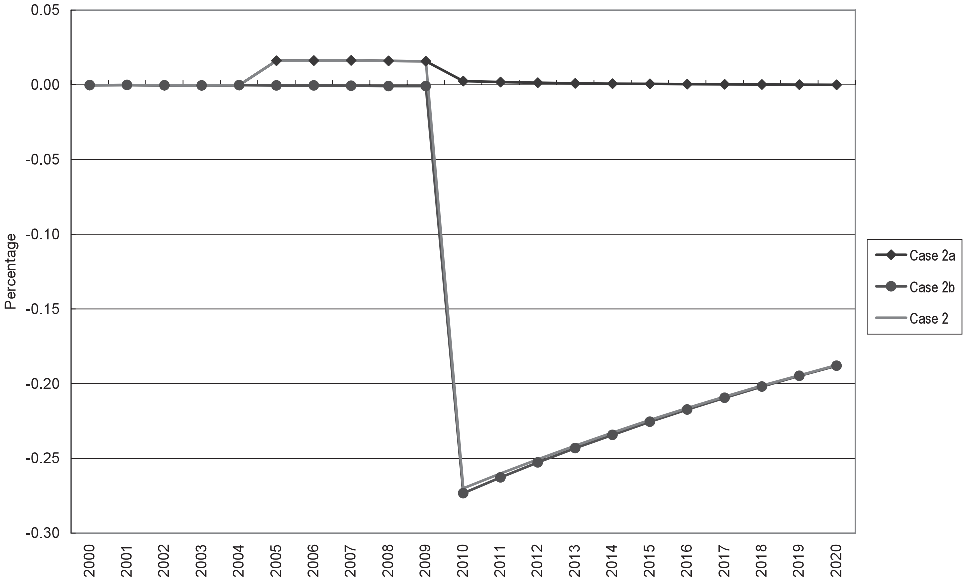


Figure 4-6 Changes in CO_2 Emissions



4.3 Comparison of CO_2 Emissions and Associated Costs

Figure 4-7 compares the total amount of CO_2 emissions in both scenarios. The pipeline project reduces 170.11 million tons of carbon in the form of CO_2 emissions, though the pipeline investment (construction) increases emissions by 12.94 million tons of carbon in the form of CO_2. Overall, the expected reduction is 157.04 million tons of carbon in the form of CO_2. On the other hand, the CO_2 reduction in the natural gas thermal power plant project is expected to be 34.43 million tons of carbon, although an increase of 0.97 million tons of carbon is brought about by the plant investment (construction). In this case, the overall effect is considered to be 33.33 million tons of carbon in the form of CO_2.

Table 4-4 shows a comparison of the effects of the CO_2 reduction. The total amounts of CO_2 reduction in the table are the same values indicated in Figure 4-7. Values for tons of carbon are converted into tons of CO_2. The reduction cost is the initial investment cost for each project. The unit reduction costs, which are costs by the amount of CO_2 reduced, are evaluated in yuan, yen, and US dollars.[6]

Moreover, "Direct effect" (of the reduction) in the table represents the estimated value for the effect of the CO_2 reduction directly experienced in the sector, which is assumed to shift demand from coal (and in part, oil) to natural gas in both scenarios. These changes, however, affect not only the sector concerned but also other sectors through the interdependence of production among sectors. The amount of the reduction, which occurs in the model simulation, is called "Total effect" (of the reduction) here. This effect is divided between the two cases in the table, Case 1b and Case 2b, to evaluate the effect of demand shift from coal to natural gas, and Case 1 and Case 2 to consider not only the demand shift in energy but also the effect of investment.

[6] The exchange rates used here are 15 yen to the yuan, and 120 yen to the US dollar.

"Direct effect" (of the reduction) in the pipeline project is estimated at US$28.51 per ton of CO_2, and that of the natural gas thermal power plant project is US$20.98 per ton of CO_2. The difference between them is somewhat large, partly because the sectors in which the demand shift in energy appears directly are not the same. In the former project, not only the electricity sector, but also the chemical, transportation, and household sectors show changes in their energy-demand mix, whereas only the electricity sector is concerned in the latter project. The effect on the electricity sector is expected to be large in terms of CO_2 reduction.

"Total effect" (of the reduction) shows that the unit reduction cost ends up somewhat lower than is the case for "Direct effect" (of the reduction.) For the pipeline project, the cost is estimated at US$28.06 per ton of CO_2, but rises further to US$30.39 per ton of CO_2 when we add the effect of the investment (construction). For the natural gas thermal power plant project the cost becomes US$20.79 per ton of CO_2, and US$21.48 per ton of CO_2 with the effect of investment (construction) added.

The demand shift from coal to natural gas increases natural gas production, while decreasing coal production. These changes in production affect other areas of production through changes in the demand of intermediate input and in relative prices. The result of such changes in production is a strengthening of CO_2 reduction in the economy. In addition, investment in (construction of) the project causes additional CO_2 emissions. The CO_2 reduction cost to society as a whole rises when we take the latter into account.

It should be noted that the full lifespan of each project was not considered. The costs obtained are values estimated for our simulation period, 2000 to 2020. Therefore, each reduction cost has the possibility of decreasing further when we consider that the lifetime of the projects is typically longer than those twenty years. [7]

Figure 4-7 Sum of CO_2 Emissions from 2000 to 2020

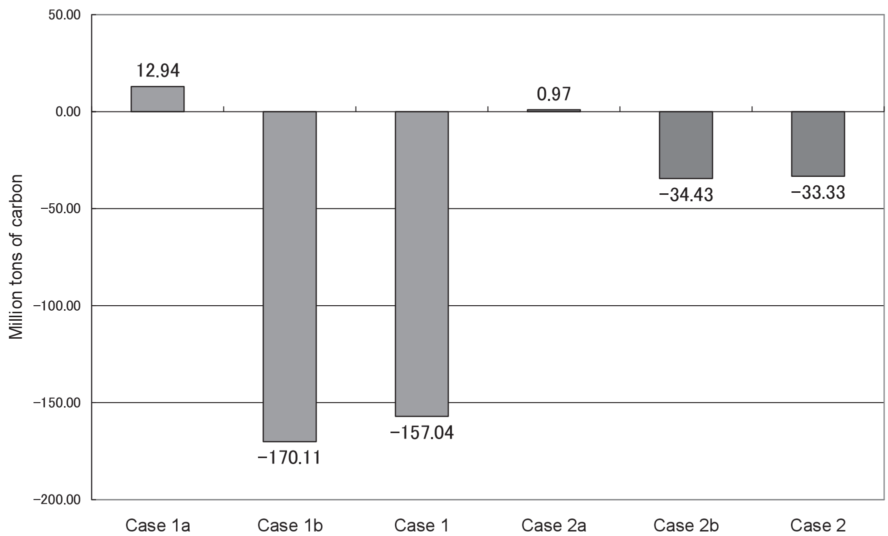


Table4-4 Comparison of Reduction Costs of CO_2 Emissions

			CO_2 Reduction		Reduction Cost	Unit Reduction Cost		
			Million tons of carbon	Million tons of CO_2	Billion yuan	Yuan/ton of CO_2	Yen/ton of CO_2	Dollar/ton of CO_2
Pipeline Project	Direct Effect		167.39	613.75	140.0	228	3,422	28.51
	Total Effect	Demand Shift Only	170.11	623.74	140.0	224	3,367	28.06
		Demand Shift and Investment	157.04	575.80	140.0	243	3,647	30.39
Natural Gas Electric Power Plant Project	Direct Effect		34.13	125.14	21.0	168	2,517	20.98
	Total Effect	Demand Shift Only	34.43	126.25	21.0	166	2,495	20.79
		Demand Shift and Investment	33.33	122.22	21.0	172	2,577	21.48

5. Concluding Remarks

Our simulation attempted to predict the growth of the Chinese economy until 2020 and to evaluate the effect of two possible projects on the Chinese economy and environment.

According to our predictions, China will continue to grow at a relatively high rate, although the growth rate will decline gradually to less than 5% per year. The amount of real GDP in 2020 will increase to 2.78 times the amount in 2000. The overall energy demand in 2020 will increase to 1.95 times the amount in 2000. Also, while the efficiency of energy use will increase, the amount of energy demand will continue to rise, which will induce more CO_2 emissions. The emissions will grow 1.91 times in volume between 2000 and 2020.

The impact analyses of the pipeline project and the thermal power plant project, both of which relate to natural gas usage, raise several points. The pipeline project we evaluated in our model will not have a large impact on the macro-economy of China on the whole, in the sense that the project will not change the future growth path of the economy. This is simply because investment in the project is only 0.3% of GDP. Investment in the projects will, of course, produce positive impacts on the economy. The effect is limited to the period when the investment occurs, during which time the production in the metal and machinery industries, which produce capital goods, increases greatly. However, the energy shift in both projects will assert a slightly negative impact on production as a whole, mainly because the

[7] If we extend the simulation periods to 2030 under the same conditions, the direct cost of CO_2 reduction decreases to US$17.23 per ton of CO_2 for the pipeline project, and US$10.93 per ton of CO_2 for the power plant project.

Comparison of the Reduction Costs of CO_2 Emissions

		CO_2 Reduction		Reduction Cost	Unit Reduction Cost		
		Million tons of carbon	Million tons of CO_2	Billion yuan	Yuan/ton of CO_2	Yen/ton of CO_2	Dollar/ton of CO_2
Pipeline Project	Direct effect through 2020	162.38	595.38	140.0	235	3,527	29.39
	Direct effect through 2030	277.07	1,015.92	140.0	138	2,067	17.23
Natural Gas Electric Power Plant Project	Direct effect through 2020	34.31	125.80	21.0	167	2,504	20.87
	Direct effect through 2030	65.50	240.16	21.0	87	1,312	10.93

difference in efficiency induces more reduction in coal use.

CO_2 emissions increase in periods of expansion. On the other hand, the demand shift from coal to natural gas has the effect of reducing CO_2 emissions, because natural gas demonstrates a high level of efficiency in power generation and low CO_2 emissions. Although they offset one another, CO_2 reduction gets the upper-hand over CO_2 increase throughout the simulation periods. A similar effect is expected for the natural gas thermal power plant project, though the scale of the impact differs. The direct cost of CO_2 reduction is estimated at US$28.51 per ton of CO_2 for the pipeline project, and US$20.98 per ton of CO_2 for the power plant project. However, the costs increase to US$30.39 per ton of CO_2 and US$21.48 per ton of CO_2, respectively, for the economy as a whole.

These results are tentative in the sense that our model simulation is limited to the area of demand and in that the effects of changes in the supply situation and improvements in productivity have not sufficiently been taken into consideration. These issues remain to be solved by a future elaboration of our model. At the same time, we should consider the international aspects of interdependency, with the main focus being on interdependency among East Asian countries.

Acknowledgments

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References

Ichimura, S & H. J. Wang (2003) *Interregional Input-Output Analysis of the Chinese Economy*, World Scientific, Singapore.

Ito, K & Y. Murota, et al. (2000) "A Long-Term Econometric Analysis of Macro-Economy and Energy Demand and Supply in China and Korea", *Energy Economics*, The Institute of Energy Economics Japan, pp.1-15 (in Japanese).

Kinoshita, S. et al. (2002) "An Econometric Analysis on the Growth Patterns and Interdependency of East Asian Economies", The International Centre for the Study of East Asian Development, Kitakyushu (ICSEAD) Working Paper Series Vol.2002-14 (in Japanese).

Kim, Y. H. & M. Uchida (2003) *The New Wave in Northeast Asia: Energy and Electricity Business in the 21st* Century, Keio University Press, Tokyo.

Klein, L. R. & S. Ichimura (ed.) (2000) *Econometric Modeling of China*, World Scientific Publishing.

M. H. Pesaran, R. P. Smith & T. Akiyama (1998) *Energy Demand in Asian Developing Economies*, Oxford University Press.

Nakicenovic, N., A. Grübler & A. McDonald (ed.) (1998) *Global Energy Perspectives*, Cambridge University Press, Cambridge, UK.

Energy Balances and the Economic Development of China An Econometric Analysis using the Global Macroeconomic and Energy Model

Osamu Nakamura*

Abstract

The world petroleum demand-supply balances are becoming increasingly tight in step with the high growth rate of the world economy. This study analyzes world energy balances and economic development by means of an econometric analysis with special emphasis on the Chinese economy, which is achieving rapid economic growth accompanied by a large consumption of energy. According to this study, world energy demand is expected to increase in tandem with the high-growth performance of the world economy in the future. World energy prices will likely reach a high level through the sharp increase in energy demand of some of the major energy-consuming countries, including China. With strong economic growth, the Chinese economy is expected to accelerate the demand for energy, which will result in increased Chinese influence on world energy balances.

Keywords: *energy balances, economic development, oil prices, energy model, macroeconometric model, scenario, forecast*

1. Introduction

In broad overview, oil prices are now getting higher, as the demand for oil is increasing sharply in the world market. In 2006, the crude oil price passed the 70-dollar-per-barrel mark in WTI-terms. It is expected that one of the reasons for oil price-hikes hinges on the high economic growth of some Asian countries, particularly China. In the case of China, the economic development following the open door policy has been remarkable, with rapid economic growth, and motorization has also accelerated with the sharp increase in per capita income.

In the process of economic development, China has been a net importer of oil since 1996 and now is suffering from a jump in the price of the energy it needs for the sustainable economic development of a country with such a large population. This situation is expected to continue for several years into the future with the construction boom for the Beijing Olympic Games in 2008 and for the Shanghai Exposition in 2010.

It seems that the current situation concerning world energy balances is very similar to that of the early 1970s, just before the first oil crisis, and is a critical problem not only for oil-importing countries but also oil-exporting countries, including China. The oil crises' damage to the world economy is unforgettable, especially that to oil-importing economies which persisted for more than a decade.

This paper, therefore, analyzes the Chinese energy demand-supply structure and economic development focusing on the energy balances and energy prices in the world using an econometric analysis. At the same time, this paper makes forecasts on world energy

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balances and the world economy by using the Global Macroeconomic and Energy Model.

In the 1970s, many studies discussed the energy constraints and the impacts of oil price hikes on the world economy, which forecast the shortage of natural resources and the fatal results for humanity in the future (Meadows, 1972; Leontief, 1977). Since then, econometric study has been popular and has been employed for the analysis of the relationship between energy balances and economic development (Adams, 1979; Walter, 1980; Nakamura, 1984). After the oil crises, global warming has been a hot issue and many studies have discussed energy demand and its impact on the environment, with the IEA (OECD) and the United Nations central in this (Dean and Hoeller, 1992). This paper is also an econometric study on energy balances and economic development, which is similar to the studies in the 1970s and early 1980s listed above.

Following this introduction, Section 2 reviews the energy balances in China; Section 3 explains the model system employed in this study; Section 4 investigates the future forecasts of energy balances and economic development of China within the world economy; and the final section, Section 5, forms the conclusion of this study.

2. Energy Balances in China

2-1. Changes in energy supply and demand in China

In the last quarter of the 20th century, China successfully achieved high economic growth rates. Especially after the introduction of the open door policy, the economic development of China has gained strength within the world economic system, attracting foreign capital and trade. In the process of economic development, energy demands have increased sharply in China. China has, therefore, increased its imports of crude oil and oil products from the rest of the world and has been a net oil-importer since the middle of the 1990s. As a result, the total energy demand of China reached 1,409.4 million TOE (metric tons of oil equivalent) for 2003 as a whole, which represented 13% of total world energy demand. Therefore, the high economic growth rate of China, given the size of its population, has a huge impact on world energy demand—China imports a lot of crude oil and oil products, although the Chinese economy is still heavily dependent on coal and coal products as a major energy source.

Table 1 shows the imports of crude oil and oil products in China compared against production from 1980 to 2003 (values in parentheses refer to the ratio of imports to production). According to Table 1, crude oil imports jumped in the early 1990s following the open door policy. The level of crude oil imports was 17 million TOE in 1995, which was five times that in 1990, and approximately 70 million TOE in 2000, which was 24 times the level in 1990. As a result of the increase in crude oil imports, the crude oil import to indigenous production ratio has increased sharply, from 0.35% in 1980, to 2.11% in 1990, 43.06% in 2000 and 53.59% in 2003, respectively. In the 1990s, China bolstered the capacity of its petroleum refineries, which resulted in an increase in crude oil imports.

On the other hand, the imports of petroleum products have also increased sharply following the open door policy. The ratio of petroleum-product imports to petroleum refineries increased from 3.3% in 1990, to 12.3% in 1995, and to 12.5% in 2000.

Behind the huge oil imports lie critical problems in the energy balances in China. Due

Table 1 Imports of crude oil and oil products, and indigenous production of crude oil and petroleum refineries in China, 1980-2003 (1,000 metric tons of oil equivalent, (%))

Year	Crude oil imports		Production	Petro. products imports		Refineries
1980	373.0	(0.35)	107,853.0	468.0	(0.59)	8,679.0
1985	255.0	(0.20)	127,143.0	905.0	(0.97)	93,455.0
1990	2,923.0	(2.11)	138,306.0	3,568.0	(3.30)	108,051.0
1995	17,090.0	(12.36)	150,044.0	17,390.0	(12.30)	141,360.0
2000	70,265.0	(43.06)	163,172.0	24,963.0	(12.50)	199,719.0
2003	91,020.0	(53.59)	169,840.0	38,603.0	(16.55)	233,209.0

Data source: IEA, OECD

to the shortage of energy for socioeconomic development, the Chinese government has made great efforts to look for new energy deposits and to diversify energy sources. At the same time, the Chinese government has introduced advanced-technology machinery and equipment, importing it from economically-advanced countries, including Japan and the US, and this has contributed to an improvement of the situation in terms of the efficiency of energy use (Akita and Ogawa, 2000). However, those efforts could not achieve a dramatic improvement in energy constraints in China.

