High-Tech Industries Development and Its Impact on Energy Use and the Environment of Taiwan

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ABSTRACT

It is widely believed that the promotion and development of high-tech industries by the Taiwanese government in the past two decades has been one of the most important factors that maintain Taiwan with an above-average rate of economic growth. However, investment on R&D activities and consequently the development of high-tech industries is usually inevitably accompanied by a promotion of energy consumption, and hence the deterioration of the environment. Additionally, it is not always guaranteed that investing in high-tech industries will certainly improve the performance of the economy. This paper explores energy use, environmental performance, resource allocation, as well as economic performance issues of the Taiwanese economy resulting from an additional high-tech R&D investment through a multi-stage investigation process. In the first stage, we estimate a set of cost functions to examine the contributions and channels of R&D investment and inter-industry R&D spillovers for some major manufacturing industries. It is interesting to see how and to what extent high-tech R&D investment have contributed to the reduction in cost for manufacturing industries. For the purpose of finding out how a sector is affected by other sectors' R&D activity, inter-sectoral technology flow matrices for several years are also established to figure out which sectors are the most important sources of R&D spillover for a specific sector. In the second stage, the estimation results from the previous stage are fitted into a multi-sector computable general equilibrium (CGE) model to examine the effects of high-tech R&D investment and spillovers on energy use, environmental performance, resource allocation and economic performance of the Taiwanese economy.

I. Introduction

Technological progress has been widely considered as one of the most important sources of economic growth. R&D investment and R&D spillovers, on the other hand,

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have been demonstrated to be the major driving forces of productivity growth and cost reduction for many industries (for example, Griliches, 1992; Bernstein, 1997; Ogagiri and Kinukawa, 1997; Mamuneas, 1999). The rapid growth of Taiwan's high-tech industries in the last fifteen years basically supports this observation. It is believed that the promotion and development of high-tech industries by the Taiwanese government in the past two decades has been one of the most important factors that have significantly transformed the structure of industry and maintained Taiwan with an above-average rate of economic growth.

However, investment on R&D activities and consequently the development of high-tech industries might inevitably accompanied by a promotion of energy consumption, and hence the deterioration of the environment. Additionally, it is not always guaranteed that investing in high-tech industries will certainly improve the performance of the economy. For instance, Berndt and Morrison (1995) found limited evidence of a positive relationship between profitability and the share of high-tech capital in the total physical capital stock. It might be true that R&D investment and the associated spillover effects can contribute to the growth of productivity for industries. But investing R&D in specific industries may also crowd out other industries' investment and weaken their competitive edge over attracting productive resources. Therefore, targeting on high-tech industries might eventually result in the reallocation of productive resources among sectors and, hence, affect the performance, energy consumption, and the environment of the whole economy.

This paper explores energy use, environmental performance, resource allocation, as well as economic performance issues of the Taiwanese economy resulting from an additional high-tech R&D investment through a multi-stage investigation process. In the first stage, we examine the inter-relationship between energy use, environmental performance, high-tech industries development and economic performance in Taiwan over the past two decades. In the second stage, we estimate a set of cost functions to examine the contributions and channels of R&D investment and inter-industry R&D spillovers for some major manufacturing industries. It is interesting to see how and to what extent high-tech R&D investment have contributed to the reduction in cost for

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developed by the author (Lin, 1996 & 1997) for the Council for Economic Planning and Development.

manufacturing industries. For the purpose of finding out how a sector is affected by other sectors' R&D activity, inter-sectoral technology flow matrices for several years are also established to figure out which sectors are the most important sources of R&D spillover for a specific sector. In the last stage, the estimation results from the previous stage are fitted into a multi-sector computable general equilibrium (CGE) model to examine the effects of high-tech R&D investment and spillovers on energy use, environmental performance, resource allocation and economic performance of the Taiwanese economy.

The organization of the paper is as follows. Section 2 explains the issues related to production and the associated spillover effects, the measurement of industry R&D capital stock and R&D spillover matrix, the estimation model, and the estimation results. The effects and channels of interindustry R&D spillovers on some major manufacturing sectors are also discussed in this section. Section 3 describes the main feature of the CGE model and its extensions. In section 4, we show the simulation results from CGE model analysis. We focus on how an additional R&D investment of one or some specific high-tech industries could effect the production and trade of other industries, the resource reallocation among sectors, the effect of energy use and the environment, as well as the performance of the whole economy. Section 5 gives the summary and conclusions of the paper.

