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CONTRIBUTION OF KNOWLEDGE-INTENSIVE SERVICES TO ECONOMIC GROWTH

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ABSTRACT

In today's economy, the service sectors comprise 65-75% of the economy in most advanced countries; however, fewer empirical and statistical studies have been performed with regard to the service sectors than manufacturing sectors to verify their impact on economic growth. In line with a recent trend in which services are becoming more knowledge-intensive, this paper focuses on Knowledge-intensive Service (KIS) activities, which produce and integrate existing service activities, and enhance knowledge production. The effect of KIS on macroeconomic indicators is examined in a Real Business Cycle (RBC) model with multiple regression analysis and simulation. According to these analyses, it is revealed that the trend of investment into KIS has a strong correlation with aggregate output and consumption, government expenditures, capital stock, and productivity, and that KIS output tends to grow in proportion to these macroeconomic trends. With further analysis, it is clarified that KIS activities contribute to capital deepening and productivity improvement. Therefore, it can be said that it is important to study KIS with regard to its impact on economic growth.

Key words: Knowledge-intensive Services (KIS), Labor-augmenting technology progress, Real Business Cycle model (RBC)

JEL Classification: L16, L86, and L89

CONTRIBUTION OF KNOWLEDGE-INTENSIVE SERVICES TO ECONOMIC GROWTH

1. Introduction

1.1. Economic growth and service sectors

In today's economy, the service sectors comprise 70-75% of the economy in most advanced countries, although fewer empirical and statistical studies have been performed with regard to the service sectors than manufacturing sectors. Various statistical issues need attention, one of which is how we measure real value added, and productivity of service sectors.

Service sectors are becoming more technology- and knowledge-intensive, as seen particularly in information technology (IT) services. As for the recent financial turmoil, it is often said that the development of technology has surpassed our ability to provide adequate governance and control over financial transactions. It is an on-going problem to measure the impact of these technologies and knowledge capital (tangibles and intangibles) used to provide such services. Input deflators and the unit of measurement for service output are still not defined in a consistent manner. Thus, the appropriate quantification of service value and the measurement of its effect on economic growth are historical questions which retain their importance in today's economy. One factor making the study of the service industry difficult is that the performance of each service sector varies widely. The macroeconomic indicators i.e. output quantity, price deflator, productivity, and capital accumulation exhibit significant variations across sectors (OECD, 1996). In addition, the methods of research on service sectors are not well understood.

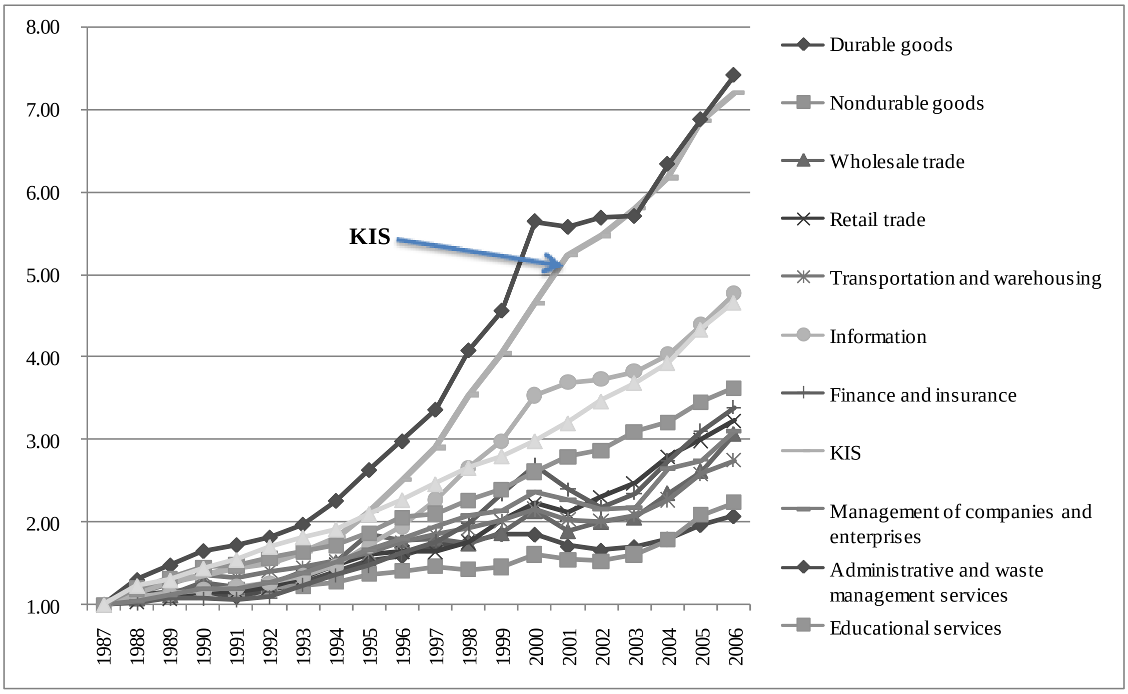
1.2. Knowledge-intensive Services (KIS)

One of the areas that have not been studied in past research is the consideration of Knowledge-intensive Services (KIS) in economic growth models. OECD has published a report on KIS (OECD, 2006). According to this KIS are defined as 'the production or integration of service activities, undertaken by firms and public sectors in the context of manufacturing or services, in combination with manufactured outputs or as stand-alone services' (p.7). KIS play a role to strengthen knowledge production activities not only in service sectors but also in manufacturing sectors. KIS are a type of service to be consumed as final output but also influence the performance of other organizations and value chains beyond sectors. Thus, it is considered that

KIS can be an important contributor to economic growth as one of the fastest growing sectors among the other service sectors (See Figure 1).

In addition, KIS contribute directly to some types of technological innovation and advancement. KIS include research and development (R&D), management consulting, information and communications services, human resource management and employment services, legal services (including those related to intellectual property rights), accounting, financing, and marketing-related service activities (p.7). These services are, as they are referred to, knowledge-intensive. Some of these services, such as financial services and information services, are also technology intensive. In other words, they are relatively labor intensive generated and delivered by employees with high levels of education and specialized expertise, knowledge and skills without using production equipment or other types of plant-specific tangible capital. The knowledge capital pertaining to such workers can be firm-specific intangibles. Figure 1 shows the relative increase of KIS in the total investment into intermediaries in the United States.

Figure-1: Growth of Investment into KIS and Other Intermediary Investment



Source: U.S. BEA (Data: 1986=100)

To narrow down the scope of research on the service industry and to incorporate the abovementioned overview on KIS, this paper examines the effect of KIS on macro economy in order to verify how KIS impact economic growth, by using correlation, multiple regression analysis and simulation.

2. Theory

2.1. Overview

In economic growth models, KIS can be considered as 'intermediaries' or support services (Hall, 1991). Theoretically it is explained how KIS interlink industries with innovative activities, and achieve the maximum rate of knowledge production. This paper uses a standard Real Business Cycle (RBC) model to capture movements in Total Factor Productivity (TFP), and other macroeconomic indicators in relation to the effect of KIS.

After Solow provided a fundamental theory for productivity measurement, Hall modified the theory by adding materials and intermediate products as inputs in addition to labor and capital, and argued that under competition and constant returns to scale, the Solow residual is uncorrelated with all variables for TFP (Gali, 1999). He showed that aggregate demand and the utilization rate of capital and labor also cause TFP fluctuations. Gali (1999) and many others examined technology shocks and their relationship to short-term effects. Fisher (2006) studied investment-specific changes, which affects labor productivity in the long run, the real price of investment goods, and investment goods prices. Hayashi and Prescott (2002) examined TFP as exogenous for Japanese economy. Basu, Fernald, and Kimball (2006) and Miyagawa, Sakuragawa and Takizawa (2006) incorporated a method to subtract the utilization rate of capital and labor, scale factors, and labor hoarding to examine pure technological shock.