2-2. Energy demand in China

Although the Chinese economy has been heavily dependent on the use of coal and coal products as a primary energy source for a long time, the ratio of petroleum products and electricity as secondary and tertiary energy sources is increasing sharply with the furthering of economic development.

As a result, overall oil demands for final consumption and for intermediate demand have been dramatically increasing—the use of crude oil for final consumption and intermediate demand was 115.09 million TOE in 1990, 147.95 million TOE in 1995, and 252.11 million TOE in 2003, while the use of coal and coal products was 532.75 million TOE in 1990, 665.17 million TOE in 1995, and 850.39 million TOE in 2003, respectively. Taking into account the limited exploitation of natural gas in China, the increase in oil demand in China has exerted great influence on world oil balances and prices.

At the same time, the increase of per capita income has accelerated motorization in China. Motorization started in the 1990s and the number of automobiles in terms of private vehicles owned was 10,400,000 in 1995, 16,089,000 in 2000 and 23,829,000 in 2003. Along with motorization, fuel consumption in the transport sector increased to 57.08 million TOE in 2003, which is a 540% increase compared to 1990. It is expected that Chinese oil demands will increase sharply with the increase in per capita income in the future.

2-3. Economic growth and energy demand: Comparison with other Asian countries

With the high dependency of economic growth on oil, the rapid economic growth of China influences the energy balances in China and the world. In this sub-section, we analyze the relation between the economic growth and energy demands of China and compare it with those of other major Asian economies.

In Table 2, β shows the income elasticity against demand for petroleum products for

Table 2 Income Elasticity to Demand for Petroleum Products (DOP) for Major Asian Economies

ln. (DOP) =	α	+	β ln. (GDP)		RRADJ	SE	DW
China	6.381	(31.8)	0.690	(26.7)	0.9924	0.028	2.310
Hong Kong	-2.936	(2.23)	0.875	(4.49)	0.8422	0.112	1.499
Taiwan	4.173	(13.78)	0.720	(20.19)	0.9782	0.040	1.714
Singapore	1.815	(2.31)	0.685	(4.67)	0.9624	0.067	2.278
Indonesia	0.0471	(2.33)	0.881	(6.82)	0.9364	0.060	1.500
Malaysia	1.094	(4.76)	0.739	(36.44)	0.986	0.034	1.766
Philippines	-11.670	(2.19)	1.566	(4.00)	0.9064	0.083	1.233
Thailand	-14.784	(3.38)	1.656	(5.78)	0.985	0.056	1.936
Korea	-6.305	(2.83)	1.452	(7.83)	0.9844	0.067	1.499
Japan	2.413	(2.69)	0.767	(11.07)	0.970	0.020	2.169

OLS results by author with IEA data, 1980-2003 (t-values indicated in parentheses)

major Asian economies, including China, the Asian NIEs, the ASEAN Four, and Japan.

According to Table 2, the income elasticity of China is 0.69, which is the second lowest, after Singapore. Considering the degree of maturity of its economic development, the Chinese income elasticity to the demand of petroleum products is not necessarily large, but rather fairly small compared to other economies. The group with the highest elasticity consists of the Philippines, Thailand and Korea.

In the case of China, the lower income elasticity explains that the economic structure in terms of industrialization is still immature and labor intensive on the whole. However, the income elasticity of China, at 0.69, appears not to be so small, but is instead large when we consider the high economic growth rate of China, at approximately 10%.

3. Model Structure

In order to analyze the influence of Chinese economic development on world energy balances and prices, both a global macroeconomic model and a global energy model were developed and combined into one model.

In this section, the composition of the model is discussed, elucidating the structures of the global macroeconomic model and the energy model.

3-1. Global macroeconometric model

The global economic model employed in this study consists of 24 country/regional macroeconomic models, which span the world economy and are listed in Table 3. The global economic model is designed to focus on not only the economic performance of each country/region but also the global economy as a whole, including world trade, primary commodity demand, international capital transfer in the world economy, etc., and related world indicators.

Table 3 Countries (economies) and regions in the global economic model

Asia & Oceania (13):	Australia, New Zealand, China (Mainland), Hong Kong, Japan, Korea, Taiwan, Indonesia, Malaysia, Philippines, Singapore, Thailand, other Asia
North America (2):	Canada, US
Central & South America (1)	
Europe & EU (5):	Germany, France, Italy, UK, other Europe
Russia & Central Asia (1)	
Middle East (1)	
Africa (1)	

Each country/regional macro model generally comprises nine sub-block models; 1) real expenditure, 2) nominal expenditure, 3) prices and wage rates, 4) production, 5) population and labor force, 6) income distribution, 7) money and finance, 8) public finance, and 9) international trade and finance. The general specification of the model is one designed to maintain consistency among the economies for comparative econometric analyses in regression and in scenario simulations. The macroeconomic model basically depends on a demand-side-oriented model (Keynesian-type model) for all countries, including advanced market economies, developing market economies and centrally-planned economies. The model, however, considers the supply side of the economy and its impact on the whole economy through price mechanisms in the economy, so that the model is a so called "demand-supply-oriented model".

As for the international trade model, the macro models are linked with one another through bilateral trade flows, using a bilateral trade model among the major economies, and using a fixed-share matrix-coefficient and world-pooling trade model between the other countries/regions.

The number of macro variables in the country/regional model is approximately 100 for the advanced countries and 50 to 60 for the developing countries, depending on the availability of data. Therefore the total number of variables in the global economic model exceeds 3,000, including bilateral trade flows.

3-2. Macroeconomic model of China

The macroeconomic model of China consists of the nine sub-block models mentioned above and of 56 endogenous variables and 16 exogenous variables, excluding bilateral trade flows.

The Chinese macro model is also dependent on the demand-side-oriented model, centered around the GDP identity and behavioral equations of GDP components. The supply side (production), however, affects each component of real GDP (demand-side) through market mechanisms (the Walrasian price adjustment process and the Marshallian quantity adjustment process), so that it can be said that the model reproduces the dynamic equilibrium process in the macro model, as a supply-demand integrated model.

The macro model of China introduces the capacity to import (CAPM) to analyze the impact of FDI and terms of trade on both demand-side and supply-side economies through use of the domestic investment (gross fixed-capital formation) behavioral equation (Shishido, 2003). Following the open door policy in China, FDI particularly has played an important role in the strengthening of the economy. In modeling the Chinese economy, we emphasize the importance of FDI for the Chinese economy, which is one of the key points of the Chinese macroeconomic model in this study (see Appendix A: A-1. Macroeconometric Model of China, for more details).

As for international trade, the bilateral trade flows, excluding energy resources, with 18 other major economies and with five regions are modeled in the international trade and finance block. Macro-merchandise export and import are calculated by totaling the bilateral trade flows in the model.

3-3. Energy model

The global energy model also comprises 24 country/regional energy models as well as the global macroeconomic model. The model covers four energy products including; 1) coal and coal products, 2) crude oil, 3) petroleum products, and 4) natural gas, which are very important primary and secondary energy sources for economic activity and are also very scarce, being limited resources globally (Nakamura, 2005).

As well as the global macroeconomic model, the world variables, including world energy demand and supply by product and the world price of each energy product, are determined in the model system. For example, the crude oil price (PWRO) is determined by the world total demand and supply of crude oil (DOW/SOW), effective US dollar rates (EXRUS), and world total import prices, which are a substitute for describing worldwide inflation, as follows.

$$\ln.(PWRO) = -36.9618 + 1.72819\ \ln.(DOW/SOW) + 1.53145\ \ln.(EXRUS) + 1.89168\ \ln.(PTW)$$
$$\text{(t-value)}\ (-2.78)\quad (2.95)\quad (8.65)\quad (3.32)$$
$$-.655650\ D98 + .618486\ D2000$$
$$(-4.07)\quad (3.58)$$

OLS(1980-2003) RRADJ = 0.9204 SE = 0.131 DW = 1.661

3-4. Structure of country/regional energy model

The country/regional energy model consists of five sub-block models including 1) the total primary-energy-supply block, 2) the supply-demand condition block, 3) the demand block, 4) the international trade block, and 5) the prices block, for each product.

The first sub-block model defines the total primary energy supply including indigenous production (X), imports (M), exports (E), stock changes (J, exogenous variable), and international marine bunkers (B, exogenous variable) in the identity equation (Equation 1) and determines indigenous products (X) in the behavioral equation (Equation 2), as follows:

1) Total primary energy supply (TPES) block:

$$TPES = X + M - E + (-J) + B \qquad \text{(Equation 1)}$$
$$X = f(\ (+)GDP,\ (+/-)\ PW/PW(-1),\ (+)X(-1)\ ) \qquad \text{(Equation 2)}$$

The second sub-block defines the supply-demand condition to allow investigation of the relationship between indigenous production, imports, export stock changes and international marine bunkers as the supply factors on the left-hand side, and the final consumption (CF) and intermediate demands (U) as the demand factors on the right-hand side in the identity equation (Equation 3).

2) Supply-Demand condition block:

X + M − E + (-J) + B = CF + U (Equation 3)

The demand sub-block covers total demand (D) in the identity equation (Equation 4), final consumption (Equation 5), intermediate demand (Equations 6-13), electricity demand (DEL) (Equation 14), and refinery production (Equations 15-16), as follows:

3) Demand block:

D = CF + U + E + J (Equation 4)
CF = f((+)GDP, (-)PM/PM*, (+/-)TIME) (Equation 5)
Ucl = UEcl + UOTcl (coal & coal products) (Equation 6-1)
Uco = UEco + URco + UOToc (crude oil) (Equation 6-2)
Uop = UEop + (URop − XRop) + UOTop) (oil products) (Equation 6-3)
Ung = UEng − XRng + UOTng (natural gas) (Equation 6-4)
UE = α XREL (Equation 7-1)
UE = f((+)GDP (-) PM/PM*, (+/-) TIME) (Equation 7-2)
UE = f((+)DEL (-) PM/PM*, (+/-) TIME) (Equation 7-3)
URoc = f((+) XRop) (Equation 8)
(only for the relation between crude oil and oil products)
DEL = f((+)GDP, (-) PM/PM*, (+)FDEL(-1)) (Equation 9)
XRop = f((+)Dop, (-) Mop, (-) PMop/PMop*, (+)XRop(-1)) (Equation 10-1)
XRng = f ((+) URGop, (+/-) PMng/PMng*, (+)XRng(-1)) (Equation 10-2)

The international trade block covers the international trade of each energy resource item to determine the imports based on the imports equations (Equation 11-1 and Equation 11-2), and the bilateral exports (Eij) and exports (E) based on the fixed-share matrix-coefficient (γij) in Equation 12 and in Equation 13, respectively.

4) International trade block:

M = f((+) D, (-) X, (-)PM/PM*, (-) PM*EXRI/100) (Equation 11-1)
(for coal, crude oil and natural gas)
M = f((+) D, (-) XR, (-) PM/PM*, (-) PM*EXRI/100) (Equation 11-2)
(for oil products)
E(i,j) = γij * Mj (Equation 12)
Ei = Σj (Ei,j) (Equation 13)

5) Price block:

PE = f((+)PW) (for major exporting countries) (Equation 14-1)
PE = f((+)PMS, (+/-)EXRI, (+) PE(-1)) (Equation 14-2)
PM = MNS / M*100 (MNSj = Σi(Eij*PESi) (Equation 15)

As seen in each sub-block, the major components of the demand-side economy are basically explained by the income and price effects via market mechanisms. As for the price effects, both import prices relative to substitutable product (PM/PM*) and import prices in terms of local currency (PM*EXRI) are considered as price effects in the model. The regression results explain that the price effects are significant in many equations in spite of primary commodities, which make it possible to analyze the substitution effects through price mechanisms in the model (see Appendix B).

4. Forecasts (Most likely scenario)

In this section we analyze the future world energy balances and economic growth with special emphasis on the Chinese economy by using the global macroeconomic and energy model discussed in the previous section.

4-1. Forecasts for the world economy and energy balances

Assuming a projection to be the most likely scenario, in which the current global political and economic situations will continue without major change—including war and conflict—forecasts of the world economy and energy balances were made up to the year 2015.

For the forecasts, we assume that the exogenous variables are dependent on recent trends. For example, the official discount rate is one of the key exogenous variables, which was extrapolated based on the recent trends in each country (see Appendix Table 1 in Appendix C), while exchange rates of major countries excluding China are determined endogenously using PPP (purchasing power parity) and interest-rate parity (please see the example of the Japanese yen to the US dollar in Appendix D).

Table 4 shows the forecast for world economic growth including a number of major countries and regions, and real world trade. According to the results of our forecasts, the world economy as a whole is expected to continue in its very strong performance, growing at 4.2% in 2006, 3.9% in 2007, 4.1% in 2008, 3.8% in 2009 and 3.9% in 2010, respectively. The annual average growth rate will likely be 4.0% in the latter half of the 2000s and 3.8% in the first half of the 2010s. World trade will also show a high rate of increase of 6.3% in 2006, 5.1% in 2007, 5.7% in 2008, 4.9% in 2009 and 4.2% in 2010, respectively. The annual average rate of increase will likely be 5.1% in the latter half of the 2000s and 4.3% in the first half of the 2010s.

As for real economic growth rates, each country/region will likely continue to put in a strong performance, except for Japan. It is expected that the annual average growth rate will be 2.9% in the latter half of the 2000s and 2.8% in the first half of the 2010s for the US, 1.7% and 1.5% for Japan, 10.0% and 8.6% for China, 5.5% and 5.3% for the three Asian NIEs, and 4.8% and 4.2% for the ASEAN Four, for the same time-periods respectively. Chinese economic growth, in particular, will be striking, with a 9-10% annual growth rate during the 2000s, strongly affecting the world economy and world energy balances.

Concerning world energy balances and prices, world energy demand will likely increase strongly in line with the high economic growth rate of the world economy, and, with the large energy demand, high energy prices will also continue (see Table 5).

Table 4 Forecasts for the World Economy, Real Economic Growth and World Trade (%)

	2005	2006	2007	2008	2009	2010	2005-2010	2010-2015
World Economy	3.9	4.2	3.9	4.1	3.8	3.9	4.0	3.8
Japan	3.1	2.7	2.0	1.8	1.2	1.5	1.7	1.5
United States	3.5	3.1	3.2	3.0	2.9	2.7	2.9	2.8
China	10.1	9.8	10.2	10.7	10.1	9.9	10.0	8.6
Three Asian NIEs	5.8	5.6	5.3	5.9	5.1	4.9	5.5	5.3
ASEAN Four	5.4	5.9	4.7	5.0	4.8	4.3	4.8	4.2
World Trade	8.9	6.3	5.1	5.7	4.9	4.2	5.1	4.3

As for coal and coal products, world demand is expected to increase at approximately 2.5% in the latter half of the 2000s and at 1.1% in the first half of the 2010s. However, the price of coal and coal products will stay at a high level, at approximately 45-50 dollars per metric ton in terms of Australian coal—even after 2007—and will be largely dependent on the high prices of petroleum and petroleum products. As a result, the world demand for coal and coal products will likely be 3,265 million TOE in 2010 and 3,444 million TOE in 2015.

On the other hand, world crude oil demand is expected to maintain a strong increase, as a main energy resource, in line with the high growth rate of the world economy in the future. As a result, world crude oil demand will likely increase by 16% in the latter half of the 2000s and by 12% in the first half of the 2010s, which will be a larger increase than the 10% increase in the first half of the 2000s. With the large world demand for crude oil, the oil price will remain high at $66.40 per barrel in 2006, $62.30 per barrel in 2007, $51.60 per barrel in 2008, $55.90 per barrel in 2010, and $56.90 per barrel in 2015.

Regarding natural gas, world demand is also expected to maintain a strong increase at 4.0-4.5% over the coming decade, being used as a natural resource substituting for crude oil and coal. As a result, the world demand for natural gas will likely be 3,006 million TOE in 2010 and 3,689 million TOE in 2015, in which world natural gas demand is expected to exceed the world coal- and coal-products demand in the first half of the 2010s. The price of natural gas is also expected to stay at a high level in the future, correlating with crude oil prices.

**Table 5 World Energy Demands* and Prices, 2005-2015 :
Coal and Coal Products, Crude Oil, Petroleum Products, and Natural Gas (MTOE)**

	2005	2006	2007	2008	2009	2010	2015
Coal and Coal Products							
World demand	2864.4	2957.1	3084.9	3169.0	3203.7	3264.6	3443.5
(%)	(3.1)	(3.2)	(4.3)	(2.7)	(1.1)	(1.9)	(1.1)
Price (Australia, US$/MT)	51.0	55.7	48.6	43.3	46.7	49.2	51.5
Crude Oil							
World demand	4086.3	4178.8	4287.1	4459.0	4631.6	4744.9	5317.4
(%)	(2.9)	(2.3)	(2.6)	(4.0)	(3.9)	(2.4)	(2.3)
Price (Dubai, $/B)	49.2	66.4	62.3	51.6	54.8	55.9	56.9
Natural Gas							
World demand	2437.2	2529.9	2637.8	2751.4	2873.0	3006.3	3688.8
(%)	(3.9)	(3.5)	(4.3)	(4.3)	(4.4)	(4.4)	(4.5)
Price (Russia, $/1000m^3)	212.9	301.5	312.7	322.3	293.1	284.0	286.5

* Final consumption + intermediate demand

4-2. Forecasts for the Chinese economy

Based on the assumed values for exogenous variables (please see Appendix Table 2 in Appendix C), we made forecasts for the Chinese economy to the year 2015.

Table 6 shows the results of the economic forecasts for China. According to the forecasts, the Chinese economy is expected to continue its strong economic performance during the period of the forecast. The annual economic growth rates will likely be 9.8% in 2006, 10.2% in 2007, 10.7% in 2008, and 9.9% in 2010, maintaining an economic growth rate of approximately 10%. As a result of its high economic growth rate, the size of the Chinese economy is expected to grow to 22.544 trillion yuan in 2010 and 32.248 trillion yuan in 2015, which will be 2.5 times, and 3.6 times the level in 2000, respectively.