II. Issues Related to Production and Spillover

1. Measurement of R&D Capital Stock and R&D Spillover

Following Bernstein and Nadiri (1988), Bernstein (1989, 1997), and Odigiri and Kinukawa (1997), we set up a cost function which includes R&D capital stock, output level, and prices of conventional factors of production such as physical capital and labor. R&D capital stock is a measure of technological state of the industry at a certain point in time. It may accumulate and depreciate over time. It consists of two separate parts. One is the level of technology accumulated by the industry through its own R&D investment and activities in the past; and the other is the level of technology the industry received from other industries' R&D activities. From the economic point of view, it is an indicator of the future potential of the industry to develop new products or processes. The estimation of R&D capital involves the specification of the lag structure and the determination of the rate of obsolescence of R&D capital. A detailed explanation of the estimation method can be found in Griliches (1980) and Nadiri (1980). We estimate the R&D capital stocks of major manufacturing industries for years 1982-1995 using the perpetual method as that proposed by Goto and Suzuki (1989). The R&D capital stocks for some major manufacturing sectors are shown in Table 1.

[insert Table 1 here]

An industry's R&D investment is not only an important factor for acquiring scientific and technological knowledge that can significantly improve the production of that industry, an industry engaging in R&D activities will also generate benefit that diffuses to all other industries of the economy through interindustry relations. The industry that receive benefit from other industries, on the other hand, will result in growth in total factor productivity. Due to the interindustry repercussion of R&D investment and its resultant new scientific and technological knowledge, the economic welfare will be improved further.

The spillover of R&D benefit can be in two forms. In the case of product innovation, the benefit of R&D efforts embodies in the goods produced by sectors conducting R&D activity. Those goods are then used by other sectors as intermediate inputs, as investment goods, or as final consumption goods, which can result in the growth in total factor productivity of the buying sectors. In the case of process innovation, the gain in efficiency will result in lower price and/or higher quality goods, which may enhance the cost position or performance of the purchasing sectors.

The estimation of the flow of R&D benefit embodied in intermediate goods from one sector to another can be obtained through the construction of technology flow matrix as that suggested by Schmookler (1966) and empirically estimated by

Sveikauskas (1981), Terleckyj (1974, 1982), and Scherer (1982). Using an input-output transactions flow table, the element of the technology flow matrix, a_{ij}, is constructed as a ratio of the sales of the goods produced by sector i to sector j to the output of sector i. And the flow of benefit embodied in intermediate goods from sector i to sector j, r_{ij}, can be estimated as follows:

$$r_{ij} = a_{ij}*E_i \qquad (1)$$

where Ei is the R&D expenditure of sector i.

Similar to intermediate goods, the flow of R&D benefit embodied in investment goods can be estimated by using the fixed capital formation matrix, b_{ij}.[1] The flow of R&D benefit embodied in investment goods from sector i to sector j, r'_{ij}, is estimated as follows:

$$r'_{ij} = b_{ij}*E_i. \qquad (2)$$

Taking (1) and (2) together, we can define that the total inflow of R&D benefit embodied in intermediate and investment goods to the sector j, I_j, takes the following form:

$$I_j = \sum_i r_{ij} + \sum_i r'_{ij}. \qquad (3)$$

Similarly, the total spillover of R&D benefit embodied in intermediate and investment goods from sector i, S_i, is defined as follows:

$$S_i = \sum_j r_{ij} + \sum_j r'_{ij}. \qquad (4)$$

[1] The capital formation matrix can be expressed as the product of two related matrices, a transactions flow matrix and a capital flow matrix. Please refer to Goto and Suzuki (1989) for details.