This paper is based on Hayashi and Prescott (2002), and studied KIS from macroeconomic perspectives, which are modified to align Bureau of Economic Analysis (BEA) data and U.S. Census data following McGrattan and Prescott (2008).

2.2. Growth Model

1) Technology

The production function, Y, for industry i at time t is written in:

$$Y_{i,t} = A_t \cdot K_{i,t}^{\theta} \cdot L_i^{1-\theta} \quad (0<\theta<1) \tag{1}$$

where productivity is A, capital, K, and labor input, L. Labor input is $L = (hE)$, in which h is hours per employee and E is employment. Therefore, it is rewritten as follows:

$$Y_{i,t} = A_t \cdot K_{i,t}^{\theta} \cdot (hE)_{i,t}^{1-\theta}. \tag{2}$$

In this case, A is labor-augmenting technological progress. The capital stock for the next period is given by:

$$K_{t+1} = (1-\delta)K_t + X_t. \tag{3}$$

X is investment in intermediaries. K is the sum of capital stock. δ is depreciation rate, which explained in detail in Table B in the *Appendix*. Investment into intermediaries, X, are a composite of KIS, and other types of intermediaries. Therefore, X is derived from:

$$X = f(X_T, \varepsilon), \tag{4}$$

in which X_t is a composite index of energy, materials, purchased services less KIS based on the KLEMS (K-capital, L-labor, E-energy, M-materials, and S-purchased services) model of BEA (U.S. Census Bureau, 2003) and Strassner, Medeiros, and Smith (2005). ε is the investment into KIS as intermediary. KIS include scientific R&D services and organizational structure management (i.e. consulting, finance) etc. as defined in detail in the *Appendix*. The maximum present value is equal to after-tax profits less net investment in capital, which is obtained from:

$$P_{i,t} = (1-\tau_{i,t})(Y_{i,t} - W_{i,t}E_{i,t} - \delta_{i,t}K_{T,i,t} - X_{i,t}) - K_{T,i,t+1} + K_{T,i,t}. \tag{5}$$

Taxable profits are equal to sales less expenses, which are wage payments, tangible depreciation, and expensed investments on intermediaries. K_T denotes capital stock for tangibles since depreciation rates are not usually applied to intangibles or knowledge capital. $\tau_{i,t}$ is business tax rate. $x^{\theta/(1-\theta)}\mathrm{x}^{\theta/(1-\theta)}$ is the capital intensity factor ($x \equiv K/Y$) (Prescott and McGrattan, 2008).

2) Household

The household utility function is:

$$\max_{\{c_t K_{t+1}\}} \sum_{t=0}^{\infty} \beta N_t [\log c_t], \tag{6}$$

in which c_t is per member consumption *($c_t \equiv C_t/N_t$)* at time *t*. β is as defined in the *Parameters* section in the *Appendix*. Hours per employee is denoted as h, and working-age population, N. e is the ratio of aggregate employment to the working-age population, N (E/N). Then, marginal utility of household is derived from:

$$\frac{C_{t+1}}{C_t} = \beta[1 + (1-\tau_K)(r_{t+1} - \delta)]. \tag{7}$$

The household tax rate is lump-sum taxes (π), except for the tax on capital income at rate τ_K. r_t is the rental rate of capital. The budget constraint of the household is:

$$C_t \prec \omega_t h_t E_t + r_t K_t - \tau_K (r_t - \delta) K_t - \pi_t I_t - X_t \tag{8}$$

where I is personal income. ω_t represents wage rate subject to the marginal productivity condition for labor:

$$\omega_t = (1-\theta)A_t K_t^{\theta}(hE)_t^{-\theta}. \tag{9}$$

3) Government

Aggregate output, Y_t, consists of consumption, C_t, government expenditures, G_t, and investment, X_t. Investment refers to the aggregate of domestic private investment and the current account (CA) surplus:

$$Y_t = C_t + X_t + G_t + CA_t. \tag{10}$$

Government taxes personal income at rate π. As is mentioned, tax on capital gain is at rate τ_K. For corporate profit, the tax rate is set to τ_i, as in the *Parameters* section in the *Appendix*. As for the trends of some important variables, please refer to the following set of figures