With the approaching global events of the Beijing Olympic Games in 2008 and the Shanghai Exposition in 2010, domestic investment (gross fixed-capital formation) will likely continue to see strong increases, of 14.9% in 2007, 12.9% in 2008, 12.1% in 2009 and 11.7% in 2010. The unemployment rate may be expected to stay fairly low and stable at approximately 4.1-4.4% in the coming decade, owing to rapid economic growth.

Concerning trade balances, the Chinese trade surplus is expected to remain large in the future in spite of the appreciation of the yuan against the U.S. dollar and oil price hikes. As a result, the Chinese trade balance will likely be 105.2 billion dollars in 2006, 98.7 billion dollars in 2007, 90.1 billion dollars in 2008, 82.4 billion dollars in 2010, and 67.1 billion dollars in 2015, respectively, although it will be in decline after the dramatic increase in 2005. In addition, the domestic inflation rate is expected to be moderate at approximately 2-3%, in spite of the high economic growth rate and oil price hikes, which means the supply-side economy will likely be strengthened through vital domestic investment behaviors from FDI.

Table 6 Forecasts for the Chinese Economy: Major Economic Indicators, 2005-2015

	2005	2006	2007	2008	2009	2010	2015
Real GDP (in billions of yuan)*	13,898	15,259	16,819	18,625	20,508	22,544	32,248
(%)	(10.0)	(9.8)	(10.2)	(10.7)	(10.1)	(9.9)	(8.4)
Real Investment (GFCF)*	5,926	6,739	7,742	8,739	9,793	10,936	15,857
	(18.3)	(13.7)	(14.9)	(12.9)	(12.1)	(11.7)	(9.5)
Unemployment rate (%)	4.18	4.22	4.31	4.10	4.15	4.31	4.44
Trade balance (billion US$)	133.3	105.2	98.7	90.1	86.0	82.4	67.1
Consumer Prices (%)	1.9	1.7	2.3	2.8	2.6	3.0	2.7
Exchange rates (yuan per $) **	8.19	7.92	7.80	7.70	7.70	7.70	7.70

*Converted to 2000 real value, based on the 1990 real value calculated in the model
**Exogenous variable

4-3. Forecasts for Chinese energy balances

With the strong performance of the economy in China, energy demands will likely increase consistently in the future as well. Table 7 shows the results of the forecasts for total demand and imports, by fuel type.

According to the forecasts, the total demand for coal and coal products, which is comprised of final consumption and intermediate demand, is expected to maintain strong increases in the period for which forecasts were made. The annual average rate of increase in the total demand of coal and coal products will likely be 8.2% in the latter half of the 2000s and 5.3% in the first half of the 2010s. As a result, the total demand will likely be 1,599.4 million TOE in 2010, and 1,851.2 million TOE in 2015, which will be 1.45 times, and 1.68 times the value in 2000. With the much larger tonnage of coal and coal products compared to other fuels, the large increases in total demand of coal and coal products may indicate that the Chinese economy will likely continue its heavy dependence on coal when oil prices are high in the future. Imports of coal and coal products will also increase in line with the total energy-demand increase in the future.

As for crude oil, the total demand, which is basically utilized by petroleum refineries, is expected to increase consistently due to high economic growth rates and the continuing advance of electrification in China. The annual average rate of increase will likely be 8.7% in the latter half of the 2010s and 7.8% in the first half of 2010s. The total demand will likely be 461.3 million TOE in 2010, and 621.7 million TOE in 2015, which will be 1.53 times, and 2.05 times the value in 2000, respectively. With the big increases in demand, the imports of crude oil will also show sustained large increases in the period for which forecasts were made. Imports will likely be 250.6 million TOE in 2010 and 341.8 million TOE in 2015. The ratio of imports to total demand will be 54.3% in 2010, and 55.0% in 2015, larger than the 2000-figure of 43.9%.

Concerning natural gas, the total demand is expected to increase sharply, in line with China's high economic growth rates in the period for which forecasts were made. The annual average rate of increase will likely be 10.4% in the latter half of the 2010s, and 8.1% in the first half of the 2010s, which will be the highest rate of increase for any of the fuels.

Table 7 Energy Balances in China, 2005-2015 (MTOE)

	2005	2006	2007	2008	2009	2010	2015
Coal and Coal Products							
Total Demand*	1099.8	1214.5	1315.4	1404.2	1507.1	1599.4	1851.2
(%)	(11.2)	(10.4)	(8.3)	(6.8)	(7.3)	(6.1)	(5.1)
Imports	6.5	6.9	7.3	7.7	7.7	8.0	9.6
(%)	(5.2)	(6.7)	(5.8)	(4.8)	(4.8)	(4.3)	(4.2)
Crude Oil							
Total demand*	302.6	329.4	357.6	390.9	425.0	461.3	621.7
(%)	(9.1)	(8.8)	(8.6)	(9.3)	(8.7)	(8.5)	(7.8)
Imports	132.7	152.5	173.4	198.6	223.3	250.6	341.8
(%)	(21.3)	(14.8)	(13.7)	(14.6)	(12.9)	(11.7)	(8.6)
Petroleum Products							
Total Demand*	310.6	340.8	375.1	412.8	444.7	480.9	629.1
(%)	(11.43)	(9.7)	(10.2)	(9.9)	(7.7)	(8.1)	(7.2)
Imports	57.6	67.8	78.3	88.8	101.8	114.9	157.5
(%)	(21.3)	(17.7)	(15.4)	(13.4)	(14.7)	(12.9)	(8.21)
Natural Gas							
Total Demand*	42.2	47.5	52.8	57.4	62.5	68.9	94.3
(%)	(11.8)	(12.4)	(11.2)	(8.6)	(8.9)	(10.3)	(8.1)
Imports	-	-	-	-	-	-	-
Electricity							
Total Demand*	161.7	181.8	204.9	229.0	253.1	276.3	364.7
(%)	(13.1)	(12.4)	(12.7)	(11.7)	(10.5)	(9.1)	(7.2)

* Final consumption + intermediate demand

5. Concluding Remarks

After the oil crises, there were advances in energy conservation technology, and, in the 1990s and the early 2000s, crude oil prices fell to the low level of approximately 20 dollars per barrel. At the time, many countries enjoyed lower oil prices to aid their economic development. It may be supposed, however, that the state of world energy balances had been changing and we are now faced with a new era concerning world energy balances. Some of the large energy-consuming countries, including China, India, Brazil, and the US, experienced accelerated economic growth during the period mentioned above. China, in particular, has succeeded in speeding its economic development with an economic growth rate of approximately 10%, following the open door policy. Under these conditions, we consider that the high prices of energy resources for the sustainable growth of the world economy—as was the case in the 1970s—will likely continue in the future.

This paper examines the energy balances and economic development of China in the long -term perspective of the world economy. According to the projection forecasts to the year 2015, world energy demand is expected to consistently increase in step with world economic growth and energy prices will likely stay at a high level in comparison to the last decade. Crude oil demand will likely continue to increase at an average annual rate of 3.1% and 2.3% in the periods 2005-2010, and 2010-2015, respectively, and crude oil prices will likely be approximately 55-60 dollars per barrel in the same periods.

At the same time, the Chinese economy is also expected to continue its strong economic performance up to 2015, and China's crude oil demand is expected to increase strongly with an annual average rate of increase of 8.7% and 7.8% in 2005-2010 and 2010-2015, respectively. As a result, the proportion of China's crude oil demand within the world total will likely increase from 7.4% in 2005 to 9.7% in 2010 and to 11.7% in 2015, which will heighten the Chinese influence on world energy balances.

Within these circumstances, the world economy, as well as China, will be required to adjust economic policy to sustain socioeconomic development, taking into consideration not only the finiteness of natural resources, but also environment problems including global warming. In addition, it is worth noting that we will continue to develop new technologies for energy saving and alternative energy sources in the future, as was the case after the oil crises in the 1970s.

For further study in the future, we will make some alternative-scenario simulations using this econometric system, which cannot be included in this paper due to space limitations. In addition, we will introduce an input-output model in order to study the impact of motorization and structural changes on the Chinese economy.

References

Adams, F. G. (1978) *Primary Commodity Markets in a World Model System, in Stabilizing World Commodity Markets*, Lexington: Heath Lexington

Akita, T. & M. Ogawa (2000) Trade, Energy and the Environment: An International Environmental Input-Output Analysis of CO_2 Emissions between China and Japan, *The Journal of Econometric Study of Northeast Asia (JESNA)*, Vol.2, No.1, pp.41-84

Dean, A. & P. Hoeller (1992) Costs of Reducing CO_2 Emissions: Evidence from Six Global Models, Economic Department Working Paper No.122, OECD

Leontief, W. (1977) *The Future of the World Economy*, A United Nations Study

Meadows, D.H. et al. (1972) *The Limits to Growth: A report for the Club of Rome's Project on the Predicament of Mankind*

Nakamura, O. (2005) The World Energy Model, its Structure and Regression Results, discussion paper No.05-02

Nakamura, O. (1988) Primary Commodity Prices and Economic Development, The case studies of Indonesia, Malaysia, the Philippines and Thailand, *Soka Economic Studies*, Vol.XVII, No.4

Nakamura, O. (1984) Analysis of Factors Determining Primary Commodity Prices and its Impact on the World Economy, *Review of World Economy*, Vol.28, Nos.7 and 9 (in Japanese)

Sato, M. (1992) Development of Hokkaido Macro Input-Output Integrated Model and its Software System, *Bulletin of Soka Women's College*, Vol.12, No.3, Soka University Press (in Japanese)

Shishido, S. et al. (2003) Japanese ODA to China and Indonesia in the Context of FDI - A Comparative Multi-Sectoral Approach, *The Journal of Econometric Study of Northeast Asia (JESNA)*, Vol.4, No.2

Tinbergen, J. (1976) *Reshaping the International Order (RIO)*, A Report to the Club of Rome

Walter, C. Labys (1980) Commodity Price Stabilization Model: A Review and Appraisal, *The Journal of Policy Modeling*, Vol.3, No.2

Appendix A

A-1. Macroeconometric Model of China

I. Real Expenditure Block

GDP = CP+CG+GFCF+J+EGS-MGS

CP = +40.7010 +.238128 (GDPN-GRTAX)/PCP*100 -1.04782 PCP +.693280 CP(-1)
(3.46) (5.40) (-2.26) (11.33)

sample 1980-2002 RRADJ = 0.9984 SE = 23.303 DW = 1.878

GFCF = 2933.1+.3224*(GDP)-30.1*(INTLR-DOT(PGFCF))-2813.88*(PGFCF/PGFCF(-1)) +38.1698*(CAPM(-1)*EXR(-1)/PMGS(-1))
(4.32) (11.83) (-4.33) (-4.56) (2.81)

sample 1981-2002 RRADJ = .995 SE = 44.3864 DW = 1.324

EGS = 14.6557+.982322((EFOB+ES)/10*EXR/PEGS)
(1.62) (59.96)

sample 1983-2002 RRADJ = .995 SE = 21.6809 DW = 1.32

MGS = 1.10594+1.00530((MFOB+MS)/10*EXR/PMGS)
(.32) (130.25)

sample 1983-2002 RRADJ = .999 SE = 7.92144 DW = 1.791

CAPM = FDI/1000+EGSN/EXRI*100

II. Nominal Expenditure Block

CPN = CP*PCP/100

CGN = -396.010+.401125(WAGIN)+.861972(CGN(-1))+404.154((GEX(-1)/GRV(-1)))
(-3.16) (1.45) (7.11) (3.34)
sample 1981-2002 RRADJ = .997 SE = 25.1338 DW = 1.985

GFCFN = GFCF*PGFCF/100
JN = J*PJ/100
EGSN = EGS*PEGS/100
MGSN = MGS*PMGS/100
GDPN = CPN+CGN+GFCFN+JN+EGSN-MGSN

III. Prices and Wage Rates Block

LOG PCP = -1.04037+1.31277 LOG WAGIN -1.93288 LOG GDP/NLE +.366006 LOG PMGS
(-1.32) (4.24) (-3.20) (3.39)
sample 1980-2002 RRADJ = 0.9782 SE = 0.067 DW = 1.495

LOG PGFCF = -.051182 +1.01236 LOG PGDP
(-.67) (62.43)
sample 1980-2002 RRADJ = 0.9944 SE = 0.035 DW = 2.064

LOG PEGS = +.528245 +.305684 LOG PMGS +.278153 LOG EXR +.491165 LOG PEGS(-1)
(1.59) (2.17) (1.87) (4.37)
sample 1980-2002 RRADJ = 0.9849 SE = 0.101 DW = 1.463

PMGS = PMGS$*EXRI*100
PGDP = GDPN/GDP*100
LOG(WAGIN) = 1.39601+.308611 LOG(PCP)+1.60117 LOG(GDPS/NLE)
(4.28) (3.20) (14.96)
sample 1986-2002 RRADJ = .997 SE = .042528 DW = 1.261

IV. Production Block

LOG(GDPS/NLE) = -.161111+.757714 LOG(K/NLE)
(-1.09) (13.10)
sample 1985-2002 RRADJ = .995 SE = .024363 DW = 1.312

K = GFCF+GFCF(-1)+GFCF(-2)+GFCF(-3)+…+GFCF(-7)

V. Population and Labor Force Block

NP = NP(-1)+BNP − DNP+NPM − NPE
BNP = NP*BR
DNP = NP*DR
NL = +59.5095 +3.86121 WAGIN/PCP +.920964 NL(-1)
(7.11) (2.02) (57.77)
sample 1985-2002 RRADJ = 0.9988 SE = 2.146 DW = 1.360

LOG(NLE) = .157193-.009577 LOG(WAGIN/PCP)+.972101 LOG(NL)
(1.96) (-2.85) (78.05)
sample 1985-2002 RRADJ = .999 SE = .001988 DW = 1.431

NLW = 39.5302-9.02993 (WAGIN/PCP)+.796512 (NLW(-1))
(2.34) (-3.48) (7.26)
sample 1986-2002 RRADJ = .882 SE = 4.86482 DW = 1.584

UR = (NL-NLE)/NL*100

VI. Money and Finance Block
M1 = -479.0580 +1.75074 GDP -94.6677 INTLR -241.5938 EXR
(-2.03) (16.12) (-2.91) (-3.87)
sample 1980-2002 RRADJ = 0.9910 SE = 205.809 DW = 1.273

MTD = -1,293.63 +2.42934 GDP +21.3125 PGDP -200.1928 INTLR -563.0445 EXR
(-2.55) (10.69) (1.98) (-3.25) (-2.88)
sample 1980-2002 RRADJ = 0.9879 SE = 389.131 DW = 1.089

M2 = M1+MTD
INTLR = +1.90890 -.000561 M2 +.053801 PGDP +2.35586 D8182 +2.65664 D89
(2.28) (-7.46) (6.41) (3.05) (2.68)
sample 1980-2002 RRADJ = 0.7911 SE = 0.955 DW = 0.956

VII. Government Finance Block
GRV = GRTAX+GROTH
GEX = GEXDF+GEXOTH
GB = GRV-GEX
GRTAX = GTRATE*GDPN/100

VIII. International Trade and Finance Block
$EFOBRR<i> = \Sigma j\ (E<i,j>)$
$MFOBRR<j> = \Sigma i\ (E<i,j>)$
EFOBR = EFOBRR+EFOBER
MFOBR = MFOBRR+MFOBER
EFOB = EFOBRT*PEG/EXRI*100
MFOB = MFOBRT*PMG/EXRI*100
TB = EFOB-MFOB
CBP = TB+ES − MS + IC − ID + CTC − CTD

FDI = -12572.3+4.93074(GDP)+4.36548(ODA(-1))+.561944(FDI(-1))
(-2.18) (2.20) (2.68) (3.10)
sample 1986-2002 RRADJ = .954 SE = 4,013.40 DW = 1.226

A-2. List of Variables for the Macroeconometric Model

GDP : real GDP in billion RMB (yuan) at 1990 constant prices
CP: real final consumption expenditure in billion RMB at 1990 constant prices
CG: real government consumption in billion RMB at 1990 constant prices
GFCF: real gross fixed capital formation in billion RMB at 1990 constant prices
J: real increase in stocks in billion RMB at 1990 constant prices (exogenous variable)
EGS: real exports of goods and services in billion RMB at 1990 constant prices
MGS: real imports of goods and services in billion RMB at 1990 constant prices
GDPN: nominal GDP in billion RMB
CPN: nominal private final consumption expenditures in billion RMB
CGN: nominal government consumption in billion RMB
GFCFN: nominal gross fixed capital formation in billion RMB
JN: nominal increase in stocks in billion RMB
EGSN: nominal exports of goods and services in billion RMB
MGSN: nominal imports of goods and services in billion RMB
GDPS: real GDP derived from the production function for the future simulation
K: real capital stock in billion RMB at 1990 constant prices
NP: population in millions
NPB: number of births in millions
NPD: number of deaths in millions
BR: birth rate (exogenous variable)
DR: death rate (exogenous variable)
NPM: number of immigrants in millions (exogenous variable)
NPE: number of emigrants in millions (exogenous variable)
NL: labor force in millions
NLE: persons in employment in millions
NLW: number of waged and salaried persons in millions
NU: number of unemployed in millions
UR: rate of unemployment
WAGIN: nominal wage rates index (1990 = 100)
PGDP: general deflator for GDP (1990 = 100)
PCP: implicit deflator of private final consumption expenditure (1990 = 100)
PCG: implicit deflator of government consumption (1990 = 100)
PGFCF: implicit deflator of gross fixed capital formation (1990 = 100)
PJP: implicit deflator of inventory changes (1990 = 100)
PEGS: implicit deflator of exports of goods and services (1990 = 100)
PMGS: implicit deflator of imports of goods and services (1990 = 100)
PMS: import prices in US dollars (1990 = 100)
PM: import prices of merchandize imports (1990 = 100)
PE: export prices of merchandize exports (1990 = 100)
EXR: exchange rate, RMB/$ (exogenous variable)
EXRI: exchange rate index (1990 = 100)
E<i,j>: real bilateral trade flow excluding energy trade from country <i> to country <j> in millions of US dollars at 1990 prices
EFOBR: real merchandize exports (F.O.B. base) in million RMB at 1990 constant prices