The above calculations for total inflow and spillover of R&D benefit, however, do not take into account the inflow of technology benefit from imports (i.e., the R&D benefit from foreign goods) as well as the spillover of benefit to the final consumption and exports. In order to more accurately estimate the inflow and spillover of R&D benefit, these factors should also be taken into considerations.[2] The international R&D spillovers through exports and imports has been empirically tested by several researchers, and their results do support the existence of trade-induced learning by doing effects.[3] For Taiwan, Chuang (1994) has demonstrated that trade-induced learning, which represents the change in technology or the growth in total factor productivity, has been one of the major factors contributing to the growth of output over the past two decades.

We estimated the R&D spillover matrix for years 1991 to 1994 based upon the methodology mentioned above. The 1991 and 1992 matrices are shown in Tables 2 and 3, respectively. Sector names corresponding to the sector numbers in these tables are shown separately in Table 4.

[insert Tables 2, 3, 4 here]

2. Sources of Interindustry R&D Spillover

From the R&D spillover matrices, we can figure out over years how each sector receive R&D spillovers from other sectors, as well as how each sector spill its R&D over to other sectors in the economy. Table 5 shows the R&D flow to some selected manufacturing sectors in 1991.

[insert Table 5 here]

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[2] In reality, it is very difficult to estimate the inflow of technology benefit from imports, since we do not know exactly where these imports from and, even we know the origins, what the true transactions flow and capital formation matrices are.

[3] See, for example, Coe and Helpman (1993).

From Table 5 we can find that electrical machinery, machinery, and chemical materials are the largest sources of R&D flow to most of the industries.

3. Estimation Model and Estimation Results

The functional form we used for cost functions is Generalized Leontief (GL) flexible functional form, which has the following form:

$$C = Y\{\sum_i \sum_j \alpha_{ij} \cdot (P_i \cdot P_j)^{1/2} + \sum_i \delta_i \cdot P_i \cdot RD + \sum_i \sum_l \gamma_l \cdot P_i \cdot RD_l\} \qquad (5)$$

with $\alpha_{ij} = \alpha_{ji}$,

where C is total cost, Y is output level, P is price of conventional input, RD is R&D capital stock of the industry, RD_l is R&D capital stock of industry l, α, δ, γ are parameters, and j,i = L, M, K.

The system of factor demand equations can be derived by using Shephard's lemma, which takes the first partial derivatives of (5) with respect to factor prices. The derived demand for factor j (Q_j) is thus:

$$Q_i = Y\{\sum_i \alpha_{ij} \cdot (P_i / P_j)^{1/2} + \sum_i \delta_i \cdot RD + \sum_l \gamma_l \cdot RD_l\} \qquad (6)$$

And the factor demand to output ratio equations used for estimation purposes are thus:

$$Q_i / Y = \{\sum_i \alpha_{ij} \cdot (P_i / P_j)^{1/2} + \sum_i \delta_i \cdot RD + \sum_l \gamma_l \cdot RD_l\} + u_i \qquad (7)$$

The system of equations (7) are estimated jointly by means of Iterative seemingly unrelated regression (ISUR), using the data of 1981-1990 for most manufacturing sectors. The estimation results for chemical products, electrical machinery, and transportation machinery sectors are presented in Table 6.

[insert Table 6 here]

From Table 6, we can find that the major R&D spillover-source industries for chemical products are chemical materials and general machinery; and the major source industries for electrical machinery are artificial fibers and metal products; while the main source industry for transportation machinery is the electrical machinery sector.

The results from the estimation of industries' cost functions will then be fitted into a CGE model to examine the effects of an additional R&D investment by one or some of the high-tech industries on all other industries in the economy, as well as on the macroeconomic variables of the economy.

III. The CGE Model and Its Extensions

The CGE model used in this study for performing simulations is a revision of the CGE model developed by Lin (1996). A summary description of the model is presented as follows.

Production

Domestic producers, being profit-maximizers, produce goods and services using two primary factors, labor and capital, and intermediate goods as inputs. Intermediate goods are either produced domestically or imported, and are assumed to be qualitatively different (the Armington assumption). The intermediate sectors of the economy are divided into an aggregate energy sector (E) composed of several energy sub-sectors and other intermediate sectors. The utilization of inputs for the production of goods and services follows a two-stage decision process. As such, the production function has two parts -- one is for energy aggregate and primary inputs, which are variable in composition, and the other is for other intermediate sectors, which are characterized by fixed input-output coefficients. The output markets are perfectly competitive, with producers' equilibria occurring at the points where output prices equal their unit costs.