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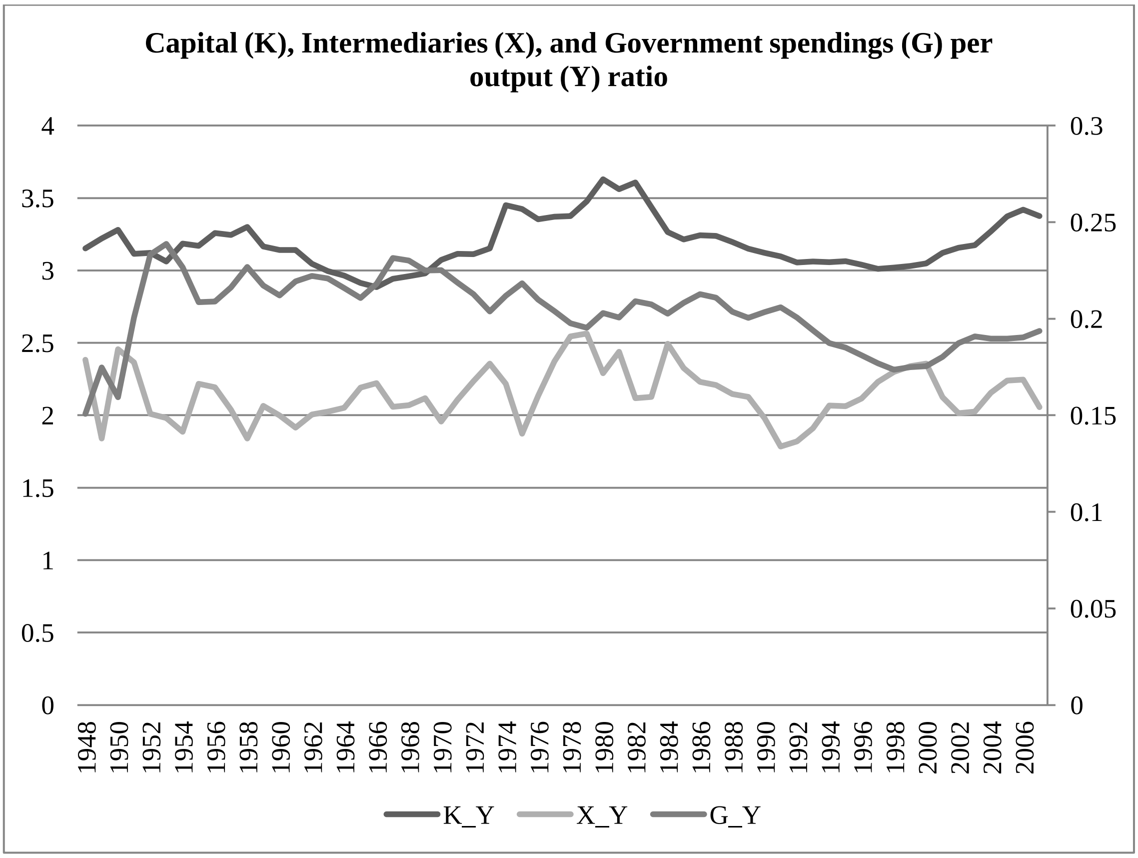
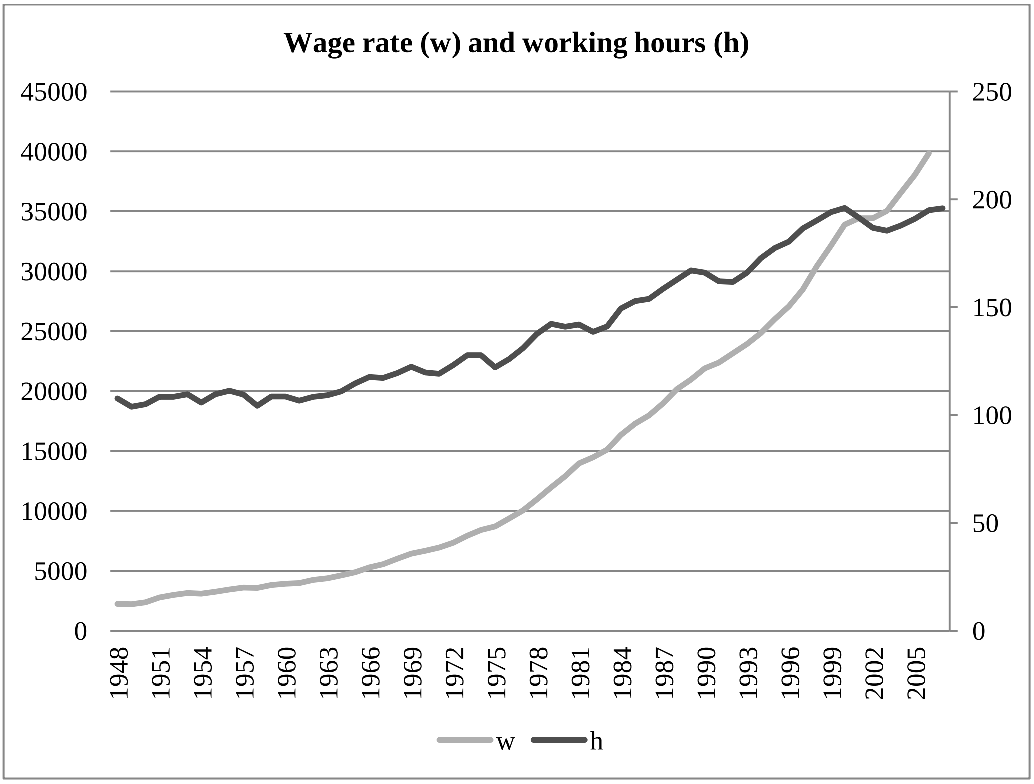
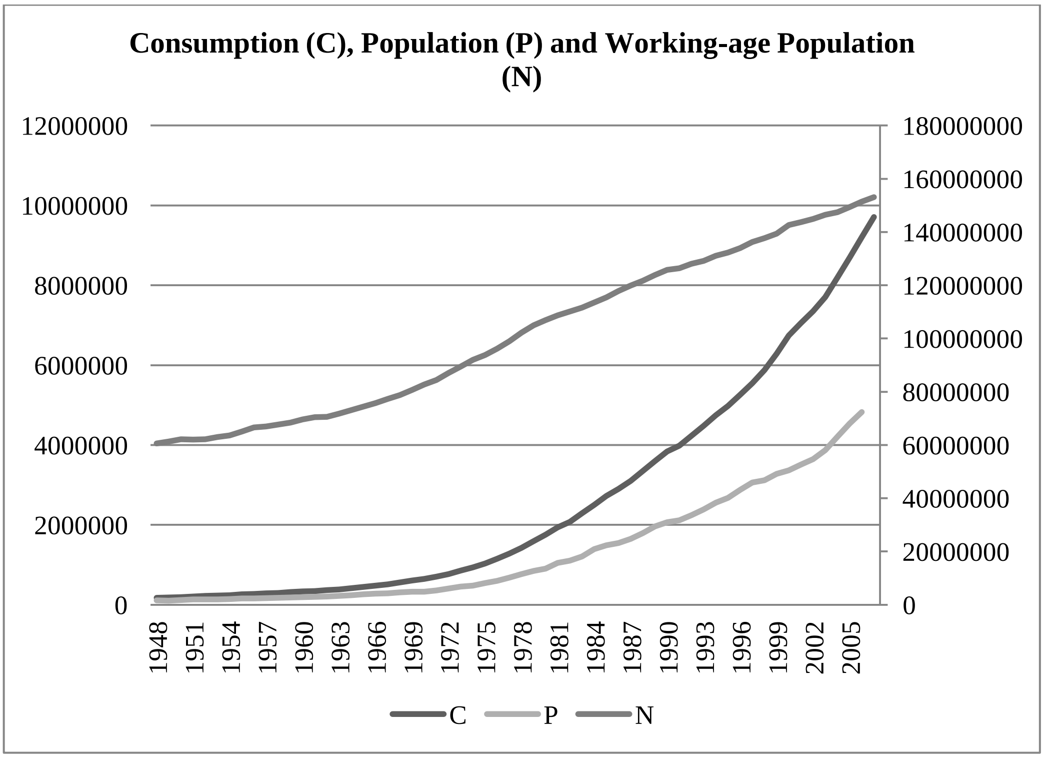
Figure 2: Trends of Major Variables



Note: K_Y corresponds to the left axis. X_Y and G_Y are on the right axis.



Note: Hours worked is scaled to the right axis. Unit: w (million), and h (hours/month)



Note: Working-age population is referred to the right axis.
Unit: C (million), P (million), and N (Thousand)

2.3. Correlation and Regression Analysis

Based on the models defined in the previous section, data is prepared as summarized in Table 3. Analyses are performed to clarify correlations between the investment in KIS (ε) and the other variables.

The following equations are based on Basu et al. (2006) and used for detrending variables by defining as follows:

$$\tilde{k}_t \equiv \frac{K_t}{A_t^{\frac{1}{1-\theta}} N_t},\ \tilde{c}_t \equiv \frac{C_t}{A_t^{\frac{1}{1-\theta}} N_t},\ y_t \equiv \frac{Y_t}{A_t^{\frac{1}{1-\theta}} N_t},\ \gamma_t \equiv \frac{A_{t+1}^{\frac{1}{1-\theta}}}{A_t^{\frac{1}{1-\theta}}},\ \psi_t \equiv \frac{G_t}{Y_t},\ n_t \equiv \frac{N_{t+1}}{N_t},\ x = \frac{\frac{\frac{\gamma}{\beta}-1}{1-\tau}+\delta}{\theta}^{\frac{1}{\theta-1}} \tag{11}$$

Cumulative periodogram white-noise test is applied to both intermediaries (X_T) and KIS (ε). Bartlett's (B) statistic and Probability >B are 1.723 and 0.005 respectively for X_T and 2.036 and 0.000 respectively for ε. For all the other variables in the analysis, the probability is found to be 0.000 for all.