MFOBR: real merchandize imports (F.O.B. base) in million RMB at 1990 constant prices
EFOBRR: real merchandize exports (F.O.B. base) excluding energy exports
MFOBRR: real merchandize imports (F.O.B. base) excluding energy imports
EFOBER: real energy exports (F.O.B. base) in million RMB at 1990 constant prices
MFOBER: real energy imports (F.O.B. base) in million RMB at 1990 constant prices
EGFOBN: nominal merchandize exports (F.O.B. base) in million RMB
MGFOBN: nominal merchandize imports (F.O.B. base) in million RMB
EFOB: merchandize exports in millions of US dollars
MFOB: merchandize imports in millions of US dollars
ES: service exports in millions of US dollars (exogenous variable)
MS: service imports in millions of US dollars (exogenous variable)
IC: income, credit, in millions of US dollars (exogenous variable)
ID: income, debit, in millions of US dollars (exogenous variable)
CTC: current transfer, credit, in millions of US dollars (exogenous variable)
DCT: current transfer, debit, in millions of US dollars (exogenous variable)
TB: trade balance in millions of US dollars
CBP: current accounts in millions of US dollars
M1: money supply, M1, cash plus demand deposit
MTD: money supply, quasi money, time deposit money
M2: M1 plus MTD
INTOR: official discount rate, nominal (exogenous variable)
INTTD: time deposit rate, nominal
INTLR: lending rate, nominal
GRV: government revenue
GEX: government expenditure
GEXDF: government defense expenditure (exogenous variable)
GEXOTH: other government expenditure (exogenous variable)
GRTAX: government tax revenue
GTRATE: average tax rate (exogenous variable)
NAUTO: number of automobiles, private use
CAPM: capacity to import in billions of US dollars
FDI: foreign direct investment from abroad in millions of US dollars

Appendix B

B-1. Energy Model of China
Coal and coal products (-CL)

XCL = 80562.3+.06554(PWCL*EXRI/100)+.74397(XCL(-1))
(4.22) (2.96) (8.89)
OLSQ (1981-2003) RRADJ = .985 SD = 15,553.1 DW = 1.528

CFCL = 114823.7+82.176(GDP)-2.218(CFOP)+.93966(CFCL(-1))
(2.72) (2.73) (-2.63) (9.27)
OLSQ (1981-2003) RRADJ = .937 SD = 12,498.0 DW = 2.200

MCL/DCL = .000197-.000111(PMCL(-1)/PMOP(-1))+.89662(MCL(-1)/DCL(-1)) +.001066(D96)
(.99) (-2.65) (6.38) (2.79)
OLSQ (1981-2003) RRADJ = .789 SD = .000392 DW = 2.044

UECL = 10773.6+9.8740*(GDP)-2549.6(PECL/PMOP)+.80625(UECL(-1))
(2.71) (2.48) (-2.30) (4.05)
OLSQ (1981-2003) RRADJ = .991 SD = 4,164.7 DW = 1.943

Crude oil (-CO)
XOC = 12774.6+.03775(PWOC(-1)*EXRI(-1)/100)+.92853(XOC(-1))
(1.95) (2.49) (13.77)
OLSQ (1981-2003) RRADJ = .972 SD = 3,299.8 DW = 1.710

CFOC = 555721.0+1.0004(GDP)+.24288(CFOC(-1))-268.903(TIME)
(1.57) (1.89) (2.04) (-196)
OLSQ (1981-2003) RRADJ = .473 SD = 845.922 DW = 2.291

MOC = -27445.3+.23895(DOC)+.87312(MOC(-1))
(-1.87) (1.92) (2.81)
OLSQ (1981-2003) RRADJ = .842 SD = 6,883.63 DW = 1.404

UEOC = -603.209+.008332(XREL)-4.8624(PEOC/PMCL)+.97660(UEOC(-1))
(-1.99) (2.05) (-1.58) (14.11)
OLSQ (1981-2003) RRADJ = .979 SD = 222.843 DW = 1.782

UROC = -248.041+1.0103(XROP)
(-.59) (287.02)
OLSQ (1981-2003) RRADJ = .9999. SD = 604.001 DW = 1.673

Oil products (-OP)
CFOP = 7942.55+12.9932(GDP)+.67851(CFOP(-1))
(2.72) (3.09) (5.06)
OLSQ (1982-2003) RRADJ = .996 SD = 2,035.01 DW = 2.129

MOP = -14455.0+.21134(DOP)-2433.4(PMOP*EXRI/(PMOP(-1)*EXRI(-1)))
(-4.11) (11.54) (-2.97)
OLSQ (1981-2003) RRADJ = .915 SD = 2,984.5 DW = 1.623

XROP = 15066.3+.83885(DOP)
(6.90) (52.705)
OLSQ (1981-2003) RRADJ = .995 SD = 2,987.6 DW = 1.743

UEOP/GDP = .54843-.35995(PMOP/PMOP(-1))+.867221(UEOP(-1)/GDP(-1))
(.86) (-1.79) (26.66)

OLSQ (1981-2003) RRADJ = .953 SD = .86558 DW = 2.388

UEOP/XREL = 11.0065-.022886(PMOP/PMOP(-1))+.75439(UEOP(-1)/XREL(-1)) -.005223*(TIME)

(1.55) (-1.85) (4.63) (-1.79)

OLSQ (1981-2003) RRADJ = .944 SD = .04022 DW = 2.371

Natural gas (-NG)

CFNG = 7228.05+2.0531(GDP)-228.39(PENG/PMOP)

(11.75) (9.84) (-3.45)

OLSQ (1981-2003) RRADJ = .941 SD = 757.785 DW = 1.442

UENG = 267.287+.017334(XRELE)-399.76(PENG/PENG(-1))+822.64(D97)

(1.17) (7.43) (-1.88) (3.23)

OLSQ (1981-2003) RRADJ = .844 SD = 205.885 DW = 1.329

Electricity production

XREL = 2566.74+6.4733(GDP)+.72885(XREL(-1))

(2.57) (2.62) (4.39)

OLSQ (1981-2003) RRADJ = .996 SD = 1,577

B-2. List of Variables for Energy Model

(1) Variable

X: indigenous production
M: imports
E: exports
B: international marine bunkers (exogenous variable)
J: stock changes (exogenous variable)
S: total primary energy supply
D: total demand (= CF+U+E+J)
U: intermediate demand, total
UE: intermediate demand for electricity
UR: refinery intermediate demand for oil product (URop) and for natural gas (URng)
UOT: other intermediate demand (exogenous variable)
CF: final consumption
XR: refinery and gas work output in oil products and in natural gas
PE: export price in US dollars
PM: import price in US dollars
PM*: import price of another substitutable item in US dollars
PW: world price in US dollars
XREL: electricity production

(2) Products (subscription)

CL: coal and coal products (-cl)
OC: crude oil, NGL and feedstocks (-oc)
OP: petroleum products (-op)

NG: natural gas (-ng)
EL: electricity (-el)

Appendix C

Appendix Table 1. Official discount rates of major countries

	2006	2007	2008	2009	2010	2001-2015
US	6.30	6.50	6.50	6.50	6.50	6.50
Japan	0.50	0.50	0.50	0.50	0.50	0.50
Canada	4.50	4.50	4.50	4.50	4.50	4.50
EU	4.50	4.50	4.50	4.50	4.50	4.50
Hong Kong	6.75	6.75	6.75	6.75	6.75	6.75
Indonesia	9.75	11.00	11.00	11.00	11.00	11.00
The Philippines	5.70	6.00	6.00	6.00	6.00	6.00
Thailand	6.50	6.50	6.50	6.50	6.50	6.50
Korea	2.75	3.00	3.00	3.00	3.00	3.00

Appendix Table 2. Assumed values for the major exogenous variables for China

	2006	2007	2008	2009	2010	2001-2015
Birth rate (%)	1.20	1.15	1.10	1.10	1.10	1.10
Death rate (%)	0.65	0.65	0.65	0.65	0.65	0.65
Bank rate (%)	3.3	3.3	3.3	3.3	3.3	3.3
ODA 〈$M〉	1450	1400	1300	1000	800	500

Appendix D : Regression result of Japanese exchange rates to US dollar (Yen/US dollar)

EXR = 36.8 + 93.78 (PEX<JAPAN>/PGDP<US>) - 74.7 (INTGB<JAPAN>/INTGB<US>)
(4.07) (13.95) (-3.58)
sample 1981-2005 RRADJ = 0.916 SE = 13.39 DW = 1.283
(EXR: yen/US dollar rates, PEX: export price, PGDP: GDP deflator, INTGB: long-term government bond yields)

Improvement in Performance due to the Privatization of Township and Village Enterprises in China: Productivity and Profitability

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Abstract

We measure the improvement in performance of township and village enterprises (TVEs) due to privatization, by estimating production functions and profit-rate functions and controlling for the endogeneity problem of the choice to privatize (the self-selection bias problem). The results do not show any statistically significant improvement of productivity of TVEs with privatization, but do show statistically significant improvement of TVE profitability due to privatization. Privatization increases technical efficiency, but the effect is canceled out by a declining net work-rate in productivity. In view of the greater technical efficiency and reduced operating costs following privatization, it appears that privatization of TVEs motivates their managers via a clarification of the property rights of TVEs and through selling their assets to private owners. However, it is still necessary to look more closely at the factors causing the declining net work-rate and take appropriate measures to deal with them.

JEL Classification numbers: D24; O12; O53; P31.

Keywords: *township and village enterprises; the improvement in performance due to privatization; productivity and profitability; declining net work-rate.*

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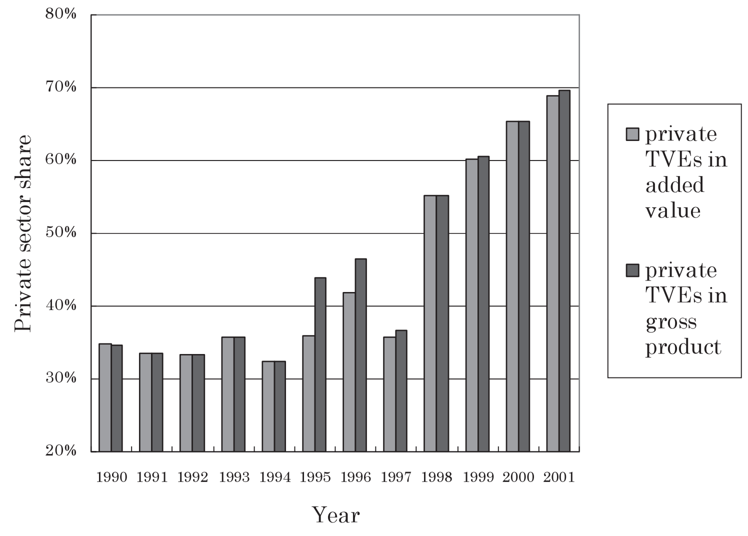
1. Introduction

From the late 1990s there has been massive privatization of publicly-owned enterprises (state-owned and collective-owned enterprises) in China. In particular, the privatization of collective-owned township and village enterprises (TVEs) has been rapid since 1998 (see Figure 1). In this privatization drive the number of TVEs categorized as "private" has increased, and collective-owned assets in privatized TVEs have fallen; assets in privatized TVEs tend to be concentrated in the hands of the firms' managers.

Figure 1 Private Sector Share in Chinese TVEs



Sources: China Township and Village Enterprises Yearbook, various years

Various publications have discussed the aims and the context of TVE privatization. Li and Rozelle (2000) state that privatization is partly a response to the sluggish performance of TVEs, as shown in their generally slow growth since 1993, so that they can evolve and remain competitive. Yep (2001) argues that the strengthening of TVE managers' bargaining positions is a crucial determinant of the pattern of privatization in rural China. Specifically, Yep (2001) insists that the local governments' strategy of furthering local managerial talent was by necessity accompanied by the granting of greater financial rewards, so that further dilution of the collective share in TVE assets was inevitable. Tan (2000) also highlighted the declining importance in the role of community government and the increasing importance of the role of the manager in TVEs and market development. Sun (2000) pointed out the worsening debt burden of TVEs, together with the strong incentive for the community (township or village) government to privatize collective-owned TVEs to get rid of the unlimited liability associated with collective-owned TVEs and so avoid the threat of community bankruptcy. Park and Shen (2003) argued that recent changes in the economic environment should undermine the relative profitability of joint-liability lending, which featured bank loans to collective-owned TVEs until recently. They state that the resulting reductions in joint-liability lending may have increased adverse selection and moral hazard problems, reducing the efficiency of collective-owned TVEs.

Many of the references cited above point out the declining performance of (collective-owned) TVEs in relation to TVE privatization which was expected to improve the declining performance of TVEs. There have been several quantitative studies of the effect of privatization of TVEs on their productivity.

Li and Rozelle (2000) measure the effects of TVE privatization on productivity (technical efficiency) by estimating a production function using panel data from 1994-97 on 168 township-level enterprises in Jiangsu and Zhejiang provinces. They measure the effect of privatization by estimating the coefficient for a private-ownership dummy in the production function. Moreover, to control for selection bias (the problem that ownership—a private ownership dummy—is endogenous in the determination of an enterprise's performance), they use the Heckman two-step method.[1] Their results indicate a positive effect of privatization on the productivity of TVEs, although not immediately; there is a time-lag after privatization. They argue that the delay is because transitional costs reduce private-firm efficiency in the year that a firm is privatized.

Sonobe and Otsuka (2003) assess the effect on productivity of TVE privatization using panel data[2] from 1995-98 on 56 enterprises in the garment industry, and 58 in the casting industry, in Shanghai and in Jiangsu and Anhui provinces. Their findings are significant for two reasons; (1) they chose specific industries for their measurement, so that their assumption of identical production function parameters for the enterprises in the sample is highly plausible; and (2) they adopted the share of the private owners (not discontinuous dummy variables) as a privatization variable, so that their empirical model is able to characterize privatization as a continuous process. Their empirical results indicate that productivity was significantly enhanced by privatization, with a time-lag of a few years.

Both Li and Rozelle (2000) and Sonobe and Otsuka (2003) find improvements in productivity of TVEs following privatization, with a time-lag. However, there are several reasons to interpret their results with caution. In the first stage of the Heckman two-step method, namely the probit model estimation, Li and Rozelle (2000) use variables indicating a firm's traits and production environment in a given year as independent variables for the probability of private ownership in that year. It is not clear that the choice of private ownership in the given year depends on the firm's traits and production environment in that same year. Moreover, it is possible that the variables for a firm's traits in the given year are endogenous with respect to private ownership in that year; the endogeneity of the choice of private ownership (or private-ownership dummy), which they aim to eliminate by employing the Heckman two-step method, would not be adequately removed. It is more reasonable to suppose that the probability of private ownership in a given year depends on the firm's traits and production environment in previous years. Next, although Sonobe and

[1] However, drawing on the results of their estimation they conclude that for the most part there is no serious selection bias.

[2] Data for all variables, however, are complete only for 1995 and 1998, and the differences in data between those two years are used for the measurement of the data which is lacking. Thus the regression analysis used is a cross-sectional one in form.

Otsuka (2003) recognize the possibility that the choice of privatization is endogenous, they nevertheless treat the privatization variable as exogenous. Moreover, in their production (growth) function the growth rate of real added value per capita during 1995-98 is regressed to several variables, including the increases in the share of private ownership during the whole year 1997. It seems a little unreasonable to include as an independent variable the increases in the share of private ownership in 1997, when the dependent variable, the growth rate of real added value per capita during the sample periods, includes growth before 1996.[3] Both pairs of authors focus wholly on productivity as the variable representing a firm's performance, which privatization is expected to improve, ignoring important alternative measures such as profitability (in particular, the profit-gross assets ratio)—productivity and profitability may move differently.

Also, neither work decomposes the change in productivity, measured as a change of a constant nature, into several components, and they assume that the productivity change (a change with a constant nature) is equal to the change in technical efficiency. This is explicit in Li and Rozelle (2000). However, a productivity change can be caused by factors other than a change in pure technical efficiency. It is therefore important in analyzing the effect of privatization to decompose the measured productivity change into the technical efficiency change and other components. The present paper takes the net work-rate change for equipment and machines as another component of the measured productivity change.[4]

Finally, both Li and Rozelle and Sonobe and Otsuka assume that only the constant term is subject to change through privatization in the empirical production function model used for analyzing productivity change, and that the other coefficients of the model do not change upon privatization. But privatization has diverse effects on the conditions for production, so that the other coefficients are also likely to change.

We therefore first adjust for the possibility that the choice of privatization is endogenous (the self-selection bias problem) by using the Heckman two-step method, following Li and Rozelle (2000), and in the first stage probit model estimation we use lagged enterprise-trait variables as independent variables, specifically those from the previous year. This makes it possible to adopt a more reasonable choice of the variable representing the probability of private ownership in the current year, and ensure that the independent variables in the probit model are not endogenous in the choice of private ownership in the current year. Second, we measure not only the change in productivity with privatization of TVEs but also the change in profitability. Third, the change in productivity with privatization is decomposed into components due to the change in technical efficiency and the change in net work-rate, both of which are measured. Similarly, the change in profitability with privatization is also decomposed into several components which are measured separately. Fourth, in estimating the production function and the profit-rate function, we suppose that the constant and also the other coefficients change upon privatization. We therefore estimate production functions

[3] Therefore, if the availability of data permits, it would be better to adopt the growth rate of real added value per capita in each year during the period 1995-98 as three dependent variables, which would be explained by the dependent variables of the previous year, rather than only one dependent variable—the growth rate during the entire sample period 1995-98.