To account for inter-fuel substitution, a "two-tier" specification is used for the cost functions. This reflects a two-stage sequential optimization decision for producers. The energy aggregate with a flexible functional form is also specified. Underlying this formulation is the assumption that labor, capital, and the energy aggregate are homothetically weakly separable.

For the current application, similar to the cost function used for estimation purposes, the Generalized Leontief (GL) functional form is used for all the flexible cost functions. This gives

$$C = Y\{\sum_i \sum_j \alpha_{ij} \cdot (P_i \cdot P_j)^{1/2} + \sum_i \delta_i \cdot P_i \cdot RD + \sum_i \sum_l \gamma_l \cdot P_i \cdot RD_l\} \qquad (7)$$

with $\alpha_{ji} = \alpha_{ij}$ j, i = L,K,E

The above specificstion indicates that the industry's own R&D capital, as well as the R&D capital of major spillover-source industries will have effects on the production cost of the industry.

Note that in the previous section we specify the cost function with three inputs, labor, capital, and material, with energy input being a part of the material input. Here we specify in the CGE model the cost function with also three inputs. but instead of including an aggregate material sector in the function, we include in the function an aggregate energy sector.

Domestic producers produce goods both for the domestic market and for export, and the domestically produced goods (Y) are transformed into either exports (XE) or domestic-market goods (XS), through a constant elasticity of transformation (CET) function:

$$Y = AT\left[\gamma XE^{\delta} + (1-\gamma)XS^{\delta}\right]^{1/\delta} \quad (8)$$

where γ is the share weight, δ is the derived elasticity of transformation between exports and domestic-market goods, and AT is a shift parameter.

Domestically used goods are treated as composite goods (XC) comprised of domestically produced (XS) and imported goods (XM), with the goods from these two sources being less than perfect substitutes. According to this, domestically used composite goods are constant-elasticity-of-substitution (CES) aggregates of imports and domestic-market goods.

By using Shephard's lemma one can derive the demand for labor, capital, and the aggregate quantity of energy from equation (7). For example, for energy:

$$E = Y\left[\alpha_{jj} + \sum_{i}\alpha_{ji}(P_i / P_j)^{1/2}\right] \quad (9)$$

with j = E and i = K,L

When labor and capital are both assumed to be perfectly mobile, full employment is reached with economy-wide average prices of labor and capital services (WL and WK, respectively) adjusting accordingly. By introducing differential wage rates and prices of capital services, one has:

$$P_L = WL \cdot fds_L \quad (10)$$

$$P_K = WK \cdot fds_K \quad (11)$$

where fds is the factor proportionality, which determines the ratios of sector-specific wage rates and capital service prices to their economy-wide average counterparts.

Consumption

Households are assumed to be the only private consumers of the domestic use composite goods (XC). Aggregate households maximize a simplified Stone-Geary utility function leading to a system of domestic consumption functions known as the linear expenditure system (LES), which has the following form:

$$P \cdot CD = \sum_h d_h Y_h (1 - s_h)(1 - t_h) \qquad (12)$$

where

Yh	=	income received by household h
CD	=	consumer demand for good i
dh	=	share of disposable income spent on the good by household h
sh	=	savings rate for household h
th	=	income tax rate for household h

In the model, the aggregate of households can be disaggregated into several household groups either by income class or by regional group, depending on the simulation needs. As such, payments to factors of production and transfers are distributed to each of the household groups, and each household group then spends its after-tax income according to its own expenditure function, as shown in equation (12).

Government demand for composite good i is defined as the value share of good i in the exogenously-given aggregate real government spending on goods and services. In addition to fixed investment, gross private domestic investment also includes additions to stocks. Stocks are assumed to be kept at some proportion of the domestic output.

The modeling framework is general enough to incorporate several alternative views of equilibrium (for instance, classical and Keynesian). In addition, other components of the flow-of-funds account, such as the current account balance and government deficit, are considered in conjunction with the above for policy analysis purposes.

