



NORTH-HOLLAND

A Growth Model of “Miracle” in Korea

Atsuko Ueda, *University of Tsukuba*

High economic performance in East Asia has motivated arguments on the sources of economic growth, including the role of the government to encourage more investment than would have been allocated by market forces. The purpose of this paper is to quantitatively investigate whether or not macroeconomic investment behavior of a growing economy can be explained by market forces. Focusing on Korea during the period 1960–90, a stochastic growth model with production is estimated with a numerical solution to approximate the optimal investment behavior during the course of economic development. The estimation result suggests that market forces do not explain the rise in investment rates in the 1960s and 1970s, while investment behavior in the 1980s coincides with optimizing investment behavior. © 2000 Society for Policy Modeling. Published by Elsevier Science Inc.

1. INTRODUCTION

Strong economic performance in East Asia in the last decades is deserved to be called a “miracle.” Sources of the success in East Asia have been sought in an outward oriented policy, high rates of investment, high standard of education, rich and low-waged labor supply, cultural background, and so on. In addition, the growth experience in East Asia attracts attention in the context of the role of the government in driving economic growth. Following an early contribution by Jones and Sakong (1980), Amsden (1989), Wade (1990), and the World Bank (1993) investigate importance of the role of the government in these countries in detail by giving rich examples.

Pack and Westphal (1986) argue that, in order to achieve international competitiveness, *more investment is required than would*

Address correspondence to A. Ueda, University of Tsukuba, Institute of Policy and Planning Sciences, 1-1-1 Tennodai, Tsukuba, Ibaraki 305, Japan.

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have been allocated by market forces in a *laissez-faire* regime. They look for a reason in market imperfections associated with technological change; technology is not acquired automatically, but markets do not fully reflect the cost of acquisition of new technology. Wade (1990) argues, more strongly, that the static conditions of market failure are irrelevant for growth and innovation; that is, efficient allocation of resources in a current market may not be efficient when considering future growth. However, the arguments of this literature is mainly based on observations on government interventions, but has not offered empirical evidences to prove that investment in East Asia has been made beyond market forces.

The purpose of this paper is to *quantitatively* investigate whether or not investment behavior in East Asia is explained by market forces, focusing on the Republic of Korea (henceforth, Korea) during the period 1960–90 when Korea achieved rapid economic growth.

In 1960, the real per capita GDP of Korea was \$923, which was almost the same level as Taiwan (\$964), Thailand (\$985), and the Philippines (\$1,183).¹ By 1985, it was \$3,858: slightly lower than Taiwan, about 50 percent higher than Thailand, and more than twice that of the Philippines. The annual average growth rate of Korea was 5.7 percent during 1960–85, while the world average was 2.1 percent. Also, Korea improved in investment rates from 8.6 percent in 1960 to 29.2 percent in 1988, while the investment rates in the U.S. ranged from 14.9 to 20.1 percent during the same period.

The previous studies on the role of the government consider the Korean government as the strongest interventionist in East Asia.² In the early 1960s, Korea suffered from political instability and economic stagnation. After Park Chung-Hee took power and being President from 1963 to 1979, Park implemented various economic policies, *giving the highest priority to economic growth*, including 5-year Economic Development Plans, a low-interest policy by putting commercial banks under the control of the government, nursing *Chaebol* (conglomerates in the manufacturing sector), and strong “advice” from bureaucrats. In the 1980s after Park’s regime, Korea took the first step toward economic liberalization.

¹The figures in this paragraph are from Summers and Heston (1991), real GDP per capita in 1985 international prices.

²This paragraph is based on World Bank (1992), Amsden (1989), Mason et al. (1980), and Jones and Sakong (1980).

These historical observations are major foundations to claim the role of the government to promote investment, but there is little evidence in which investment in Korea has been made beyond optimizing behavior considering future growth of Korea. Also, it is not impossible that the government intervention is restricted to make up for market failure such as underdeveloped financial market. Then, investment behavior can be explained by market forces rather than the governmental policies.

The plan of this paper is as follows. Section 2 describes a stochastic growth model with production, and develops an estimation method. It is natural that the people consider further output growth associated with capital accumulation and productivity growth into their investment decision. Therefore, this paper applies a dynamic model with production that allows future capital accumulation and productivity growth. Furthermore, optimal investment behavior must be analyzed during the course of economic development. For this purpose, the analysis introduces numerical methods to approximate the solution of the dynamic model and develops a simulation-estimation method. Section 3 describes the data and preparatory analysis of the production technology that is used in the estimation. Section 4 presents the estimation result. The result suggests that the actual investment behavior can be explained as an optimal behavior in the 1980s, but a rise in investment rates in the 1960s and the 1970s cannot be explained by market forces. To investigate the reasons, effects of structural change and externalities are investigated. Section 5 gives concluding remarks.