[4] If, as has been the case in the preceding literature, one measures the effects on productivity of privatization by estimating the coefficient of, for instance, a privatization dummy inserted into a constant term of production function which does not use the net work-rate variable as an independent variable, a part of the measured change, through privatization, of the constant term must be attributable to the net work rate-change before and after privatization.

and profit-rate functions for collective-owned (i.e., non-private) enterprises and for private enterprises. From the resulting estimates and the data for firms privatized during the sample period, the productivity and profitability change with privatization is measured.

The data used here is a panel for 85 village enterprises, which is made up of the 20% re-sampling data of the Rural China Fixed Point Observation—Enterprise data (RCFPO-E data). The RCFPO-E data was collected by the Research Center of Rural Economy and originally consisted of information on village enterprises located across the whole of China for the period 1986 onwards. The survey of TVEs in Li and Rozelle (2000) concentrates only on township enterprises, so that comparison of the present results with their results will reveal the difference between township and village enterprises.[5]

Section 2 explains the data used and the statistics taken to describe the data sample. Section 3 describes our empirical model. Section 4 considers the results. A discussion and conclusions are presented in Section 5.

2. Data and descriptive statistics of data sample

Our empirical analysis is based on panel data consisting of the 20% re-sampling data of RCFPO-E data as noted above. Some of the authors took part in the data re-sampling. The sampling unit for the procedure was the village. The re-sampled villages were chosen using criteria including the quality and continuity of data available for each village. Our sample enterprises are located in the re-sampled villages.

The panel consists of annual observations for the period 1996-2000 made on 85 village enterprises located in eight provinces: Hebei, Shanxi, Liaoning, Heilongjiang (northern area), Anhui (eastern area), Sichuan, Yunnan and Ningxia (southern and western area).[6] The number of observations is 244, so that the panel is unbalanced.

We next present the deflation procedures used in the current analysis and discuss the data samples, concentrating on the difference between collective-owned and private enterprises. In particular, we look at the change in firms' attributes following privatization for the 28 firms privatized during the sample period.

2.1 Deflation

In estimating the production function, gross output (GY), fixed capital (K), working capital (WK), labor (L), and the intermediate inputs to fixed capital ratio (M/K) are used, whereas for the profit-rate function we use the profit to gross assets ratio (P/GA), the gross

[5] This kind of comparison would be made successfully, if possible, with the township enterprises located in the same geographical area as our sample village enterprises. Regrettably, our data do not contain information for township enterprises, and the geographical area of township enterprises studied in the preceding literature, including Li and Rozelle (2000), does not completely correspond to our sample area. Therefore, it should be noted that our comparison of village and township enterprises, which is derived from the present results for village enterprises and the preceding literature's results for township enterprises, is mismatched geographically.

[6] In order to construct panel data with sufficient quality to get reliable results, we must restrict the geographical coverage of our panel data to the eight provinces stated in the text. Although the geographical choice for sample enterprises may be the best one given the constraints of the data availability for the present analysis, we should acknowledge that a wider geographical coverage of sample enterprises, if possible, would increase the reliability of our empirical evidence.

output to gross assets ratio (GY/GA), the financial cost per unit asset (FC/GA), labor productivity (GY/L), the wage rate (W), and the operating cost per unit asset (OC/GA). The variables involved in the regressions are defined as follows. Gross output is measured by sales revenue. Fixed capital is measured by the real original value of fixed assets, whose deflation method will be explained below. Working capital is defined as the nominal value of working assets, since working capital is a monetary productive factor, and is measured nominally. Labor is taken as the total number of employees at year-end. Gross output and intermediate inputs are deflated to the 1995 fixed prices using the deflators for gross output and intermediate inputs. These price deflators are computed for each industry.

The price deflator for gross output is derived from data on the "ex-factory price indices of industrial products by sector" and the "services price index", as set out in the *China Statistical Yearbook*, and the "construction price index" published in *China Statistical Abstract*. In more detail, the price index for each sector in the "ex-factory price indices of industrial products by sector" is assigned to the industrial enterprises belonging to each sector. The "construction price index" and "services price index" are assigned to construction enterprises, and wholesale, retail and catering enterprises, respectively. The price index for the food industry in the "ex-factory price indices of industrial products by sector" is assigned also to agricultural enterprises, because these enterprises are likely to be engaged in the processing of agricultural products. The deflator for gross output is normalized by taking the 1995 index as 100%.

The price deflator for intermediate inputs is derived from the data on the "purchase price index of materials, fuels, and engines" published in the *China Statistical Abstract*. The deflator for intermediate inputs is derived as a weighted average price index, in which the weighting is the average share of each component in the sum of the value of current intermediate inputs for each industry in the sample. The shares of intermediate inputs are based on the input-output table for China for 1997 published in the *China Statistical Yearbook 1998*. The deflator for intermediate inputs is also normalized by taking the 1995 index as 100%.

Fixed capital is measured by the real original value of fixed assets. The price deflator for fixed assets, DEFA, is derived from the "price indices of investment in fixed assets" in the *China Statistical Yearbook*. The deflator for fixed assets, DEFA, takes the 1995 index as the price base. Since fixed assets is a stock variable, the real original value of fixed assets is calculated by accumulating each year's gross investments deflated to the 1995 real price. The equation is as follows:

$$DOF_t=(1-s)\ DOF_{t-1}+(OF_t-OF_{t-1}+sOF_{t-1})/DEFA_t, \qquad t=1995\text{-}2000$$

where s denotes the rate of physical depreciation of fixed assets each year, assumed to be 3%, OF is the nominal value of the original value of fixed assets and DOF the deflated original value of fixed assets.

By considering the year of establishment of the sample firm, we compute the real original value of fixed assets in 1995, which is the starting year of our data. More specifically, we first take the nominal original value of gross investment between 1995 and 1996 as a base value, and assume that this base value of gross investment took place each year from the establishment of the firm until 1995. Based on this assumption, we compute the sum of nominal values of gross investment and physical depreciation of fixed assets for each year from the establishment of the firm until 1995. We then subtract it from the nominal original value of fixed assets in 1995, and by deflating the remainder by the deflator for fixed assets (DEFA) in the year of establishment we obtain the real original value of fixed assets in the year of establishment. Finally, in the way shown in the equation above, we sum the real values of gross investment every year from establishment until 1995 and add them onto the real original value of fixed assets in the year of establishment, so as to compute the real original value of fixed assets in 1995.

Profit is defined as profit before tax. Gross assets are measured by the sum of the net values of fixed assets, working assets, and the other assets in the balance sheet. Financial costs and operating costs are taken as the financial costs and the main business costs in profit and loss statements. The wage rate is calculated as the total wage bill divided by the number of employees. Profit and wage rate are deflated to the 1995 fixed prices by the deflators for gross output. Financial cost and operating cost are deflated to the 1995 fixed prices by the deflators for intermediate inputs. For gross assets, the nominal value is used. [7]

2.2 Descriptive statistics of the data sample

We now consider the data sample according to its descriptive statistics (Tables 1 and 2). We classify the enterprises into collective-owned and private enterprises (for the definitions see footnote[8]), and pick out those enterprises privatized during the sample period (1996-2000) from the private enterprises. In other words, for convenience, in these tables we classify as privatized enterprises those which were originally collective-owned enterprises but were privatized during the sample period.

[7] We also deflated various gross asset variables and carried out regression analysis using them. However, it was found that the results were very similar to those using the nominal value of gross assets. Therefore, we present the results using the nominal value of gross assets in this paper.

[8] Regrettably, we cannot follow the measurement and estimation by industry, and adoption of continuous private owner-share variables as the privatization variable, as in Sonobe and Otsuka (2003). This is as our sample does not include a large enough number of firms to permit estimation by industry, especially firms privatized during the sample period, and also because although we can find out the private-owner shares of the enterprises designated as "private" in publications, we are unable to find out for the most part the same information for the enterprises designated as "non-private" in publications, namely collective-owned enterprises. As for the latter, it is only natural that the owner-shares of the enterprises that have not yet been privatized are not settled and knowable, since the privatization process of public-owned enterprises includes clarification of property rights, in other words owner-share, as its first step. To put it another way, it is highly likely that the enterprises whose shares of property rights are clarified and those whose shares of property rights have not yet been clarified are registered as "private" and "non-private", respectively, in the original data book. We define as private enterprises, whose private ownership dummy is 1, those which are registered as "private" in the data book and whose private-owner shares are more than 50 percent.

Table 1
Descriptive Statistics (1)[a]

Company-type	Production Function Analysis						
	Gross output	Fixed capital	Working capital	Labor	Intermediate inputs/Fixed capital	Gross output/ Fixed capital	Gross output/ Labor
	(GY)	(K)	(WK)	(L)	(M/K)	(GY/K)	(GY/L)
	(unit = 100 yuan)	(unit = 100 yuan)	(unit = 100 yuan)	(persons)			(unit = 100 yuan)
Collective-owned village enterprises[b]	46448.055	21061.446	15080.621	51.218	1.751	2.493	722.485
	(177827.424)	(39047.584)	(28955.831)	(77.344)	(3.651)	(4.502)	(1432.906)
Private enterprises[c]	35469.790	25061.301	27151.464	44.364	1.830	2.690	637.746
	(1000204.501)	(63098.744)	(68386.676)	(79.266)	(3.583)	(4.402)	(1744.891)
Privatized during the sample period[d]	17377.731	14055.701	18758.000	33.389	2.256	2.997	406.549
	(39726.519)	(25038.565)	(47322.869)	(53.872)	(4.534)	(5.272)	(348.645)
(1) Before privatization[e]	15837.791	10350.377	16313.120	37.012	3.967	4.783	388.928
(2) After privatization	15027.295	12296.130	17096.052	25.119	1.787	2.687	453.184
Difference: (2) · (1)	-810.496	1945.753	782.932	-11.893	-2.179	-2.096[f]	64.255[g]

[a] This table (and also Table 2) presents the sample means of variables, with standard deviations reported in parentheses.
[b] 45 firms
[c] 40 firms
[d] 28 firms
[e] What is presented here are not the simple averages of samples before privatization. They are calculated as follows:
First the average value before privatization within each of the 28 firms is calculated.
Then, we calculate the average of the within-firm averages of the 28 firms and present it here. This is the same as for after privatization.
[f] The difference is not statistically significant even at 10%.
[g] The difference is not statistically significant even at 10%.

Table 2
Descriptive Statistics (2)

Company-type	Profit Rate Function Analysis						
	Profit/Gross assets (P/GA)	Profit (P) (unit = 100 yuan)	Gross assets (GA) (unit = 100 yuan)	Gross output/ Gross assets (GY/GA)	Financial cost (FC) (unit = 100 yuan)	Wage rate (W) (unit = 100 yuan)	Operating cost (OC) (unit = 100 yuan)
Collective-owned village enterprises	0.393	6363.020	24756.109	1.795	630.256	62.635	37369.688
	(0.957)	(31868.739)	(43198.784)	(3.242)	(1956.503)	(125.456)	(149412.752)
Private enterprises	0.286	4135.595	46601.749	1.392	1172.639	55.026	27974.554
	(0.679)	(13920.072)	(122461.712)	(1.870)	(3306.976)	(63.851)	(81934.198)
Privatized during the sample period	0.129	1709.727	29689.878	1.071	1095.683	49.080	13024.506
	(0.355)	(6384.130)	(70114.201)	(1.042)	(2875.193)	(30.963)	(29855.587)
(1) Before privatization[a]	0.041	1204.574	15884.408	1.211	420.673	38.477	19504.588
(2) After privatization	0.259	4854.324	15370.065	1.177	348.874	53.225	26358.554
Difference: (2) · (1)	0.218[b]	3649.750	-514.344	-0.034	-71.799	14.748	6853.966

[a] For the procedure to calculate the average value, see note a of Table 1
[b] The difference is statistically significant at 1%.

First, we find that a typical private enterprise, especially one privatized during the sample period, is smaller than a typical collective-owned (village) enterprise, according to their mean gross output (GY) and labor (L) as shown in Table 1. Second, the performance of private or privatized enterprises is inferior to that of collective-owned enterprises. As for productivity, private enterprises, especially privatized enterprises, have lower mean labor productivity (GY/L) than collective-owned enterprises. In other words, these enterprises generally have redundant employees. The mean gross output to gross assets ratio, namely the gross asset productivity (GY/GA), is also lower in private enterprises than in collective-owned enterprises, and particularly so in privatized enterprises. As for profitability, a typical private or privatized enterprise has a lower profit to gross assets ratio (P/GA) than a typical collective-owned enterprise. Since a typical private or privatized enterprise is smaller than a typical collective-owned enterprise, the profit (P) is correspondingly smaller. Third, the mean wage rate (W) is lower in private or privatized enterprises than in collective-owned enterprises, and the former typically includes more low-wage employment than the latter.

However, it is not clear whether the features of private or privatized enterprises indicated in these descriptive statistics represent the effects of privatization of TVEs or the consequences of privatizing particular types of TVEs. This issue is considered in later sections.

As a preliminary analysis, we now compare the mean productivity and profit rate after privatization of the 28 firms privatized during the sample period with the values before privatization. The relevant figures are presented in Tables 1 and 2 (comparison of mean productivities in Table 1, and of mean profit rates in Table 2). Tests on the differences between the means, based on a normal distribution, show that there are no statistically significant improvements following privatization in capital productivity (GY/K) and labor productivity (GY/L), but a statistically significant change is seen in the profit rate, defined as the profit to gross assets ratio (P/GA). In the rough evaluation at this stage, the two measures of performance (productivity and profitability) indicate differing effects of the privatization of TVEs. As well as these performance measures, we report the mean changes upon privatization of several variables in Tables 1, 2 and 3.

Table 3
Other variables averaged before and after privatization for the 28 firms privatized during the sample period

Profit Rate Function Analysis	Financial cost/Gross assets (FC/GA)	Operating cost/Gross assets (OC/GA)
(1) Before privatization[a]	0.027	0.917
(2) After privatization	0.019	0.777
Difference: (2)-(1)	-0.008	-0.140

[a] For the procedure to calculate the average value, see note a of Table 1

First, mean labor (L) decreases considerably upon privatization, from 37.0 persons before privatization to 25.1 persons afterwards (see Table 1). This reduction is impressive in comparison with the other productive factors; the fixed capital (K) and working capital (WK) increase on average with privatization (Table 1). This appears to reflect the dismissal of workers (possibly along with the replacement of others) as part of management reform and restructuring following privatization. Our recent field survey indicates that in most cases thorough management reform and restructuring is conducted after privatization by the manager(s) who end up with most of the firm's assets and become its owner(s). This reform and restructuring is characterized by the dismissal of workers (and replacing high-cost workers born locally with cheaper migrants), which is the most important aspect of reform and restructuring, together with organizational reform and the recruitment of talented workers. Consequently, similar reform and restructuring is very likely to be carried out in our sample. The mean value of the wage rate (W) increases from 38.477 (unit = 100 yuan) before privatization to 53.225 (unit = 100 yuan) after privatization (see Table 2). This suggests that privatized enterprises in our sample not only dismiss workers but also recruit talented persons by offering high wages or increasing the wages of remaining workers to increase their motivation to work. This is consistent with the observation that enterprises privatized during the sample period tend to have a lower wage rate. Privatized enterprises characterized by labor intensive production methods using low wage employment are short of highly educated or skilled workers. They tackle that problem by targeted recruitment following privatization, and select the best of their existing workforce, increasing their motivation by increasing their wages rather than seeking cheaper migrant labor.

Second, the financial cost per unit asset (FC/GA) and operating cost per unit asset (OC/GA), which are involved in our estimation of the profit-rate function, also clearly decrease on average from before privatization to after privatization. This appears to be a consequence of management reform and restructuring after privatization.

Third, the intermediate inputs to fixed capital ratio (M/K), which is involved in estimating the production function, decreases on average following privatization (from 3.967 before privatization to 1.787 afterwards—see Table 1). The present work takes the intermediate inputs to fixed capital ratio (M/K) to be a good proxy for the net work-rate for equipment and machines, following Basu (1996).[9] Accordingly, the change in value shows that the net work-rate in our sample tends to decline following privatization. A closer study of the fall in M/K provides useful information about the declining net work-rate. First, let us discover whether the decreasing M/K is due to a fall in M or an increase in K, by plotting the growth rates of fixed capital (K) and M/K, and intermediate inputs (M) and M/K for the 28 privatized firms in scatter diagrams (Figures 2 and 3). These diagrams indicate that the fall in M/K is because M decreases upon privatization. Next, we consider what effect the fall in M/K has on the gross output (GY) and the profit to gross assets ratio (P/GA), which are the dependent variables in the production function analysis and the profit-rate function analysis (Figures 4 and 5). These diagrams show that the falling M/K is very likely to have a negative influence on both the gross output (sales) and the profit to gross assets ratio. Consequently, it is reasonable to suppose that the firms do not deliberately induce the fall in net work-rate, but are faced with it due to certain external conditions. In fact the correlation between the growth rate of M/K and the change in profit to gross assets ratio (correlation coefficient 0.309) is weaker than that between the growth rates of M/K and gross output (correlation coefficient 0.765). The reason is shown graphically in Figures 6 and 7; the reduction in

[9] Basu (1996) asserts that the use of intermediate inputs is a convenient indicator of the net work-rate based on his finding that material growth is a good measure of unobserved changes in capital and labor utilization in the US economy. And, as stated below (in Section 3), the production change attributable to the net work-rate change is considered as a kind of productivity change in a broad sense in this paper.

M/K has a negative impact on the profit to gross assets ratio through the decreasing gross output to gross assets ratio (GY/GA), but has a positive effect on it through the decreasing operating cost to gross assets ratio (OC/GA). In summary, the declining net work-rate has a purely negative influence on productivity, but has both negative and positive influences on profitability, resulting in a weaker overall negative influence.