The basic data set for the study is a social accounting matrix (SAM) of the Taiwan economy for 1991. In addition to providing the basic data set for model calibration, this SAM also provides initial values for endogenous variables and levels for exogenous variables. In this study there are 23 production sectors, including 10 high-tech sectors. The definition of sectors is shown in Table 7.

[insert Table 7 here]

As shown in Table 7, the model includes several energy-related sectors, which have facilitated us with the ability of dealing with simulations related to energy use issues. In addition to the basic model described above, we also extend the model to include some elements for handling the effects of environment due to the change in R&D activities in some high-tech industries. Moreover, the benchmark models have also been calibrated to both 1991 and 1999 years. This has made a comparison of the economic and environmental effects between the two years possible.

IV. Simulation Results

The simulation results are divided into two parts. The first part includes two sets of simulations performed using the basic CGE model for 1991. The first set of simulations simulates the case of increasing R&D capital stock (which is accumulated from R&D investment) by 5%. We perform this analysis by increasing the R&D capital of the high-tech industries one at a time, and the results are presented in Tables 8 and 9. Table 8 shows the effects on macroeconomic variables such as real GDP, exports and imports. The results indicate that increasing R&D investment for a specific high-tech industry, without taking into account the increase in consumption and the crowding out of other investment, the performance of the whole economy in most cases is worse than without increasing. For example, when information equipment industry increases its R&D investment by 5%, the real GDP will decrease by 0.059%. This result might be attributed to the fact that, with the total labor and capital stocks in the economy are fixed, the industry with a better cost position due to some additional R&D investment will expand its production which, in turn, will attract more productive resources move to the industry. This will then reduce the stocks of resources shared by other industries, and hence result in the decline in real GDP.

[insert Tbale 8 here]

The sectoral results shown in Table 9 reveal that not all industries increasing R&D investment will lead to an increase in their output. This is because although increase in R&D investment can result in the reduction in production cost, the resultant changes in relative prices in intermediate goods and in factors of production, will generate substitution effects among intermediate and among primary inputs in an industry. And this will lead to further rounds of adjustments that might eventually cause the industry's output to decline.

[insert Table 9 here]

The second set of simulations simulates the increase in R&D capital for a specific high-tech industry by NT$ 50 million. This amount of increase is in general less than the first set of simulations. As such, the magnitudes of change in variables are smaller. The results are shown in Tables 10 and 11.

[insert Tables 10, 11 here]

The above simulation results indicate that neither the economy nor the specific industry will always be better off by simply increasing the R&D investment for the specific industry. The effects of resource reallocation and relative price changes resulting from targeting on one or some of the industries should be taken into consideration in forming the policies.

The major simulation results derived from the extended models are presented in

Tables 12 and 13. We have so far simulated an imposition of carbon tax on energy use for both 1991 and 1999; as well as for the short run and the long run.

Table 12 Long-run Results

	1991 (1)	1999 (2)	(2)/(1)
EXR	-0.443	-1.015	2.289
Imports	-1.082	-2.056	1.899
Investment	-3.886	-6.617	1.702
Real GDP	-1.190	-2.309	1.939
Exports	-1.002	-2.014	2.009
Welfare	-0.407	-1.069	2.626

Table 13 Short-run Results

	1991 (1)	1999 (2)	(2)/(1)
EXR	-0.096	0.143	-1.493
Imports	-0.311	-0.107	0.344
Investment	-1.160	0.617	-0.532
Real GDP	-0.433	-0.033	0.076
Exports	-0.311	-0.127	0.409
Welfare	-0.250	-0.117	0.470

The results from Tables 12 and 13 indicate that, comparing 1991 and 1999, in the short run, the imposition of a carbon tax will have greater impact on the economy for 1991. However, in the long run, the impact has been reversed, i.e., year 1999 will received greater impacts due to the same environmental policy. The results for energy use and the environment are still under revision. As such, relevant policy implications with respect to high-tech industries development and environmental protection shall be resulted in a latter time.