Then, Box-Jenkins autoregressive integrated moving-average (ARIMA) model is also fitted to the variables, which specify models with linear autoregressive moving-average (ARMA) disturbances. Next, Augmented Dickey-Fuller (ADF) test and Phillips-Perron (PP) test are applied[1] to the variables to see if they follow a unit-root process. To check the autocorrelations, partial autocorrelations, and Portmanteau (Q) statistics, a corrogram is produced in each process to visually check the status of autoregression for all variables as well as their residuals along with Breusch-Godfrey LM test. After visually checking ARMA disturbances for X_T by using the corrogram, ADF test is applied, in which MacKinnon approximate p-value for Z(t) is found to become 0.198. According to the PP test for unit root, MacKinnon approximate p-value for Z(t) is 0.992. Breusch-Godfrey LM test for autocorrelation also shows that the probability > chi-squared becomes 0.319. Therefore, based on the idea of progression of differences, the first-order difference is derived for X_T. ADF test and PP test are applied, in which MacKinnon approximate p-value becomes 0.000 and 0.071 respectively. As for ε, the result of ADF test and PP test is 0.665 and 0.876 respectively. Then, by taking the first-order sequence of difference, the same tests are applied again. The MacKinnon approximate p-value becomes 1.000 and 0.649 respectively. Corrogram also shows the existence of autoregression with the variable in the first-order difference. Therefore, the second-order sequence of difference for ε is produced, and the

[1] In this process, lags are defined as: INT(12*(years/100)$^{(1/4)}$).

same procedures are performed. The MacKinnon approximate p-value is reduced to 0.004 and 0.001 respectively in ADF test and PP test.

By incorporating the results, the panels are regressed by taking intermediaries (X_T) and KIS (ε) as independent variables. The regression is performed with 95% confidence level using Huber/White/sandwich estimator for robustness. Independent variables in the panels are shown in Table 1. Each variable is examined, and excluded in stepwise method when p value becomes more than 0.1 (>0.1). Outliers are also excluded if standard deviation is above three (>3). The model should be excluded from analysis when Variance Inflation Factor (VIF) is greater or equal to ten (≧10) according to collinearity statistics. Table 1 is a collection of results, in which significant level is shown either at 0.01(*), 0.05(**), or 0.10(+). The partial and semipartial correlation coefficients of the independent variables, the squared correlations, and significance are reported in the table.

According to the results, KIS have more impact on these macro indicators than X_T has. KIS is significant for values such as *Y, C, G, K, L, A, P, W, N*, and *h* in spite of differences in R2. Employment rate (*e*), capital-to-output ratio (*K/Y*), intermediaries-to-output ratio (*X/Y*), or government spending share (*G/Y*) do not exhibit statistical significance. Among all the variables that represent the high R2s, the highest coefficient is shown for *P*, followed by *C*.

Overall it can be interpreted that KIS vary in line with macroeconomic trends much closer than the other types of intermediaries. It has become clear that KIS grows when the aggregate economy expands. At the same time, the growth of KIS has outpaced GDP in recent years as is shown in Figure 1 and Table 3. To clarify this point, the following section of this paper is given to discuss the output and input of KIS and its effect on capital stock and productivity, by simulating the future trend for KIS.

Table 1: Regression

Dependent Var.	Independent Var.	Coef.	Constant	P	Prob > F	R-squared	Robust Std. Error	VIF	Partial Corr.	Semipartial Corr.	Partial Corr.^2	Semipartial Corr.^2	Significance Value	Breusch-Pagan / Cook-Weisberg test for heteroskedasticity	
Y	Xkis	0.205**	10.510*	0	0.0916	0.258	0.074	1	0.4803	0.4662	0.2307	0.2173	0.1349	chi2(2)	0.24
	Xt			0.5916				NA	0.1507	0.1298	0.0227	0.0169	0.6582	Prob > chi2	0.8859
C	Xkis	0.109**	14.579*	0	0.0144	0.328	0.037	1	0.5501	0.5356	0.3026	0.2869	0.0796	chi2(2)	0.24
	Xt			0.6835				NA	0.1241	0.1017	0.0154	0.0103	0.7163	Prob > chi2	0.8848
G	Xkis	0.086**	9.316*	0	0.0216	0.298	0.021232	1	0.5262	0.5163	0.2769	0.2666	0.0964	chi2(2)	9.62
	Xt			0.7868				NA	0.0858	0.0718	0.0074	0.0052	0.802	Prob > chi2	0.0081
K	Xkis	0.100**	16.175*	0	0.0181	0.304	0.018817	1	0.5295	0.5173	0.2804	0.2676	0.0939	chi2(2)	0.8697
	Xt			0.2037				NA	0.1109	0.0925	0.0123	0.0085	0.7455	Prob > chi2	0.4359
L	Xkis	0.0258**	16.391*	0	0.014	0.28	0.012937	1	0.5078	0.4956	0.2578	0.2456	0.1108	chi2(2)	0.8697
	Xt			0.6656				NA	0.1197	0.1014	0.0143	0.0103	0.7259	Prob > chi2	0.4359
A	Xkis	0.018**	7.780*	0	0.038	0.254	0.00608	1	0.4843	0.4766	0.2345	0.2272	0.1312	chi2(2)	11.45
	Xt			0.3158				NA	0.0764	0.0659	0.0058	0.0043	0.8234	Prob > chi2	0.0033
P	Xkis	0.105**	13.976*	0	0.0145	0.354	0.035638	1	0.5746	0.5613	0.3302	0.3151	0.0644	chi2(2)	0.8697
	Xt			0.7495				NA	0.1028	0.0826	0.0106	0.0068	0.7636	Prob > chi2	0.4359
W	Xkis	0.098**	14.303*	0	0.0128	0.317	0.032549	1	0.5392	0.5238	0.2908	0.2743	0.0869	chi2(2)	0.8697
	Xt			0.1285				NA	0.1381	0.1141	0.0191	0.013	0.6854	Prob > chi2	0.4359
N	Xkis	0.023**	17.406*	0	0.0123	0.325	0.002745	1	0.5474	0.5331	0.2996	0.2842	0.0814	chi2(2)	4.94
	Xt			0.6706				NA	0.1236	0.1015	0.0153	0.0103	0.7173	Prob > chi2	0.0844
e	Xkis			0.3388	0	0		NA	0.1513	0.1506	0.0229	0.0227	0.657	chi2(2)	
	Xt			0.7814				NA	0.0582	0.0574	0.0034	0.0033	0.865	Prob > chi2	
h	Xkis	0.021**	4.998*	0	0	0.016	0.0075	1	0.4746	0.4616	0.2252	0.213	0.1402	chi2(2)	10.03
	Xt			0.6137				NA	0.1426	0.1233	0.0203	0.0152	0.6758	Prob > chi2	0.0066
K/Y	Xkis			0.7694	0	0		NA	-0.1051	-0.1048	0.011	0.011	0.7584	chi2(2)	
	Xt			0.8475				NA	-0.0483	-0.048	0.0023	0.0023	0.8878	Prob > chi2	
X/Y	Xkis			0.6733	0	0		NA	0.0862	0.0857	0.0074	0.0073	0.801	chi2(2)	
	Xt			0.7315				NA	0.088	0.0875	0.0077	0.0077	0.7969	Prob > chi2	
G/Y	Xkis			0.1118	0	0		NA	-0.4208	-0.4039	0.1771	0.1632	0.1975	chi2(2)	
	Xt			0.5467				NA	-0.205	-0.1824	0.042	0.0333	0.5453	Prob > chi2	

Note: Any p values other than 0 refer to the values based on which the corresponding variable is removed from the model. ** significant at 5%; * significant at 1%. Observations: 20.