Figure 2 Correlation between the Growth Rates of M/K and K before and after Privatization

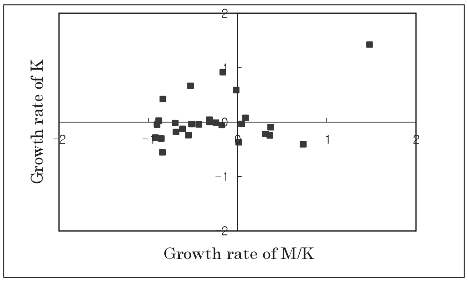


Figure 3 Correlation between the Growth Rates of M/K and M before and after Privatization

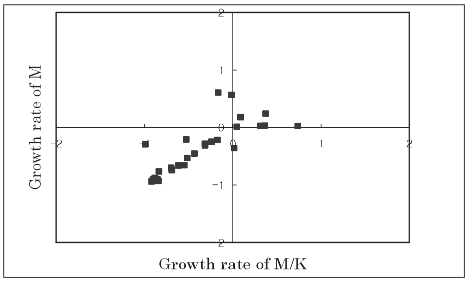


Figure 4 Correlation between the Growth Rates of M/K and GY between before and after Privatization

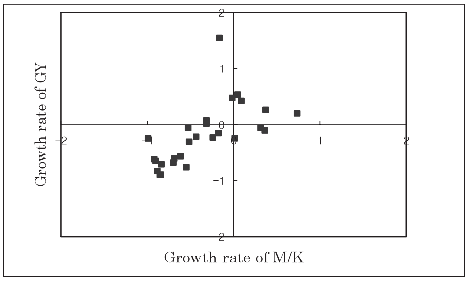


Figure 5 Correlation between the Growth Rates of M/K and the Change of P/GA before and after Privatization

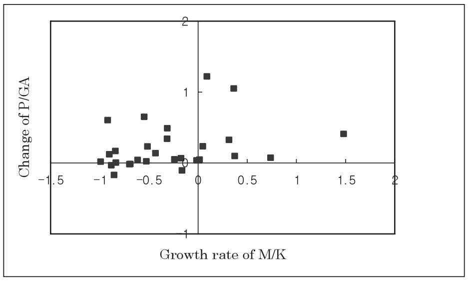


Figure 6 Correlation between the Growth Rates of M/K and GY/GA before and after Privatization

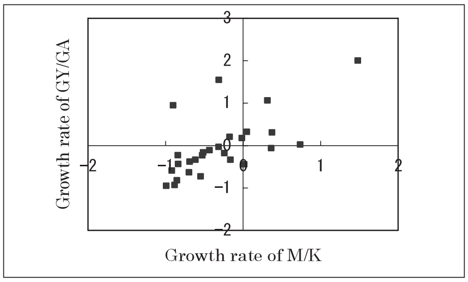
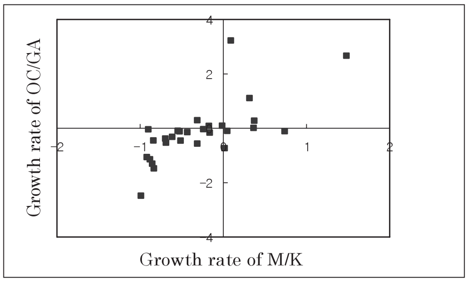


Figure 7 Correlation between the Growth Rates of M/K and OC/GA before and after Privatization



Following this analysis of the descriptive statistics, we next investigate in depth the effect of privatization of TVEs on their performance, by estimating the production function and the profit-rate function.

3. Empirical model

We estimate production functions and profit-rate functions of collective-owned (non-private) enterprises and of private enterprises, using the Heckman two-step method to control for the possibility that the variable which represents whether an enterprise is privatized is endogenous (the self-selection bias problem). From the results of the estimation for both types of enterprises, we measure the productivity and profitability improvement due to privatization for the 28 firms privatized during the sample period. Moreover, the productivity and profitability changes following privatization are decomposed into several parts.

In the first step of the Heckman two-step method, we estimate a probit model for explaining the decision to privatize:

$$\text{Prob(private)= Prob}(I_{it}=1)=\text{Prob}(\alpha X_{it-1}+\beta Z_{it-1}+\varepsilon_{it}>0), \quad (1)$$

where X_{it-1} represents the (one-period) lagged independent and dependent variables of the production function and the profit-rate function, and Z_{it-1} represents the other lagged independent variables. In this paper, lagged gross output (GY), profit before tax (P), fixed capital (K), working capital (WK), labor (L) and labor productivity (GY/L), and year dummy variables, are all used as X_{it-1}. The lagged amount of tax payment (TAX) and amount of payments to government other than tax (QTAX: quasi-tax), and a one-period lagged private ownership dummy (I_{it-1}) are all included in Z_{it-1}. The lagged private ownership dummy is used because privatization is basically irreversible, so that a firm is very likely to be privately run in a given year if it was already private in the previous year, and this determinant factor should be controlled in equation (1).

Next we estimate production functions and profit-rate functions for collective-owned enterprises and private enterprises respectively, correcting the potential bias caused by the endogeneity problem of the variable representing privatization (the self-selection bias problem). By estimating functions for collective-owned enterprises and for private enterprises, we allow the possibility that all coefficients of functions can differ before and after privatization for TVEs which turn into private enterprises from collective-owned ones (through privatization). The inverse Mills ratio obtained from the estimation results of the probit model, equation (1), are introduced into the production functions or profit-rate functions:

$$y_{cit}=\alpha_c X_{cit}+\gamma_c \lambda_{cit}+u_{cit} \quad (2)$$

$$y_{pit}=\alpha_p X_{pit}+\gamma_p \lambda_{pit}+u_{pit}, \quad (3)$$

where dependent variable y (y_{cit} or y_{pit}) represents logarithmic gross output (lnGY) in the production function, and profit-gross assets ratio (P/GA) in the profit-rate function. Here λ_{cit} and λ_{pit} denote the inverse Mills ratios. Subscripts c and p represent collective-owned enterprises and private enterprises, respectively. Finally, u_{cit} and u_{pit} are the stochastic error terms.

In the production functions, three logarithmic productive factors are used as X_{it}:

logarithmic fixed capital (lnK), logarithmic working capital (lnWK), and logarithmic labor (lnL);[10] and the intermediate inputs-fixed capital ratio (M/K) and year dummy variables are also used. The intermediate inputs-fixed capital ratio (M/K) is assumed to be a proxy for the net work-rate for equipment and machines. In other words, in this paper we estimate a Cobb-Douglas type production function with the net work-rate variable. Introduction of a net work-rate variable into the production function therefore enables us to analyze explicitly the change in production attributable to the net work-rate factor. Since the change in production due to the change in net work-rate is not caused by increasing or decreasing inputs, we consider it as a kind of productivity change. The change in net work-rate, however, differs from the change in technical efficiency. Consequently, the change in productivity is taken in this study to have components attributable to change in technical efficiency and net work-rate.

In the profit-rate functions, the following variables are used as X_{it}: the gross output-gross assets ratio (GY/GA), the financial cost per unit asset (FC/GA), labor productivity (GY/L), the wage rate (W), the operating cost per unit asset (OC/GA), and year dummy variables. The profit-rate function is a reduced-form equation, not a structural-form equation derived strictly from the Cobb-Douglas type production function used by the authors and in the profit-maximizing behavior of enterprises. From the theoretical viewpoint, under the assumption of profit-maximizing behavior, a firm's profit is decided by several endogenous variables: productivity (here including technical efficiency and net work-rate) and the unit costs of productive factors (here including fixed capital, working capital, and labor). The above-mentioned independent variables in the profit-rate functions are adopted as proxies for these theoretical determinants, though they do not perfectly correspond to theoretical determinants.

The gross output-gross assets ratio (GY/GA) and labor productivity (GY/L) are assumed to represent productivity. We should note that change in productivity is represented not only by these variables but also by other components of the empirical model; for example, changes in parameters and the operating cost per unit asset (OC/GA). The financial cost per unit asset (FC/GA) and the wage rate (W) are intended to represent unit costs of productive factors (capital and labor). The operating cost per unit asset (OC/GA) is partly intended to represent the unit costs of productive factors, but its change can represent change in productivity too, as mentioned above. The estimated coefficients of proxy variables for productivity are expected to be positive, while those for unit costs of productive factors are expected to be negative. Of course, the estimated coefficient of the operating cost per unit asset (OC/GA) is expected to be negative. For both the production function and profit-rate function, we use panel estimation, so that an individual firm-specific term is also included in X_{it}.[11]

Based on equations (2) and (3), we obtain estimates of the production functions or profit-rate functions for collective-owned enterprises (equation (4)) and private enterprises (equation (5)):

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[10] That is, the specification of production function using these productive factors as independent variables (and gross output, GY, as a dependent variable) follows the specification of the production function adopted by Li and Rozelle (2000).

[11] Thus, if the fixed-effects model is adopted in panel estimation (as will be done in our estimations), the number of firm-specific dummy variables used in the empirical model equals the number of firms in the sample.

$$\hat{y}_{cit}=\hat{\alpha}_c X_{cit}+\hat{\gamma}_c \lambda_{cit} \tag{4}$$

$$\hat{y}_{pit}=\hat{\alpha}_p X_{pit}+\hat{\gamma}_p \lambda_{pit}. \tag{5}$$

We can now obtain the change of mean $\hat{y}$ upon privatization[13] for the 28 firms privatized during the sample period:

$$\overline{y}_p-\overline{y}_c=\hat{\alpha}_p\overline{X}_p-\hat{\alpha}_c\overline{X}_c+\hat{\gamma}_p\overline{\lambda}_p-\hat{\gamma}_c\overline{\lambda}_c$$

$$=[(\mathbf{I}-\mathbf{D})\overline{X}_p+\mathbf{D}\overline{X}_c](\hat{\alpha}_p-\hat{\alpha}_c)+(\overline{X}_p-\overline{X}_c)[\mathbf{D}\hat{\alpha}_p+(\mathbf{I}-\mathbf{D})\hat{\alpha}_c]+\hat{\gamma}_p\overline{\lambda}_p-\hat{\gamma}_c\overline{\lambda}_c, \tag{6}$$

where **I** is the identity matrix and **D** is a weighted diagonal matrix. Equation (6) decomposes the change of mean $\hat{y}$ (logarithmic gross output or profit-gross assets ratio) following privatization for the 28 firms into three parts: (a) a component due to the changes of parameters following privatization; (b) a component due to changes of the average characteristics of the firms following privatization; and (c) a component due to selectivity bias.

To measure changes in productivity following privatization, it is necessary to take (a) and that component within (b) which is due to the change in the mean of the net work-rate proxy, M/K. This is because gross output ($\hat{y}$) does not accurately represent productivity; we cannot take those components in (b) due to the changes in the productivity factors (K, WK, L) and the time dummy variables[12] and (c) (the component due to selectivity bias) as being due to the change in productivity through privatization. Therefore:

productivity change

$$=[(\mathbf{I}-\mathbf{D})\overline{X}_p+\mathbf{D}\overline{X}_c](\hat{\alpha}_p-\hat{\alpha}_c)+(\overline{(M/K)}_p-\overline{(M/K)}_c)[D\hat{\alpha}_p+(1-D)\hat{\alpha}_c]. \tag{7}$$

The first term in equation (7) represents the change in productivity caused by changes in parameters, namely the change in technical efficiency, and the second term represents the change in productivity caused by the change in the net work-rate.

To measure the effect of privatization on profitability, since the profit-gross assets ratio ($\hat{y}$) is itself a profitability measure, we should take (a) and (b)[13], and remove (c):

profitability change

$$=[(\mathbf{I}-\mathbf{D})\overline{X}_p+\mathbf{D}\overline{X}_c](\hat{\alpha}_p-\hat{\alpha}_c)+(\overline{X}_p-\overline{X}_c)[\mathbf{D}\hat{\alpha}_p+(\mathbf{I}-\mathbf{D})\hat{\alpha}_c]. \tag{8}$$

The measurements of the changes in productivity and profitability depend on the choice of weighting in matrix **D**. In this paper we take two extreme cases: (Ⅰ) **D**=0 and (Ⅱ) **D=I**.

[12] The component due to the changes in time dummy variables in (b) cannot be included in the measuring of change in productivity or profitability caused by privatization because the latter should be due to the difference in time-specific macroeconomic conditions.

[13] Here also, the component due to changes in the time dummy variables in (b) is not included in the measuring of change in profitability caused by privatization. For the reason see Footnote 12.

In case (Ⅰ), we measure the expected difference between the situation where parameters change through privatization and the situation where they do not, based on the characteristics of the firms (variables) after privatization; and we measure the expected difference between the situation where the characteristics of firms (variables) change through privatization and the situation where they do not, based on parameters before privatization, i.e., for collective-owned enterprises. Case (Ⅰ) may be interpreted as the following: we measure the extent of improvement in productivity or profitability of privatized firms through parameter changes, compared with that for firms that were not privatized, and the extent of improvement in productivity or profitability of privatized firms through changes in their characteristics caused by privatization. In short, this is a measurement based on the state of the enterprises after privatization.

In case (Ⅱ), we measure the expected difference between the situation where parameters change through privatization and the situation where they do not, based on the characteristics of firms (variables) before privatization; and we measure the expected difference between the situation where the characteristics of firms (variables) change through privatization and the situation where they do not, based on the parameters after privatization, i.e., for collective-owned enterprises. Case (Ⅱ) may be interpreted as the following: we measure how much improvement in productivity or profitability the firms would have experienced through changes in parameters if they had been privatized, when in fact they had not yet been privatized, and how much improvement in productivity or profitability a privatization would have led to in the firms through changes in their characteristics. In short, this is a measurement based on the state of the enterprises before privatization.

4. Empirical results

The estimates of the probit model for the choice to privatize (Table 4) raise a number of points.

Table 4
Estimates of Probit Model[a]

	(I_{it} = 1 if privatized) ML
Constant	-1.647
	(-6.489)
Year dummy	
1997	-0.455
	(-0.888)
1998	1.460***
	(5.231)
1999	0.450**
	(2.413)
2000	0.550*
	(1.755)
GY_{-1}	0.203×10^{-5}
	(0.961)
P_{-1}	0.168×10^{-4}
	(0.568)
K_{-1}	0.394×10^{-5}
	(0.653)
WK_{-1}	0.964×10^{-5}*
	(1.645)
L_{-1}	-0.681×10^{-2}**
	(-2.533)
$(GY/L)_{-1}$	-0.300×10^{-3}*
	(-1.699)
TAX_{-1}	0.140×10^{-4}
	(0.164)
$QTAX_{-1}$	-0.106×10^{-3}*
	(-1.812)
I_{it-1}	4.544***
	(8.469)
Pseudo-R^2	0.759
Log of likelihood	-116.283
Obs. No.	244

[a] This table shows regression coefficients. We report *t* values in parentheses.
*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

First, the estimated coefficients of the year dummy variables after 1997, especially the 1998 dummy, are positive and statistically significant, indicating that privatization of TVEs has accelerated since 1998. Second, the estimated coefficients of L_{-1} are significant and negative, indicating that smaller firms tend to be privatized. Third, the estimated coefficient of TAX_{-1} (amount of tax payment) is not statistically significant, whereas that of

$QTAX_{-1}$ (amount of payments to government other than tax) is significant and negative. The second and third findings indicate that privatization of TVEs are a risk to their operation; village governments are reluctant to privatize TVEs which are important for their local economies and public finances. If privatizing a large-scale TVE (having many employees) led to worsening performance, serious problems for the local economy and society, such as an increase in unemployment, could arise. Risk-averse village governments therefore tend to privatize smaller firms experimentally. Similarly, if privatization of a TVE which contributed substantial payment to the government other than tax (and more important in village finances than formal tax) led to worsening performance, serious problems for village finances could arise. Village governments therefore tend to privatize such firms experimentally. In contrast we do not find any significant effect of formal tax (which is less important for village finances) on the likelihood of privatization; this third finding clearly indicates that concern about village finances has a strong effect on whether to privatize. Fourth, the estimated coefficient of $(GY/L)_{-1}$ is significant and negative, indicating that firms with lower labor productivity, in other words redundant employees, tend to be privatized. In other words, privatization is expected to resolve the problem of redundant labor in TVEs. Finally, the estimated coefficient of $(WK)_{-1}$ (working capital) is significant and positive. We cannot tell clearly whether this indicates that firms with abundant reserve funds (because of good fund management) tend to be privatized, or whether firms that need to hold substantial funds or accumulate stock (because of a declining turnover rate of working capital) tend to be privatized.

Tables 5 and 6 report the results of estimating the production functions and profit-rate functions, controlling for the possibility that the choice to privatize is endogenous (the self-selection bias problem).[14] These results raise a number of points.

[14] We adopt fixed-effect models in all our panel estimations, since random-effect models are rejected by the Hausman test at a level of 1%.