V. Concluding Remarks

R&D investment and R&D spillovers have been demonstrated to be the major driving forces of productivity growth and cost reduction for many industries. However, investment in high-tech industries may or may not improve the performance of the economy, since investing R&D in specific industries may crowd out other industries' from attracting productive resources and may result in the changes in relative prices of factors. As such, targeting on high-tech industries might eventually result in the reallocation of productive resources possibly worsen the performance of the whole economy.

In this paper we intend to explore resource allocation, energy use, environmental and economic performance issues of the Taiwanese economy resulting from an additional high-tech R&D investment through a two-stage investigation process. In the first stage, we estimate a set of cost functions to examine the contributions and channels of R&D investment and interindustry R&D spillovers for some major manufacturing industries. In the second stage, the estimation results are fitted into a multi-sector computable general equilibrium (CGE) model to examine the effects of high-tech R&D investment and spillovers on resource allocation and economic performance of the economy. The simulation results so far indicate that with total labor and capital stocks kept fixed, increasing R&D investment for specific industry will not necessarily lead to an increase in output for the industry, as well as an increase in real GDP for the whole economy.

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Table 4 Sector Definition of R&D Spillover Matrix

Sector number	Sector Name
1	Primary Industry
2	Food Processing
3	Beverage and Tobacco
4	Textile Industry
5	Wearing Apparel
6	Wood and Bamboo Products
7	Paper and Paper Products
8	Chemical Materials
9	Artificial Fibers
10	Chemical Products
11	Petroleum Refining
12	Non-metallic Mineral Products
13	Basic Metals
14	Metal Products
15	Machinery
16	Electrical Machinery
17	Transportation Machinery
18	Misc. Industrial Products
19	Infrastructure Industry
20	Services

Table 5 Major Sources of R&D Flow to Selected Sectors, 1991

Sector No.	Sector	Sources 1	Sources 2	Sources 3	Total
8	Chemical Materials	Petrol. Refining 81 (21.7%)	Electr. Machinery 29 (7.8%)	Machinery 20 (5.3%)	374 (100%)
9	Artificial Fibers	Chemical Materials 440 (15.1%)	Chemical Products 148 (5.1%)	Electr. Machinery 97 (3.3%)	2914 (100%)
10	Chemical Products	Chemical Materials 109 (18.5%)	Artificial Fibers 96 (16.3%)	Textiles 33 (5.6%)	589 (100%)
13	Basic Metals	Machinery 96 (13.8%)	Petrol. Refining 83 (11.9%)	Electr. Machinery 23 (3.3%)	698 (100%)
14	Metal Products	Basic Metals 149 (23.1%)	Electr. Machinery 73 (11.3%)	Artificial Fibers 52 (8.1%)	645 (100%)
15	Machinery	Electr. Machinery 728 (61.4%)	Basic Metals 132 (11.1%)	Metal Products 47 (3.9%)	1186 (100%)
16	Electrical Machinery	Artificial Fibers 491 (3.1%)	Metal Products 173 (1.1%)	Machinery 130 (0.8%)	15635 (100%)
17	Transportation Machinery	Electr. Machinery 421 (18.3%)	Basic Metals 88 (3.8%)	Artificial Fibers 71 (3.1%)	2299 (100%)

Table 6 Estimation Results

Parameters	Chemical Products	Electrical Machinery	Transportation Machinery
α_{11}	40.35*	76.43*	-31.64
	(2.59)	(3.69)	(-0.49)
α_{12}	1.14*	-0.40	8.03*
	(2.27)	(-0.57)	(2.84)
α_{13}	-12.54	20.19*	-55.76*
	(-0.96)	(6.81)	(-4.75)
α_{22}	0.54*	0.57*	0.17
	(21.55)	(38.88)	(1.38)
α_{23}	1.51	0.14	3.46*
	(1.33)	(1.05)	(5.72)
α_{33}	470.27*	19.45*	28.19*
	(5.02)	(8.75)	(3.08)
δ_L	-0.0005	-0.00005*	-0.00006
	(-0.74)	(-3.25)	(-0.39)
δ_M	-0.00002*	-0.000003*	-0.000001
	(7.91)	(-7.08)	(-1.83)
δ_K	-0.008	-0.00001*	-0.0001*
	(1.68)	(-2.04)	(-3.12)
γ_1	-0.00001*	-0.000003*	-0.000003*
	(-3.17)	(-3.26)	(-3.66)
	Chemical Materials	Artificial Fibers	Elect. Machinery
γ_2	-0.00001*	-0.00001*	-0.00001
	(-4.18)	(5.87)	(-0.57)
	Machinery	Metal Products	Basic Metals
$\bar{R}^2$			
Labor	0.68	0.70	0.61
Material	0.83	0.83	0.30
Capital	0.26	0.65	0.83

Notes: Numbers in parenthesis are t statistics.