3. Simulation

Output growth can be achieved by several factors. According to Jorgenson, Ho, and Stiroh (2003), growth in productivity is decomposed by capital deepening, labor quality improvement, and total factor productivity (TFP) growth. Capital deepening is defined as 'increases in capital per worker enhance labor productivity.' Labor quality improvement is expressed as 'the contribution of increases in labor input per hour worked.' Based on the supplemental data presented in Table 4, capital input per worker has increased the most since 1986 followed by capital stock per worker although the growth is not as much as the level of capital input per worker. Labor productivity (output per worker) has approximately doubled during the twenty years. Labor hours and unit labor costs have remained in a 2-4% increase range. Output per hour has improved also although data is not available for the whole period. It is considered that the output growth of 3.77 points is achieved by the improvement of both capital stock accumulation and labor productivity.

The following section is to obtain further result on the trend of KIS in terms of capital stock and TFP. By using the parameters and equations shown below, the trend of KIS is simulated by using the data during 1987-2006, the period when accurate data for KIS is available.

3.1. Models and Parameters

Data is simulated for the period of fifty years starting in 1987 ending in 2036 (the projection period is therefore thirty years starting from 2006) assuming that the average growth rate of GDP is 4% annually and the average growth rate of KIS is at 7.5%. These growth rates are observed as an average sample growth rate for the data period of twenty years. Based on the data in Table 4 and Table 5, TFP for the entire economy and TFP specific for KIS are chained to 1986 level (1986=100) for data consistency. Capital level per worker for KIS is also chained to 1986 due to lack of detailed data. Therefore, the net capital level for KIS must be compared to the net capital level for the entire economy percentage wise in terms of growth rate. Initial capital level is obtained by the capital level in 1986 divided by TFP, in which capital grows at 4.8% annually and TFP grows at γ each year. As for KIS, the capital level increases at 3.3% annually according to the given data. In addition, TFP for KIS is supposed to grow at 3.9% a year. The average growth rate for the KIS output and KIS ratio to the aggregate output is 7.5% and 3.5% respectively. According to the conditions above, the capital growth level for the entire economy is given by:

$$\dot{k}_t = (\dot{k}_{t-1} * 1.048)^{1-\frac{Y_\varepsilon}{Y}} + (\dot{k}_{t-1}{}^{\frac{Y_\varepsilon}{Y}} * \dot{k}_{KIS,t-1}); \tag{12}$$

$$\dot{k}h_t = \left(\frac{\dot{c}c_t}{(1-\theta) * \frac{36}{\alpha}} \right)^{\frac{1}{\theta}}, \tag{13}$$

in which $\dot{k}h_t$ is the rate of capital per worker and $\dot{c}c_t$ is consumption level at time *t*, and the average weekly working hour is 36 hrs. TFP growth rate (γ) is also supposed to grow at 0.9% annually. Therefore, the TFP growth rate is obtained when KIS are counted from:

$$\gamma_t = (\gamma_{t-1} * 1.009)^{1-\frac{Y_\varepsilon}{Y}} + (\gamma_{t-1}{}^{\frac{Y_\varepsilon}{Y}} * \gamma_{KIS,t-1}). \tag{14}$$

Besides these variables, the population growth rate and government spending share are set to the level of 2006. As for the other parameters, please refer to Table 2.

3.2. Analysis

According to the result, capital per worker (*kh*) would grow at 0.027 points more if KIS should be counted and grow at the current pace at the end of the projection period of 2036. TFP growth rate (γ) would improve at 0.043 points above the current growth level. Please refer to Figure 3 and Figure 4. It is assumed that KIS would have an effect to enhance capital accumulation and productivity improvement. Therefore, the combination of these two aspects would change the initial capital level, and its convergence speed. At the same time, it is not clear how much KIS would contribute to the capital accumulation in terms of intangibles, i.e. capital stock resulting from R&D investment, due to lack of detailed data for the subsector of KIS. KIS sector has been investing in tangible capital, and productive capital stock has accumulated at a faster pace than the overall economy. This is a contributor to the enhancement of capital stock for KIS, although it is important to clarify how KIS strengthen the capacity of knowledge accumulation and intangibles.

Figure 3: Effects of KIS on TFP

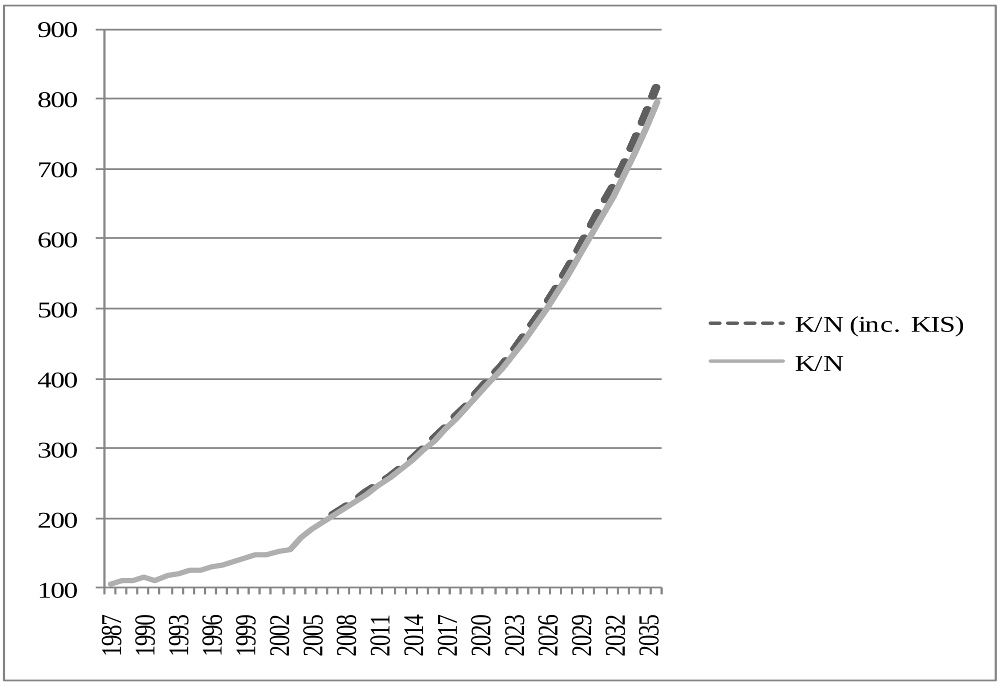
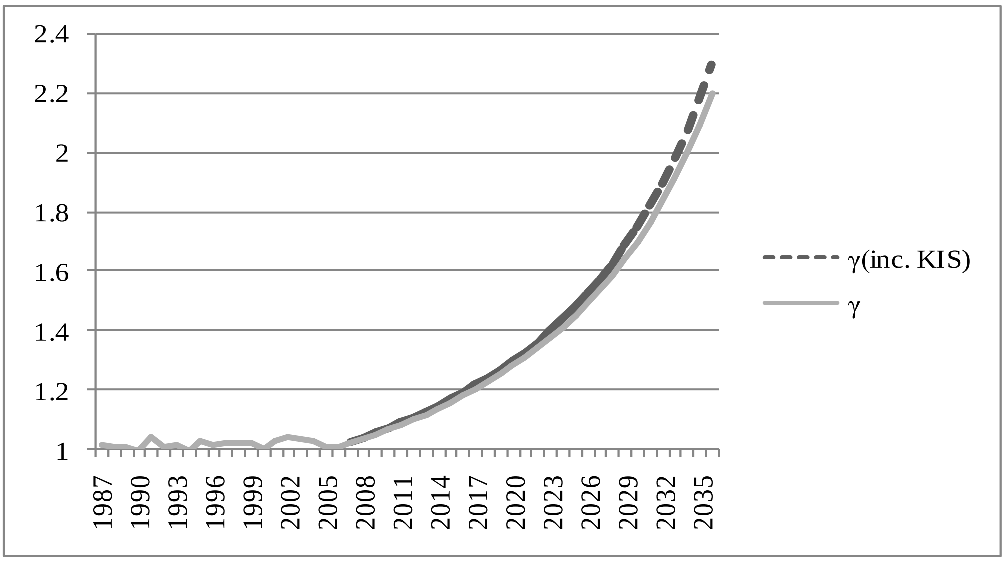