Table 5
Estimates of Production Function[a]

	1nGY	
	Fixed Effects[b]	
	Collective-Owned	Private
Year dummy		
1997	0.225**	-0.130
	(2.016)	(-1.134)
1998	-0.702**	-0.261**
	(-2.547)	(-2.257)
1999	-0.240**	-0.188
	(-2.007)	(1.451)
2000	-0.055	0.023
	(-0.422)	(0.164)
1nK	0.422***	0.491***
	(4.376)	(2.637)
1nWK	0.049*	0.080
	(1.772)	(0.575)
1nL	0.494***	0.572***
	(5.223)	(3.665)
M/K	0.118***	0.433***
	(5.423)	(6.862)
Inverse Mills' ratio	-1.171**	0.098
	(-2.011)	(1.223)
Hausman test [c]	$X^2(9) = 25.787$	$X^2(9) = 29.996$
p value	0.002	0.000
Adj. R^2	0.955	0.982
Obs. No.	134	110

[a] This table shows regression coefficients. We report *t* values in parentheses.
[b] In order to save space, we omit estimated coefficients of firm-specific dummy variables.
[c] The Hausman test is designed to test the null hypothesis that random effects estimators are consistent. It rejects the random effects model at the 1% level. Thus, we adopt a fixed-effects model in panel estimation.
*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

Table 6
Estimates of Profit Rate Function[a]

	P/GA	
	Fixed Effects[b]	
	Collective-Owned	Private
Year dummy		
1997	0.072*	-0.194×10^{-3}
	(1.829)	(-0.005)
1998	-0.120	-0.376×10^{-2}
	(-1.246)	(-0.099)
1999	-0.163×10^{-4}	0.050
	(-0.003)	(1.294)
2000	0.053	0.165***
	(1.084)	(3.791)
GY/GA	0.907***	0.724***
	(39.107)	(19.009)
FC/GA	-0.621	-2.663***
	(-0.937)	(-3.496)
GY/L	0.241×10^{-4}	0.320×10^{-4}
	(1.299)	(0.865)
W	0.834×10^{-4}	-0.123×10^{-2}***
	(0.651)	(-3.113)
OC/GA	-0.892***	-0.740***
	(-28.784)	(-10.279)
Inverse Mills' ratio	-0.338*	0.041*
	(-1.709)	(1.676)
Hausman test[c]	$X^2(10) = 25.070$	$X^2(10) = 41.216$
p value	0.005	0.000
Adj. R^2	0.973	0.976
Obs. No.	134	110

[a] This table shows regression coefficients. We report *t* values in parentheses.
[b] In order to save space, we omit estimated coefficients of firm-specific dummy variables.
[c] The Hausman test is designed to test the null hypothesis that random effects estimators are consistent. It rejects the random effects model at the 1% level. Thus, we adopt a fixed-effects model in panel estimation.
*Significant at 10%.
**Significant at 5%.
***Significant at 1%.

First, three of the four estimated coefficients of the inverse Mills' ratios are statistically significant in our estimates of production functions and profit-rate functions. This implies that we cannot ignore the endogeneity problem in the decision to privatize when estimating both functions.

Second, in the estimates of production functions, the estimated coefficient of the net work-rate proxy M/K is larger for private enterprises than for collective-owned enterprises,[15] indicating that the net work-rate has a stronger influence on production in private enterprises than in collective-owned enterprises. Furthermore, the estimated coefficient of working capital (lnWK) is not statistically significant for private enterprises. This indicates that the raising of the net work-rate by circulating working capital efficiently is a more critical issue for private enterprises than the amount of working capital. The sum of the estimated coefficients of the productive factors (lnK, lnWK and lnL) in the estimates for private enterprises indicates that economies of scale may arise in production in private enterprises.[16] The model is therefore able to predict a trend toward mergers of private enterprises.

Third, the influence of the gross output-gross assets ratio (GY/GA) and of the operating cost per unit asset (OC/GA) on the profit-gross assets ratio (P/GA) is striking for both collective-owned enterprises and private enterprises. For private enterprises, however, the estimated coefficients of the financial cost per unit asset (FC/GA) and the wage rate (W) are also significant and negative,[17] indicating that the profitability of private enterprises tends to depend on these costs more than for collective-owned enterprises. Reducing those costs will also be important in raising the profitability of private enterprises. In particular, the estimated coefficient of FC/GA is larger than those of the other variables normalized by gross assets (GY/GA and OC/GA), indicating that the profitability of private enterprises depends strongly on their financial costs. In fact, FC/GA tends to decrease with privatization in our sample, as shown in Section 2.

Based on the estimates presented above, we measure the improvement in productivity and profitability following privatization for the 28 firms privatized during the sample period, and decompose the improvement into several parts. The results (in Tables 7 and 8) raise the points which follow the tables below. We mention only robust results that can be observed in both case (Ⅰ) and case (Ⅱ) and are not dependent on the choice of matrix **D** in the productivity and profitability measurement equations (7) and (8).

[15] In addition, we can confirm the statistically significant difference of the estimated coefficients of M/K between the two types of enterprise at a level of 1% in a formal t-test, which assumes that the covariance between their respective coefficients of M/K is zero. For the reason why that assumption is necessary for the t-test, see Footnote 18.

[16] The null hypothesis that the sum of the estimated coefficients of these three productive factors is one, meaning constant returns to scale, is significantly rejected at 5%.

[17] As for the statistical significance of the differences in the estimated coefficients of FC/GA and W between the two types of enterprise, the situation is the same as for M/K in the production function.

Table 7
Privatization Effect on Productivity, and its Decomposition (28 firms)

	due to parameter changes (1)	due to change in M/K[a](2)	total = (1) + (2)
Case(Ⅰ):D = 0	0.425***b	-0.258**	0.167
Case(Ⅱ):D = Ⅰ	0.831***	-0.944***	-0.114

[a] M/K is assumed to represent a firm's net work-rate.
[b] It is assumed that covariance components between the estimated coefficients of the two regression models are zero.
*Significant at 10%(t-test).
**Significant at 5%(t-test).
***Significant at 1%(t-test).

Table 8
Privatization Effect on Profitability, and its Decomposition (28 firms)

	due to parameter changes (1)	due to change in GY/GA (2)	due to change in FC/GA (3)	due to change in GY/L (4)	due to change in W (5)	due to change in OC/GA (6)	total = (1) + (2) + (3) + (4) + (5) + (6)
Case(Ⅰ): D = 0	0.121***a	-0.031***	0.005	0.002	0.001	0.125***	0.222***
Case(Ⅱ): D = Ⅰ	0.052**	-0.025***	0.020***	0.002	-0.018***	0.103***	0.136***

[a] It is assumed that covariance components between the estimated coefficients of the two regression models are zero.
*Significant at 10%(t-test).
**Significant at 5%(t-test).
***Significant at 1%(t-test).

First, we cannot find improvements in productivity with privatization in measured totals in which the sign differs between case (Ⅰ) and case (Ⅱ) and neither are statistically significant. Of the components resulting from the decomposition, the change in productivity components due to parameter changes, which appear to represent the change in technical efficiency, are significantly positive in both case (Ⅰ) and case (Ⅱ) (t-test results).[18] Privatization of TVEs certainly improves productivity by improving technical efficiency. The components due to changes in the mean of the net work-rate proxy, M/K, are significant and negative and offset the positive change in productivity due to parameter changes. As in Section 2, reducing the net work-rate cancels the improvement in productivity with privatization resulting from increasing technical efficiency. [19]

Second, we can find significant improvements in profitability with privatization in

[18] For the t-test, a variance-covariance matrix of the estimated coefficients for regression equations for both collective-owned enterprises and private enterprises is needed. In the matrix we employ, the covariance factors between the estimated coefficients for the regression equations for different enterprise types are assumed to be zero, since they cannot be estimated owing to the different numbers of observations for collective-owned enterprises and private enterprises.
[19] Li and Rozelle (2000), and Sonobe and Otsuka (2003), mentioned above, find productivity-improving effects of TVE privatization with a time-lag. However, the time-lag which is necessary for privatization effects to be found shows that the productivity improving effects of privatization are difficult to detect. We think the difficulty is very likely to be because of the declining net work-rate.

the measured totals, in contrast to the non-significant improvements in productivity. Of the resulting components, the change in profitability components due to parameter changes and due to the decreasing (mean of the) operating cost per unit asset (OC/GA) make the largest contributions to the improvements in profitability. The reduction in operating costs is caused partly by the declining net work-rate, as in Section 2, and partly by management reform and restructuring after privatization, which reduces the number of workers (also as in Section 2). The effects of reform and restructuring characterized by the dismissal of workers are visible in the increased technical efficiency in productivity following the privatization of TVEs. The improvement in profitability due to changes in parameters also shows up mainly in increased technical efficiency in the production function. In more detail, a declining net work-rate leads only to declining productivity, since in productivity measurement we estimate how efficiently the productive factors possessed at one given time produce output, whereas a declining net work-rate also partly improves the measured profitability, by decreasing the operating cost per unit asset. Improvements in profitability arising from increasing technical efficiency in production and a declining net work-rate overcome the negative effects of the declining net work-rate on profitability. [20]

Management reform and restructuring after privatization succeed in increasing the technical efficiency in production, although the positive effects are canceled by a declining net work-rate in productivity, while they increase profitability which is little affected by a decline in the net work-rate.

5. Discussion and conclusions

The main findings of this paper are as follows:

First, we cannot find a statistically significant improvement in productivity following privatization of TVEs, though there are statistically significant improvements in profitability. This is because privatization raises technical efficiency, but the effect is offset by the effect of a declining net work-rate on productivity; predominant in profitability are increased technical efficiency and the reduction in operating costs caused partly by the declining net work-rate and partly by management reform and restructuring after privatization.

Second, the increases in technical efficiency and reduction in the operating costs following privatization of TVEs is likely to be due to the management reform and restructuring that privatization brings. It therefore appears that TVE privatization motivates managers of TVEs via a clarification of the property rights of TVEs and through selling their assets to private owners.[21]

Although privatization of TVEs clearly raises their technical efficiency and reduces operating costs by motivating managers properly, some factors causing the net work-rate to fall prevent the positive effects of privatization from being fully realized. If it were not

[20] As is shown in Section 2, synthesis of the positive and negative effects of the declining net work-rate on profitability results in a somewhat negative effect overall. It indicates that besides the effect of the decreasing operating costs caused by the declining net work-rate, some effects caused by the increased technical efficiency are decisively important as a driving force for improved profitability through privatization.

[21] In the privatization of public-owned enterprises, including TVEs in China, the managers in many cases get most of the firms' assets and become the owners, and thus the moral hazard for managers that originates in the separation of ownership and management cannot arise.

for the declining net work-rate, a greater improvement in performance would be realized, not only in productivity, but also in profitability, for which we find statistically significant improvements upon privatization. For the sustainable development of private TVEs it will be necessary to learn more about the factors causing the declining net work-rate and to deal with them.

We propose two possible causes of the declining net work-rate following privatization. One is the possibility that privatized TVEs can no longer be supported by local (village) governments in sales, as they were before privatization, leading to declining net work-rates resulting from sales difficulties. The other is the possibility that privatized TVEs can no longer be supported by local (village) governments in financing (for example, by providing collateral or mediation in borrowing money from a bank), so that privatized TVEs face reduced credit worthiness. They then face difficulty in borrowing money from banks or in receiving trade credit from their suppliers, leading to declining net work-rates through a declining rate of turnover of their working capital.[22]

Our recent field survey indicates that the most serious of these potential problems is the difficulty in finance. Almost all of the private TVEs we questioned, mostly small or medium-sized enterprises, stated that difficulty in the area of financing was the most serious problem in their operations. Many face not only serious difficulty in borrowing money from banks, but also are rejected as recipients of trade credit by their suppliers, so that they have to pay by cash or in advance. Also, in the 28 firms used here for measuring the effects of privatization, loan/gross assets and accounts payable/gross assets, which represent the amount of trade credit received, decrease respectively by 15% and 16% on average following privatization. The turnover rate of their working capital (GY/WK) decreases 39% on average following privatization.

According to our recent field survey, enterprises which face serious difficulty in borrowing money from banks and receiving trade credit have three characteristics. First, they are small. Second, they do not have a close relationship with the upper tier of government in China. (This is typical of enterprises that began privately. Moreover, among formerly public-owned enterprises, formerly state-owned ones are treated more favorably in borrowing money from banks and receiving trade credit than ex-TVEs, even after privatization.) Third, they are newcomers which have not been in business long, so that they have not yet established a reputation and credit among buyers and suppliers. The privatized firms in our sample, which are village enterprises employing tens of workers, have the first two of these characteristics, and so are likely to face serious difficulty in the area of financing. Li and Rozelle (2000) find a positive effect of privatization on the productivity of TVEs, but the present analysis does not, partly because the small village enterprises from which our sample is drawn are likely to face greater difficulty in financing than the enterprises in their sample, which we believe are larger township enterprises.[23] Our view is that the declining net work-rate of privatized firms in our sample is caused by their difficulty in the area of financing and is supported by elementary empirical evidence, yet at this stage this remains a hypothesis to be tested in further research.

[22] Using statistical evidence, Brandt and Li (2003) point out that private TVEs are less favored in the bank loan markets than collective-owned TVEs. Furthermore, they also found that a privatized TVE was not discriminated against in bank loans before privatization, while coming to suffer discrimination after privatization.

[23] A similar thing can be said for Sonobe and Otsuka (2003).

References

Basu, S. (1996) "Procyclical Productivity: Increasing Returns or Cyclical Utilization?" *Quarterly Journal of Economics*, 111(3), pp.719-751.

Brandt, L. & H. Li (2003) "Bank Discrimination in Transition Economies: Ideology, Information, or Incentives?" *Journal of Comparative Economics*, 31(3), pp. 387-413.

Li, H. & S. Rozelle (2000) "Saving or Stripping Rural Industry: An Analysis of Privatization and Efficiency in China." *Agricultural Economics*, 23(3), pp.241-252.

Park, A. & M. Shen (2003) "Joint Liability Lending and the Rise and Fall of China's Township and Village Enterprises." *Journal of Development Economics*, 71(2), pp. 497-531.

Sonobe, T. & K. Otsuka (2003) "Productivity Effects of TVE Privatization: The Case of Garment and Metal Casting Enterprises in the Greater Yangtze River Region." *NBER Working Paper* No. 9621.

Sun, L. (2000) "Anticipatory Ownership Reform Driven by Competition: China's Township-Village and Private Enterprises in the 1990s." *Comparative Economic Studies*, XLII (3), pp.49-75.

Tan, Q. (2000) "Features of the Market and the Changes in the Property Rights Structure of TVEs (Shichang de Xingzhi yu Qiye Suoyouquan Anpai-Xiangzhenqiye Chanquan Gaige de Tiyan)" *China Rural Survey (Zhongguo Nongcun Guancha)*, 1, pp.30-36, (Chinese).

Yep, R. (2001) "The Evolution of Shareholding Enterprises Reform in Rural China: A Manager Empowerment Thesis." *Pacific Affairs*, 74(1), pp.53-73.

The Effect of the Chinese Renminbi on Korean Exports to Japan

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Abstract

This paper examines the impact of the Chinese renminbi on Korean exports to Japan using quarterly data from 1986Q1 to 2003Q4. Specifically, Korean exports to Japan were regressed on a number of explanatory variables, including the exchange rate of the renminbi against the Japanese yen. According to the estimation of the cointegrating vector, a 1 percent depreciation of the Korean won raises Korean exports to Japan by about 2 percent. On the other hand, a 1 percent appreciation of the renminbi raises Korean exports to Japan by slightly less than 1 percent, implying that the long-term impact of the Chinese renminbi on Korean exports to Japan is around half of the long-term impact of the Korean won. In contrast, the short-term impact of the renminbi was not clearly detected by the error correction model. Even so, the estimation results of the error correction model also confirmed the existence of a cointegrating vector.

JEL Classification: C22, F14, F31

Keywords: *exchange rate volatility, export, East Asia, cointegration, error correction model*

1. Introduction

On July 21st of 2005, the Chinese government, which had maintained a de-facto fixed exchange rate regime since 1994, announced that it would raise the value of the Chinese renminbi against the US dollar by 2.1 percent. Even though the Chinese government denies the possibility of a further revaluation of the renminbi in the near future, continual pressure from the major trading partners of China, including the US, is generating rumors that the renminbi will be further revalued upwards. In fact, the recent revaluation was also the result of strong demands from the US and other Western countries (Chang and Parker, 2004; Funke and Rahn, 2005).

The appreciation of the renminbi is, in general, expected to have positive impacts on the exports of other East Asian countries because China is recognized as their major competitor in the world market. However, despite the heated debate surrounding the value of the renminbi and the importance of this issue, the effect of the value of the Chinese renminbi on the exports of other East Asian countries has rarely been explored.[1] Against this backdrop, this study aims to determine the effect of the value of the Chinese renminbi on the export volume from Korea to Japan. Even though it focuses on the exports of one country, the research results should shed light on other cases.

To this end, quarterly export data on Korea from 1986 to 2003 were examined. Specifically, following the work of Arize, Osang and Slottje (2000), Baak et al. (2007),

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[1] Some papers investigate the impact of the renminbi on Chinese trade (Zhang, 2001; Chou, 2000; Tang, 2003). Wang, Wang and Zhang (2003) examine the effects of the Japanese yen's depreciation on Chinese exports. Bhattacharya, Ghosh, and Jansen (2001) investigate whether the emergence of China hurt Asian exports.

Chowdhury (1993), and Hassan and Tufte (1998) among others, this study examines the long-term relationship between Korean exports to Japan and other economic factors, including the real exchange rate of the Chinese renminbi, by performing cointegration tests. In addition, the short-term impact of the real exchange rate of the Chinese renminbi on Korean exports to Japan was examined by estimating error correction models. Along with the real exchange rate of the Chinese renminbi, other economic variables such as the Japanese industrial production index, the real exchange rate of the Korean won, and the exchange rate volatility of the Korean won were also employed as explanatory variables of Korean exports to Japan. Exchange rate volatility was measured by computing the quarterly standard deviations of monthly real bilateral exchange rates.

The test results indicate a negative long-term relationship between Korean exports to Japan and the real exchange rate of the Chinese renminbi against the Japanese yen. That is, depreciation of the value of the Chinese renminbi has a negative impact on the volume of Korean exports to Japan. More specifically, a 1 percent increase in the exchange rate of the Chinese renminbi (that is, a 1 percent decrease in the value of the Chinese renminbi) turns out to decrease Korean exports by about 0.9 percent.

On the other hand, a 1 percent increase in the exchange rate of the Korean won (that is, a 1 percent decrease of the value of the Korean won) turns out to increase Korean exports by about 2 percent. This implies that the impact of the Chinese renminbi on the Korean exports is half of the impact of the Korean won.