Table 7. Definitions of Sectors in CGE Model

Sector Number	Description
1	Agriculture, forestry, and fisheries
2	Coal mining and coal products
3	Crude petroleum and natural gas extraction
4	Other mining
5	Medical and health industry
6	Petroleum refining
7	Nonmetallic mineral products
8	Basic metal and products
9	General machinery
10	Pollution prevention equipment
11	Electrical machinery
12	Information industry
13	Consumer electronics
14	Communication equipment
15	Semiconductor industry
16	Transportation machinery
17	Other manufacturing
18	Precision machinery and automation
19	Construction
20	Electricity
21	Water and gas utility
22	Transportation and warehousing
23	Services

Table 8 Effects of Change in Industry R&D Capital on Macrovariables
(R&D Capital Increase by 5%)

Industry with an Increase in R&D K	Macrovariables (Δ%)		
	Real GDP	Exports	Imports
Information Industry	-0.059	2.024	0.193
Consumer Electronics	0.004	-0.124	0.004
Communication Equipment	-0.013	0.011	-0.093
Semiconductor Industry	-0.006	0.094	-0.020
Transportation Machinery	0.000	-0.001	0.001
Precision Machinery	-0.001	0.005	0.000

Table 9 Sectoral Results of Change in Industry R&D Capital
(R&D Capital Increase by 5%)

Industry with an Increase in R&D K	Δ% in Output	Top 3 Industries with an Increase in Output		
		1	2	3
Information Industry	19.94	Semiconductor 8.31	Con. Electron. 3.62	Electr. Mach. 2.23
Consumer Electronics	-4.16	Pollution Equip. 0.28	Medical Equip. 0.27	Precision Mach. 0.26
Communication Equipment	2.63	Electricity 0.62	Coal Mining 0.26	Oil Mining 0.17
Semiconductor Industry	2.75	Electr. Mach. 0.10	Other Manuf. 0.01	Electricity 0.003
Transportation Machinery	-0.001	Medical Equip. 0.04	Oil Mining 0.01	Other Mine 0.01
Precision Machinery	-0.34	Semiconductor 0.13	Information 0.04	Medical Equip. 0.04

Table 10　Effects of Change in Industry R&D Capital on Macrovariables
(R&D Capital Increase by NT$ 50 million)

Industry with an Increase in R&D K	Macrovariables (Δ%)		
	Real GDP	Exports	Imports
Information Industry	-0.005	0.173	0.018
Consumer Electronics	0.001	-0.030	0.002
Communication Equipment	-0.000	0.001	-0.004
Semiconductor Industry	-0.000	0.010	-0.001
Transportation Machinery	0.000	-0.001	0.001
Precision Machinery	-0.000	-0.000	0.001

Table 11　Sectoral Results of Change in Industry R&D Capital
(R&D Capital Increase by NT$ 50 million)

Industry with an Increase in R&D K	Δ% in Output	Top 3 Industries with an Increase in Output		
		1	2	3
Information Industry	1.73	Semiconductor 0.69	Con. Electron. 0.31	Electr. Mach. 0.19
Consumer Electronics	-0.99	Medical Equip. 0.09	Pollution Equip. 0.07	Precision Mach. 0.06
Communication Equipment	0.13	Electricity 0.03	Medical Equip. 0.02	Coal Mining 0.01
Semiconductor Industry	0.30	Medical Equip. 0.02	Electr. Mach. 0.01	Oil Mining 0.004
Transportation Machinery	-0.001	Medical Equip. 0.04	Oil Mining 0.01	Other Mine 0.01
Precision Machinery	-0.07	Medical Equip. 0.04	Oil Mining 0.01	Semiconductor 0.01