Figure 4: Effects of KIS on Capital



4. Conclusion

The service sector has been growing in today's economy although there is a relatively smaller number of empirical and statistical studies compared to manufacturing sectors, mainly due to a lack of adequate statistics and data. This paper focuses on knowledge-intensive service (KIS) activities, which have not been the focus of past research, except for narrative discussion of its importance and case studies (OECD, 2006). KIS produce and integrate existing service activities which are undertaken by firms and the public sector, both in manufacturing and service sectors. It is said that KIS strengthen knowledge production activities, and engage in innovative activities as a mediator for promoting innovation. Based on these observations, this paper examines the effect of KIS to verify how KIS impact the entire economy by using data taken from U.S. statistics. This paper employs the standard RBC model to analyze KIS with multiple regression analysis and simulation. The equations and models are based on Hayashi and Prescott (2002).

According to the results, it is revealed that KIS has an impact on the variables such as aggregate output, consumption, government expenditures, capital stock, and productivity. KIS are not related to the employment rate. Furthermore, multiple regression analysis shows that KIS have more significant impact on most macroeconomic indicators than X_T has on them. Therefore, it can be said that KIS grow with macroeconomic trends more proportionately than the other types of intermediaries. KIS sectors grow as the entire economy expands, in which the rate of KIS output growth outpaces the rate of GDP growth.

Based on these observations, further analysis on the trend of KIS is made in terms of capital stock and TFP. According to the simulated trend of KIS, capital per worker in the entire economy would grow at 0.027 points more at the end of the projection period of 2036 if KIS would grow at the current pace. TFP growth rate would also improve at 0.043 points above the current growth level. KIS contribute to the capital deepening and productivity improvement.

For future research, it is important to incorporate the effect of intangibles more precisely in the macroeconomic trend, which inherit the nature of knowledge-intensive activities. Intangibles include information software and data processing, branding, and knowledge capital. It is difficult to measure these aspects quantitatively or qualitatively such as measuring depreciation rates for software programs. Not only to capture the trend of KIS but also to reveal the performance of the entire service sector, it is necessary to devise in accurate measurement scheme. By clarifying the quantification method of values for service sectors, we would be able to reveal the trend of service sectors more clearly, and assess their impact on economic growth.

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APPENDIX

A. Data

Data sources for each parameter and value are listed below. With regard to the availability of data, this paper uses data from 1978-2006. Any missing historical data is computed based on the average rate of change over the entire data period.

1) KIS (ε)

-εε: This paper employs the definition of KIS presented by the OECD report (2006, p.7). In this report, KIS are referred to as Knowledge-intensive Service Activities (KISA). KIS are also referred to as Knowledge-intensive business services (KIBS) in a narrower definition in some literature. Following the definition of OECD, the data on KIS used in this paper is obtained from Bureau of Economic Analysis (BEA) in U.S. Department of Commerce and U.S. Census Bureau. Most KIS activities are included in *Professional, Scientific, and Technical Services* (541; 2002 North America Industry Classification System (NAICS) Definitions). According to NAICS definition, the Professional, Scientific, and Technical Services subsector group establishments are engaged *in processes where human capital is the major input*, which *make available the knowledge and skills of their employees, often on an assignment basis, where an individual or team is responsible for the delivery of services to the client* (Corrado, Hulten, and Sichel, 2006).

2) Productivity (A)

-Y: Value added by industry is obtained from the statistics of *GDP by industry and value added* (GDPbyIND_VA_NAICS) prepared by the Current Industry Analysis Division, BEA. The 1997 NAICS-based data for value added is prepared at the 22-industry level of detail for 1947-76 and the 65-industry level of detail for 1977-86. The data for 1998-2007 is also based on 1997 NAICS industry definition prepared at the 65-industry level of detail. For GDP adjusted with R&D taken as intermediaries is available from *Satellite Account* of BEA for 1959-2004.

-A: Productivity, *A*, is value added (*VA*) per production worker hour (*h)*. Total Factor productivity (TFP) is directly obtained from *Multifactor Productivity and Cost, 1948–2007* computed by Office of Productivity and Technology, Bureau of Labor Statistics, U.S. Department of Labor.

*CPI: Inflation rate is obtained from *Consumer Price Index (CPI)* and *import price indexes for selected categories* provided by the Department of Labor.

3) Labor (L)

-E: Employment is based on the data of *full-time and part-time employees* from *GDP by industry and value added*.

-w: Wage rate is *compensation of employees* (the sum of *wages and salaries* and *supplements to wages and salaries)* from the same source divided by the inflation rate.

-N: Working-age population is the population from 15 to 64, whose data is taken from *population estimate by age* from the U.S. Census Bureau, International Data Base and *Employment status of the civilian noninstitutional population, 1942 to date* from Labor Force Statistics from the Current Population Survey, the Department of Labor.

-h: Production worker hour (*h*) is retrieved from *Hours Worked by Full-Time and Part-Time Employees by Industry,* annual data from BEA. Also, U.S. Department of Labor provides *Average hours and earnings of production and nonsupervisory workers on private nonfarm payrolls by major industry sector.*

4) Intermediary (X)

Investment into various intermediaries is taken from *Intermediate inputs* from *GDP by industry and value added* prepared by BEA.

-X_T: Investment into tangibles is the sum of inputs into energy, materials, purchased services less KIS.

-ε: Data is taken from a subsector *Professional, scientific, and technical services* in *Intermediate inputs* from *GDP by industry and value added* prepared by BEA as well as *Service Annual Survey* of Census Bureau.

5) Capital stock (K)

-K_T: BEA's data contains detailed estimates for *net capital stock of nonresidential fixed assets* presented for industries by asset type (1997 NAICS-based BEA codes).

-δ: Depreciation rates are taken from *Hulten-Wykoff categories* based on U.S. Bureau of Economic Analysis (2003) and Fraumeni (1997).

6) Household consumption (C)

-C: Household consumption is taken from the data, *GDP by industry and value added,* prepared by BEA.

-π: Lump-sum taxes are derived as a sample average over the period based on the data provided by U.S. Internal Revenue Service (IRS). Data used is *Individual Income Tax Returns with*

Positive Adjusted Gross Income (AGI) for 1986-2005.

-τ_K: Information on capital gain tax policies is obtained from IRS website.

-r: Capital income data is obtained from comprehensive tables of *multifactor productivity and related capital data for private business, private nonfarm business and manufacturing* prepared by the Department of Labor, Bureau of Labor Statistics, Office of Productivity and Technology. Please refer to Harper, Berndt, and Wood (1989) for the method of calculation.

7) Government expenditures (G)

-G: Government spending is obtained from *GDP by industry and value added* prepared by BEA.

-CA: Current account surplus is indicated in *Balance on current account* presented by BEA's *U.S. International Transactions Accounts Data*.

-τ_i: Tax rate on corporate profits is derived from *Corporation Income Tax Returns: Historical Table* prepared by IRS.