The manufacturing production index of Japan and the volatility of Korean exchange rates turn out to have their expected impacts on Korean exports in the long term. The former has a positive impact, while the latter has a negative impact.

In contrast, the estimation results of the error correction model show that the short-term impacts of the Chinese renminbi were not clearly detected. However, the estimation results of the error correction model confirm the presence of a cointegrating vector.

2. Description of the model and data

2.1. The cointegration equation

This paper investigates the long-term export function by performing cointegration tests, and the short-term dynamics of the export function by estimating error correction models, as in the studies of Arize, Osang and Slottje (1999, 2000), Baak et. al. (2007), Chowdhury (1993) and Hassan and Tufte (1998).

Following the typical specification of other papers, the long-term equilibrium relation between exports and other economic variables is examined in this paper by the following equation:

$$X_t = \xi_0 + \xi_1 \cdot g_t + \xi_2 P_t + \xi_3 \sigma_t + \xi_4 P^C_t + \varepsilon_t \qquad \text{------ (1)}$$

where X_t denotes real exports from Korea to Japan; g_t the manufacturing production index of Japan; P_t the real bilateral exchange rate of the Korean won against the Japanese yen, reflecting price competitiveness; σ_t the volatility of the bilateral exchange rates of the

Korean won against the Japanese yen; P^c_t the real bilateral exchange rate of the Chinese renminbi against the Japanese yen, and ε_t a disturbance term. All variables are in natural logarithm form and the subscript t symbolizes time.

In this equation, g_t is used as a proxy for the level of economic activity in the importing country. It is expected that the higher the economic activity in the importing country, the higher the demand for exports. Therefore, the value for ξ_1 is expected to be positive. Since a higher real exchange rate implies a lower relative price, the value for ξ_2 is also expected to be positive.

Exchange rate volatility is measured by computing the quarterly standard deviations of monthly real bilateral exchange rates. According to Sercu and Uppal (2000, p. 68), "Exchange rate risk is measured using one of the following: the standard deviation of the level of the exchange rate…, the difference between actual spot rate and that predicted by the forward rate, or a time series model such as GARCH." In the case of Korea or other East Asian countries, because the forward market was not well developed, exchange rate risk in extant papers is measured by either standard deviation or GARCH.[2] In the case of Korea, papers in this area report that the exchange rate risk has significant negative impact whether the risk was measured by the standard deviation (Arize et al. (1999) and Baak et al. (2007)) or GARCH (Kim and Lee (1996)).

2.2. The error correction model

After observing the results of cointegration tests, the following dynamic error correction (EC) model was constructed and employed to see the short-term impacts of the explanatory variables on Korean exports:

$$\Delta X_t = \alpha + \lambda EC_{t-1} + \sum_{h=0}^{nx} \beta_h \Delta X_{t-h-1} + \sum_{h=0}^{np} \gamma_h \Delta P_{t-h} + \sum_{h=0}^{ng} \delta_h \Delta g_{t-h} + \sum_{h=0}^{ns} \eta_h \Delta \sigma_{t-h} + \sum_{h=0}^{nc} \pi_h \Delta P^c_{t-h} + u_t \quad \text{--(2)}$$

If the variables in equation (1) were not cointegrated, the error correction term, EC_{t-1}, was eliminated from equation (2). In addition, many estimation investigations were performed to find a parsimonious structure for equation (2). In other words, variables which were insignificant and did not generate, even though omitted, any noticeable difference in the estimation results were eliminated from equation (2).

[2] See Arize et al. (1999) and Baum et al. (2002) and their references.

2.3. The variables and data[3]

Real exports (X_t)

Real exports from Korea to Japan are defined as follows:

$$X_{ijt} = \ln\left(\frac{EX_{ijt}}{EXUV_{it}} \times 100\right)$$

where X_{ijt} denotes the log value of the real exports of country i to country j; EX_{ijt} is the monthly nominal exports of country i to country j; $EXUV_{it}$ denotes the export price index of country i.[4] Hereafter, i represents Korea and j represents Japan.

Industrial production index (g_{jt})

Industrial production indices are commonly used as a proxy for income in the literature, for example Baum, Caglayan, and Ozkan (2002). The variable g_{jt} is the natural logarithm of the industrial production index of the importing country j in time t.

Real bilateral exchange rate (P_{ijt})

The bilateral trade between two countries depends upon, among other factors, exchange rates and the relative price level of the two trading partners. Hence, real exchange rates are included in the export equations of this paper and are calculated as follows:

$$P_{ijt} = \ln\left(E_{ijt} \times \frac{CPI_{jt}}{CPI_{it}}\right)$$

where P_{ijt} symbolizes the real monthly exchange rate in natural logarithm scale; E_{ijt} is the nominal monthly exchange rate of the currency of country i against the currency of country j; CPI_{it} and CPI_{jt} denote the monthly consumer price index of the exporting country i and the importing country j, respectively.[5]

[3] In order to ensure consistency of data, variables, which were not seasonally-adjusted beforehand, were adjusted for seasonality prior to taking logarithms by use of the Census X12 method available in the software package EViews 5.

[4] In empirical tests not reported here, the export unit value index was used instead of the export price index. However, the test results were not responsive to this choice. Only marginal changes were observed.

[5] PPI can also be considered as a deflator. Because the monthly and quarterly PPI data are not available for China, PPI was not used in this paper. The computation of the Chinese CPI is explained in "Data sources".

Real exchange rate volatility (σ_{ijt})

The present study applies the standard deviation of exchange rates as the measure of exchange rate volatility.[6] Specifically, the real exchange rate volatility σ_{ijt} is defined as the natural logarithm of the quarterly standard deviation of monthly real exchange rates:

$$\sigma_{ijt} = \ln\left(\sqrt{\frac{1}{n-1}\sum_{k=1}^{n}\left(RER_{ijk} - \overline{RER_{ij}}\right)^2}\right),$$

where RER_{ijk} is the monthly real exchange rate, $\overline{RER_{ij}}$ the quarterly average of monthly real exchange rates, and k the index of the months in a quarter.

Data sources

The data spans the first quarter of 1986 to the fourth quarter of 2003. The consumer price indices (CPI) of Japan and Korea, and the export unit value indices of Korea were taken from the *International Financial Statistics (IFS)* of the International Monetary Fund (IMF), while the export price indices of Korea were obtained from the Bank of Korea.

In the case of China, consumer price indices are not reported. Instead, the annual growth rates of monthly indices from 1986 are reported in the *IFS*. The Chinese monthly consumer price indices were calculated using these growth rates and the consumer price indices for the 12 months December 2000 to November 2001.[7] Quarterly data were then calculated from these monthly data.

The data for exports from Korea to Japan were taken from the *Direction of Trade Statistics (DOTS)* of the IMF. The data on the industrial production index of Japan were obtained from the Ministry of Economy, Trade and Industry (METI) of Japan.

3. Empirical test results

3.1. Unit root tests

As preparation for cointegration tests, the presence of unit roots in the variables included in equation (1) was examined using the augmented Dickey-Fuller (ADF) test. Based on a visual examination of the time series, we allowed for a trend and an intercept in the auto-regression for the levels of exports and industrial production indices, and only an intercept for the levels of other variables and the first differences of all variables. The lengths of the lags included in the tests were determined by the Akaike information criterion.

ADF statistics for the levels of all the series, except for the volatility of the Korean exchange rates, are higher than the 5 percent critical values, and the ADF value for the level of the volatility of the Korean exchange rates is higher than the 1 percent critical value, implying the presence of unit roots. On the other hand, the statistics obtained from the first differences of the variables reject the null hypothesis of a unit root at the 5 percent

[6] See Côté (1994), Secru and Uppal (2000), and Baum et al. (2002).

[7] The Chinese consumer price indices from December 2000 to November 2001 were kindly provided by Yuqing Xing at the International University of Japan.

significance level. Tables 1-1 and 1-2 present the ADF test statistics for all five variables in equation (1).

Table 1-1 ADF Unit Root Test for Levels

Variable	Included observations after adjustments	Lags	ADF test statistic
X_t	69	2	-3.166
g_t	68	3	-3.147
P_t	68	3	-2.488
σ_t	64	7	-3.498
P^c_t	71	0	-2.560

Notes: 1) "Lags" denotes the included augmentation lags in the unit root test. 2) ADF is the augmented Dickey-Fuller test. 3) The McKinnon critical values for rejection of a hypothesis of a unit root at the 1, 5 and 10 percent levels are -4.097, -3.476 and -3.166, respectively. 4) The number of lags was determined by the Akaike criterion.

Table 1-2 ADF Unit Root Test for First Differences

Variable	Included observations after adjustments	Lags	ADF test statistic
ΔX_t	69	1	-4.019
Δg_t	68	2	-4.363
ΔP_t	67	3	-4.350
$\Delta \sigma_t$	62	8	-4.383
ΔP^c_t	70	0	-8.227

Notes: 1) The McKinnon critical values for rejection of a hypothesis of a unit root at the 1, 5 and 10 percent levels are -3.529, -2.904 and -2.590, respectively.
Refer also to the notes for Table 1-1

3.2. Cointegration tests

Johansen (1988,1991) cointegration tests were applied to test for the presence of a long-term equilibrium relationship among the variables in equation (1). We included an intercept and a trend in the cointegration equation with a view to reasonable test results. Considering the fact that we are dealing with quarterly data, the length of lags was determined to be 4. However, slight changes in the length of lags did not generate noticeable changes in the results.

Table 2 Johansen Cointegration Tests

Statistic	H_0: / H_A:	$r = 0$ / $r \geq 1$	$r \leq 1$ / $r \geq 2$	$r \leq 2$ / $r \geq 3$	$r \leq 3$ / $r = 4$	$r \leq 4$ / $r = 5$
Trace statistics		126.77**	66.08*	37.04	18.45	5.62
(p value)		0.000	0.032	0.171	0.315	0.510
Max-eigen statistics		60.69*	29.04	18.59	12.83	5.62
(p value)		0.000	0.114	0.334	0.342	0.510

Notes: 1) *r* denotes the number of cointegrating vectors. 2) The asterisks (*) and (**) indicate the rejection of the null hypothesis at the 5% and 1% significance levels, respectively.

The results of the cointegration tests are presented in Table 2, where *r* denotes the number of cointegrating vectors. Both the trace statistics and the maximum eigenvalue statistics strongly imply the presence of one cointegrating relationship for the five variables. The estimated coefficients for the long-term relationship are presented in Table 3.

Table 3 Estimates of the Cointegrating Vectors for Exports to Japan

	g_t	P_t	σ_t	P^c_t	Trend
Coefficient	2.443*	2.040*	-0.380*	-0.851*	0.006*
Standard error	0.525	0.358	0.051	0.111	0.002

Notes: The asterisk (*) indicates the rejection of the null hypothesis of zero coefficient at the 5% significance level.

The test results indicate a negative long-term relationship between Korean exports to Japan and the real exchange rate of the Chinese renminbi against the Japanese yen. That is, depreciation of the value of the Chinese renminbi has a negative impact on the volume of Korean exports to Japan. More specifically, a 1 percent increase in the exchange rate of the Chinese renminbi (that is, a 1 percent decrease in the value of the Chinese renminbi) turns out to decrease Korean exports by about 0.9 percent.

On the other hand, a 1 percent increase in the exchange rate of the Korean won (that is, a 1 percent decrease in the value of the Korean won) turns out to decrease Korean exports by about 2 percent. This implies that the impact of the Chinese renminbi on Korean exports is half of the impact of the Korean won.

The manufacturing production index of Japan and the volatility of Korean exchange rates turn out to have the expected impacts on Korean exports in the long term. The former has a positive impact, while the latter has a negative impact.

3.3. Error correction models

Since the cointegration tests in the previous section detected one long-term equilibrium relationship for each of the export equations, an error correction model was employed to observe the short-term dynamics of the export equation. The error correction term was computed using the cointegration equation reported in Table 3.

Table 4 Estimation Results for the Error Correction Model

Variables	Coefficient	Standard error
C	-0.755	0.419 *
EC_{t-1}	-0.071	0.039 *
ΔY_{t-2}	0.237	0.108 **
ΔY_{t-8}	-0.181	0.089 **
Δg_{t-1}	1.966	0.330 ***
Δg_{t-3}	-1.841	0.443 ***
Δg_{t-5}	0.929	0.370 **
ΔP_t	0.192	0.100*
ΔP_{t-1}	-0.246	0.096 **
ΔP_{t-5}	0.200	0.087 **
ΔP_{t-7}	0.208	0.080 *
ΔP_{t-8}	0.208	0.079 **
$\Delta \sigma_t$	-0.014	0.008
$\Delta \sigma_{t-1}$	0.036	0.010 ***
$\Delta \sigma_{t-2}$	0.017	0.009 *
ΔP^c_t	0.174	0.075 **
ΔP^c_{t-3}	0.162	0.076 **
R^2	0.739	
Adjusted R^2	0.649	

The estimated values of the error correction model are presented in Table 4. As can be seen from the table, the estimated coefficient value of the error correction term is negative and significant at the 10 percent significance level, confirming the presence of one long-term relationship among the variables involved. Other explanatory variables send differing messages. In the case of the Japanese industrial production index and Korean exchange rates, their overall impacts are generally as expected. However, the volatility of Korean exchange rates has an overall positive impact, which is inconsistent with its long-term impact.

In addition, the overall short-term impact of the Chinese renminbi against the Japanese yen is also different from what is implied by the long-term impact.

4. Conclusion

This paper analyzed whether, and to what extent, the value of the Chinese renminbi has significant impacts on Korean exports to Japan. In particular, the long-term impact of the Chinese exchange rate on Korean exports to Japan was measured by estimating a cointegrating vector of the Korean export function. In addition, its short-term impact was measured by employing an error correction model. The impacts of other variables, such as the exchange rate of the Korean won, the industrial production index of Japan, and the volatility of Korean exchange rates, were also measured by including them as explanatory variables in the cointegrating vector and in the error correction model.

The test results indicate a negative long-term relationship between Korean exports to Japan and the real exchange rate of the Chinese renminbi against the Japanese yen. That is, depreciation of the value of the Chinese renminbi has a negative impact on the volume of Korean exports to Japan. More specifically, a 1 percent increase in the exchange rate of the Chinese renminbi turns out to decrease Korean exports by about 0.9 percent.

On the other hand, a 1 percent increase in the exchange rate of the Korean won turns out to increase Korean exports by about 2 percent. This implies that the impact of the Chinese renminbi on Korean exports is half that of the Korean won.

The manufacturing production indices of Japan and the volatility of Korean exchange rates turned out to have the expected impacts on Korean exports in the long term. The former had a positive impact, while the latter had a negative impact.

In contrast, the estimation results of the error correction model show that the short-term impact of the Chinese renminbi was not clearly observed. However, the overall short-term impacts of other explanatory variables, except for exchange rate volatility, are, in general, consistent with the long-term impacts.

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References

Arize, A. C., T. Osang & D. J. Slottje (1999) Exchange-rate volatility in Latin America and its impact on foreign trade, Unpublished manuscript, Texas A&M University.

Arize, A. C., T. Osang & D. J. Slottje (2000) Exchange-rate volatility and foreign trade: evidence from thirteen LDC's, *Journal of Business and Economic Statistics*, vol. 18, no. 1, pp. 10-17.

Baak, S. J., A. Al-Mahmood & S. Vixathep (2007) Exchange rate volatility and exports from East Asian countries to Japan and the US, *Applied Economics*, vol. 39, pp. 947-959.

Baum, C. F., M. Caglayan & N. Ozkan (2002) Exchange rate effects on the volume of trade flows: an empirical analysis employing high-frequency data, Unpublished manuscript, Boston College.

Bhattacharya, A., S. Ghosh & W. J. Jansen (2001) Has the emergence of china hurt Asian exports? *Applied Economics Letters*, vol. 8, pp. 217-221.

Chang, G. & E. Parker (2004) The Chinese RMB issue in dynamic and global perspective, *China Economic Review*, vol. 15, pp. 323-324.

Chou, W. L. (2000) Exchange rate variability and China's exports. *Journal of Comparative Economics*, vol. 28, pp. 61-79.

Chowdhury, A. R. (1993) Does exchange rate volatility depress trade flows? Evidence from Error-Correction Models, *The Review of Economics and Statistics*, vol. 75, no. 4, pp. 700-706.

Côté, A. (1994) Exchange rate volatility and trade: a survey, Working Paper 94-5, Bank of Canada.

Funke, M. & J. Rahn (2005) Just how undervalued is the Chinese Renminbi? *World Economy*, vol. 28, no. 4, pp. 465-487.

Hassan, M. K. & D. R. Tufte (1998) Exchange rate volatility and aggregate export growth in Bangladesh, *Applied Economics*, vol. 30, pp. 189-201.

Johansen, S. (1988) Statistical analysis of cointegration vectors, *Journal of Economic Dynamics and Control*, vol.12, pp. 231-254.

Johansen, S. (1991) Estimation and hypothesis testing of cointegration vectors in Gaussian Vector Autoregressive Models, *Econometrica*, vol. 59, pp. 1551-1580.

Kim, K. & W. Lee (1996) "The impact of Korea's exchange rate volatility on Korean Trade," *Asian Economic Journal*, vol. 10, no. 1, pp. 45-60.

Secru, P. & R. Uppal (2000) *Exchange Rate Volatility, Trade, Capital Flows under Alternative Exchange Rate Regimes*. Cambridge: Cambridge University Press. Chapter 6.

Tang, T. K. (2003) An empirical analysis of China's aggregate import demand function, *China Economic Review*, vol. 14, pp. 142-163.

Wang, S., Z. Wang, & J. Zhang (2003) Stress testing analysis of the effects of Japanese yen's depreciation on Chinese exports, *Applied Economics Letters*, vol. 10, pp. 185-190.

Zhang, Z. (2001) China's exchange rate reform and exports. *Economics of Planning*, vol. 34, pp.89-112.