Table 2: Parameters

Parameter	Description	Value
θ	Capital share in production.	0.31
δ	Depreciation rate	0.15
β	Discounting factor	0.98
τ_K	Capital income tax rate	0.15
τ_i	Business tax rate	0.31
π	Lump-sum tax rates	0.135
α	Government spending share	0.19

B. Data Tables

Table 3: Data for Correlation and Regression Analysis

Year	Y (Million)	C (Million)	X (Million)	G (Million)	CA (Million)	K (Million)	L (Thou)	A	CPI_chained	Xt (Million)	! (Million)	P (Million)	W (Million)	N (Thou)	h (hour/m)
1948	269,200	175,000	48,100	40,600	5,500	848,500	51,332	3,661.544	16.382			108,366	135,464	60,621	107.646
1949	267,300	178,500	36,900	46,700	5,200	861,000	50,358	3,675.460	16.352			102,964	134,675	61,286	103.848
1950	293,800	192,200	54,100	46,800	700	963,900	52,424	3,939.406	16.531			114,596	147,175	62,208	105.085
1951	339,300	208,500	60,200	68,100	2,500	1,056,800	56,415	4,034.292	17.718			129,832	171,593	62,017	108.412
1952	358,300	219,500	54,000	83,600	1,200	1,118,200	57,702	4,105.109	18.022			132,626	185,634	62,138	108.437
1953	379,400	233,100	56,400	90,600	-700	1,161,300	58,918	4,212.674	18.243			136,384	198,996	63,015	109.636
1954	380,400	240,000	53,800	86,200	400	1,211,800	57,387	4,212.956	18.417			139,605	197,320	63,643	105.737
1955	414,800	258,800	69,000	86,500	500	1,315,000	59,080	4,392.307	18.743			155,534	212,221	65,023	109.634
1956	437,500	271,700	72,000	91,400	2,400	1,425,300	60,845	4,362.892	19.393			161,136	229,108	66,552	111.277
1957	461,100	286,900	70,500	99,700	4,100	1,496,100	61,308	4,430.376	20.038			168,104	240,029	66,929	109.547
1958	467,200	296,200	64,500	106,000	500	1,542,100	59,839	4,451.698	20.498			170,162	241,389	67,639	104.357
1959	506,600	317,600	78,500	110,000	400	1,603,700	61,587	4,650.119	20.751			185,031	259,923	68,369	108.574
1960	526,400	331,700	78,900	111,600	4,200	1,653,900	62,680	4,679.873	21.041			187,329	273,010	69,628	108.546
1961	544,700	342,100	78,200	119,500	4,900	1,711,000	62,881	4,781.635	21.278			194,827	280,663	70,459	106.612
1962	585,600	363,300	88,100	130,100	4,100	1,784,500	64,573	4,955.752	21.569			209,871	299,453	70,614	108.500
1963	617,700	382,700	93,800	136,400	4,900	1,850,800	65,619	5,102.229	21.798			222,027	314,914	71,833	109.113
1964	663,600	411,400	102,100	143,200	6,900	1,967,400	67,275	5,302.704	22.131			237,452	337,842	73,091	110.978
1965	719,100	443,800	118,200	151,500	5,600	2,095,000	69,692	5,475.536	22.535			260,267	363,752	74,455	114.675
1966	787,800	480,900	131,300	171,800	3,900	2,273,200	73,516	5,644.769	23.176			279,549	400,297	75,770	117.661
1967	832,600	507,800	128,600	192,700	3,600	2,450,000	75,442	5,655.247	23.893			288,644	428,979	77,347	117.219
1968	910,000	558,000	141,200	209,400	1,400	2,693,000	77,602	5,799.574	24.913			308,813	471,960	78,737	119.359
1969	984,600	605,200	156,400	221,500	1,400	2,934,700	79,850	5,777.857	26.149			324,427	518,311	80,734	122.373
1970	1,038,500	648,500	152,400	233,800	4,000	3,190,900	79,750	5,768.963	27.534			327,313	551,537	82,771	119.725
1971	1,127,100	701,900	178,200	246,500	600	3,510,400	79,554	5,953.103	28.911			360,701	584,528	84,382	119.148
1972	1,238,300	770,600	207,600	263,500	-3,400	3,854,700	81,583	6,123.479	30.166			402,613	638,786	87,034	123.158
1973	1,382,700	852,400	244,500	281,700	4,100	4,359,400	85,202	6,293.745	31.849			450,706	708,775	89,429	127.725
1974	1,500,000	933,400	249,400	317,900	-800	5,177,500	86,573	6,078.716	34.725			477,117	772,304	91,949	127.759
1975	1,638,300	1,034,400	230,200	357,700	16,000	5,610,200	85,044	6,141.091	38.002			540,480	814,881	93,774	122.116
1976	1,825,300	1,151,900	292,000	383,000	-1,600	6,119,200	87,402	6,364.360	40.196			599,285	899,782	96,158	125.967
1977	2,030,900	1,278,600	361,300	414,100	-23,100	6,844,300	90,421	6,469.530	42.752			675,291	994,220	99,008	131.027
1978	2,294,700	1,428,500	438,000	453,600	-25,400	7,746,300	94,785	6,556.304	45.757			769,698	1,121,305	102,250	137.636
1979	2,563,300	1,592,200	492,900	500,800	-22,500	8,912,400	98,025	6,532.189	49.548			844,546	1,255,867	104,962	142.258
1980	2,789,500	1,757,100	479,300	566,200	-13,100	10,126,900	98,379	6,385.383	54.043			905,299	1,377,738	106,940	140.942
1981	3,128,400	1,941,100	572,400	627,500	-12,500	11,141,600	99,235	6,401.636	59.119			1,047,000	1,517,666	108,670	141.968
1982	3,255,000	2,077,300	517,200	680,500	-20,000	11,739,800	97,762	6,190.620	62.726			1,102,292	1,593,915	110,204	138.628
1983	3,536,700	2,290,600	564,300	733,500	-51,700	12,156,200	98,527	6,370.469	65.207			1,205,682	1,684,752	111,550	141.075
1984	3,933,200	2,503,300	735,600	797,000	-102,700	12,842,400	103,119	6,561.020	67.655			1,393,490	1,855,310	113,544	149.358
1985	4,220,300	2,720,300	736,200	879,000	-115,200	13,560,400	105,802	6,647.057	69.713			1,491,430	1,995,688	115,461	152.813
1986	4,462,800	2,899,700	746,500	949,300	-132,700	14,468,800	107,722	6,752.445	71.250			1,544,996	2,116,605	117,834	153.838
1987	4,739,500	3,100,200	785,000	999,500	-145,200	15,346,300	110,725	6,768.328	73.196	707,327	77,673	1,648,537	2,272,102	119,865	158.404
1988	5,103,800	3,353,600	821,600	1,039,000	-110,400	16,319,200	113,960	6,817.631	75.694	732,745	88,855	1,790,196	2,453,813	121,669	162.757
1989	5,484,400	3,598,500	874,900	1,099,100	-88,200	17,275,300	116,673	6,838.307	78.557	774,724	100,176	1,965,720	2,597,628	123,869	167.072
1990	5,803,100	3,839,900	861,000	1,180,200	-78,000	18,110,700	118,158	6,881.816	81.590	755,621	105,379	2,063,806	2,756,325	125,840	166.009
1991	5,995,900	3,986,100	802,900	1,234,400	-27,500	18,574,800	116,649	6,833.411	84.443	690,145	112,755	2,117,727	2,825,737	126,346	161.999
1992	6,337,700	4,235,300	864,800	1,271,000	-33,200	19,368,000	117,060	7,013.163	86.386	747,301	117,499	2,245,445	2,967,495	128,105	161.692
1993	6,657,400	4,477,900	953,400	1,291,200	-65,000	20,380,000	119,051	7,028.276	88.381	825,864	127,536	2,385,658	3,092,477	129,200	166.076
1994	7,072,200	4,743,300	1,097,100	1,325,500	-93,600	21,621,500	121,895	7,082.824	90.259	956,492	140,608	2,557,504	3,253,779	131,056	172.667
1995	7,397,700	4,975,800	1,144,000	1,369,200	-91,400	22,669,600	124,783	7,061.749	92.106	978,387	165,613	2,675,984	3,439,757	132,304	177.478
1996	7,816,900	5,256,800	1,240,300	1,416,000	-96,200	23,768,200	127,047	7,182.074	93.853	1,045,085	195,215	2,875,357	3,627,331	133,943	180.358
1997	8,304,300	5,547,400	1,389,800	1,468,700	-101,600	25,012,100	129,888	7,249.293	95.414	1,164,431	225,369	3,059,175	3,879,086	136,297	186.475
1998	8,747,000	5,879,500	1,509,100	1,518,300	-159,900	26,404,500	133,216	7,343.663	96.472	1,234,188	274,912	3,118,616	4,187,282	137,673	190.192
1999	9,268,400	6,282,500	1,625,700	1,620,800	-260,500	28,081,100	136,347	7,438.411	97.868	1,311,567	314,133	3,276,254	4,476,613	139,368	194.071
2000	9,817,000	6,739,400	1,735,500	1,721,600	-379,500	29,917,100	139,131	7,533.582	100.000	1,374,151	361,349	3,365,147	4,833,832	142,583	195.993
2001	10,128,000	7,055,000	1,614,300	1,825,600	-367,000	31,608,900	139,033	7,541.749	102.400	1,207,518	406,782	3,507,379	4,947,939	143,734	191.594
2002	10,469,600	7,350,700	1,582,100	1,961,100	-424,400	33,061,300	137,932	7,666.484	104.187	1,156,960	425,140	3,648,614	4,986,338	144,863	186.745
2003	10,960,800	7,703,600	1,664,100	2,092,500	-499,400	34,804,700	137,612	7,868.351	106.404	1,213,060	451,040	3,870,377	5,133,390	146,510	185.420
2004	11,685,900	8,195,900	1,888,600	2,216,800	-615,400	38,201,700	139,136	8,063.887	109.462	1,409,220	479,380	4,204,158	5,385,656	147,401	187.805
2005	12,421,900	8,694,100	2,086,100	2,355,300	-713,600	41,893,600	141,235	8,195.196	113.000	1,552,535	533,565	4,534,825	5,679,266	149,320	190.969
2006	13,178,400	9,207,200	2,220,400	2,508,100	-757,300	45,052,700	143,543	8,239.342	116.567	1,661,079	559,321	4,822,331	6,032,229	151,428	195.022

Table 4: Data on Labor Productivity for KIS

Year	Employment (1987=100)	Output (Value Added, VA) (1987=100)	Compensation (1987=100)	Input (Intermediaries Input, II) (1987=100)	Labor hours (VA/Labor hours) (2000=100)	Unit labor costs (Compensation/VA) (1987=100)	Output per hour* (VA/Hours worked) (2000=100)	Output per worker* (VA/employment) (1987=100)	Output to input (VA/II) (1987=100)	Capital per worker (Capital input/employment) (1987=100)	Capital per worker* (Capital stock/employment) (1987=100)
1987	1.000	1.000	1.000	1.000		1.000		1.000	1.000	1.000	1.000
1988	1.050	1.126	1.125	1.145		0.999		1.072	0.983	1.034	1.003
1989	1.099	1.251	1.235	1.273		0.987		1.139	0.983	1.069	1.024
1990	1.129	1.376	1.355	1.367		0.985		1.219	1.007	1.103	1.033
1991	1.115	1.399	1.393	1.432		0.996		1.255	0.977	1.178	1.098
1992	1.142	1.513	1.506	1.500		0.995		1.326	1.009	1.199	1.096
1993	1.196	1.592	1.598	1.630		1.004		1.330	0.976	1.203	1.090
1994	1.267	1.687	1.689	1.812		1.001		1.331	0.931	1.188	1.060
1995	1.337	1.795	1.833	2.095		1.021		1.342	0.856	1.190	1.039
1996	1.401	1.956	1.995	2.392		1.020		1.396	0.818	1.223	1.035
1997	1.492	2.165	2.214	2.706		1.023		1.451	0.800	1.287	1.038
1998	1.576	2.358	2.475	3.211		1.050		1.495	0.734	1.413	1.078
1999	1.661	2.571	2.728	3.570		1.061		1.548	0.720	1.590	1.149
2000	1.735	2.755	2.993	4.163	1.000	1.086	1.000	1.588	0.662	1.787	1.225
2001	1.715	2.816	3.030	4.402	0.959	1.076	1.065	1.642	0.640	2.041	1.355
2002	1.663	2.872	3.012	4.502	0.936	1.049	1.114	1.727	0.638	2.282	1.494
2003	1.664	3.016	3.108	4.676	0.927	1.030	1.181	1.813	0.645	2.444	1.615
2004	1.706	3.232	3.294	5.130	0.958	1.019	1.225	1.894	0.630	2.566	1.690
2005	1.765	3.510	3.585	5.612	0.992	1.021	1.284	1.989	0.625	2.663	1.758
2006	1.828	3.770	3.866	5.994	1.039	1.026	1.317	2.062	0.629	2.736	1.832

Table 5: Data for Simulation

	Y	K/Y	Net Return	K/N	KH ratio	!	N growth	"	TFP	KIS/Y
1987	78	1.629	0.078	106	3.210	1.011	1.015	0.211	1.540	0.050
1988	84	1.595	0.085	110	3.170	1.004	1.018	0.204	1.543	0.053
1989	90	1.536	0.078	112	3.240	1.009	1.016	0.200	1.545	0.056
1990	95	1.527	0.075	116	3.220	0.990	1.004	0.203	1.548	0.058
1991	98	1.439	0.075	112	3.200	1.038	1.014	0.206	1.544	0.057
1992	104	1.450	0.076	118	3.210	1.003	1.009	0.201	1.557	0.058
1993	109	1.428	0.081	121	3.240	1.011	1.014	0.194	1.558	0.058
1994	116	1.428	0.085	126	3.300	0.996	1.010	0.187	1.562	0.057
1995	121	1.378	0.094	126	3.270	1.025	1.012	0.185	1.560	0.058
1996	128	1.365	0.101	131	3.330	1.014	1.018	0.181	1.568	0.060
1997	136	1.322	0.105	132	3.300	1.019	1.010	0.177	1.573	0.063
1998	143	1.312	0.092	137	3.140	1.019	1.012	0.174	1.579	0.065
1999	152	1.301	0.092	142	3.100	1.019	1.023	0.175	1.585	0.066
2000	161	1.301	0.083	147	2.990	1.002	1.008	0.175	1.592	0.069
2001	166	1.292	0.076	149	3.010	1.024	1.008	0.180	1.592	0.069
2002	172	1.280	0.085	152	3.050	1.038	1.011	0.187	1.600	0.067
2003	180	1.275	0.091	156	3.110	1.036	1.006	0.191	1.613	0.067
2004	192	1.321	0.105	172	3.210	1.024	1.013	0.190	1.626	0.068
2005	204	1.366	0.117	186	3.280	1.008	1.014	0.190	1.634	0.069
2006	216	1.363	0.127	195	3.260	1.009	1.011	0.190	1.637	0.070