2. A STOCHASTIC GROWTH MODEL

2.1. The Model

Consider the following aggregate production technology

$$Y_t = \theta_t \cdot F(K_t, N_t, A_t),$$

where Y_t is production, θ_t is a stochastic shock, A_t is productivity, K_t is capital stock, N_t is labor input with a growth rate $n_t = \frac{N_t}{N_{t-1}}$, $F()$ is a production function, and subscript t denotes period. Productivity may be raised by R&D efforts, learning-by-doing, spillover effects of knowledge, public services, and others. Productivity is assumed to be given for each agent in the competitive economy,

however. Suppose that a representative agent maximizes expected intertemporal utility

$$\begin{aligned} & \max E \sum_{t=0}^{\infty} \beta^t u(c_t) & (2.1) \\ \text{s.t. } & c_t + n_{t+1} \cdot k_{t+1} - k_t = y_t - \delta \cdot k_t \\ & y_t = \theta_t \cdot F(K_t, N_t, A_t)/N_t \\ & k_0: \text{ given} \\ & \ln \theta_t = \rho \cdot \ln \theta_{t-1} + \epsilon_t, \quad \epsilon_t \sim \text{i.i.d. } N(0, \sigma^2), \end{aligned}$$

where β is the discount factor ($0 < \beta < 1$), $u(c_t)$ is the instantaneous utility function

$$\frac{c_t^{1-\mu} - 1}{1 - \mu},$$

μ^{-1} is the intertemporal elasticity of substitution ($\mu > 0$), c_t is per capita consumption, y_t is per capita output, δ is the disposal rate of capital, and $\ln \theta_t$ is an AR(1) process ($0 \leq \rho < 1$).

2.2. Estimation Method

Unfortunately, the closed-form solution of the problem (2.1) is not known except special cases. The solution may be linearly approximated around the steady state, but such method may not be appropriate to check the behavior of a growing economy far from the steady state. Therefore, a nonlinear method that involves a wide range of the state space is desired to analyze a growing economy. For this purpose, this paper applies the PEA-Galerkin algorithm developed by Christiano and Fisher (1994), which is a hybrid of the projection method developed by Judd (1992) and PEA (Parameterized Expectations Approach) by den Haan and Marct (1990).

STEP 1: ESTIMATE PARAMETERS OF THE PRODUCTION TECHNOLOGY. First, estimate a set of parameter \mathbf{z} for production technology. Set an initial guess for a set of parameters \mathbf{x} for preferences.

STEP 2: SOLVE THE PROBLEM NUMERICALLY. Given an estimate $\hat{\mathbf{z}}$ at Step 1 and \mathbf{x} , obtain a numerical solution that satisfies the Euler equation

$$u'(c) = \beta \cdot E[u'(c')] \cdot \frac{1}{n'} \cdot \left(\frac{\partial y'}{\partial k'} + 1 - \delta \right) |k, \theta] \cong \beta \cdot \exp[h(k, \theta; \mathbf{a})], \quad (2.2)$$

where $h(k, \theta; \mathbf{a})$ is an orthogonal polynomial of state variables (k, θ) with a set of coefficient \mathbf{a} , and x' is the one step ahead of a variable x .

STEP 3: CALCULATE A SIMULATED SEQUENCE $\{\tilde{c}_t\}$. Calculate a simulated sequence $\{\tilde{c}_t\}$, where $\tilde{c}_t = c(k_t, \theta_t(\hat{\mathbf{z}}), \hat{\mathbf{z}}; \mathbf{x}) \cong (\beta \cdot \exp[h(k_t, \hat{\theta}_t; \mathbf{a})])^{-1/\mu}$ with the actual capital stock data $\{k_t\}$ and estimated stochastic shocks $\{\hat{\theta}_t\}$ given some \mathbf{x} and $\hat{\mathbf{z}}$ for $t = 1960 \dots 1990$.

STEP 4: REPEAT STEP 2 AND STEP 3 TO ESTIMATE \mathbf{x} TO FIT THE SIMULATED SEQUENCE TO THE ACTUAL DATA. Assuming errors are distributed normally in the log term

$$\ln c_t = \ln c(\mathbf{x}; k_t, \theta_t(\hat{\mathbf{z}}), \hat{\mathbf{z}}) + \eta_t,$$

where $\eta \sim \text{i.i.d.}, N(0, \sigma_\eta)$. Estimate $\hat{\mathbf{x}}$ by the nonlinear regression.

Accuracy of a numerical solution is tested by the accuracy test developed by Judd (1992); the Euler equation error is checked at $(k_t, \hat{\theta}_t)$ for all sample years, in addition to (100×80) equidistant grids over the state space.

STEP 5: CONSTRUCT AN ASYMPTOTIC CONFIDENCE INTERVAL OF $\{\tilde{c}_t\}$. Because the numerical solution and an estimated sequence of stochastic shocks are functions of the parameter set estimated at Step 1, I construct an asymptotic confidence interval of the sequence $\{\tilde{c}_t\}$ by the Delta method. When $\sqrt{n}(\hat{\mathbf{z}} - \mathbf{z}) \xrightarrow{D} N(0, \Sigma_z)$,

$$\sqrt{n}(c(k_t, \theta_t(\hat{\mathbf{z}}), \hat{\mathbf{z}}; \hat{\mathbf{x}}) - c(k_t, \theta_t(\mathbf{z}), \mathbf{z}; \hat{\mathbf{x}})) \xrightarrow{D} N(0, D\Sigma_z D'),$$

where D is the $(1 \times l)$ gradient vector

$$D = \left[\frac{\partial c(k_t, \theta_t(\mathbf{z}), \mathbf{z}; \hat{\mathbf{x}})}{\partial \mathbf{z}} \Big|_{\mathbf{z}=\hat{\mathbf{z}}} \right].$$

Because the gradient vector D cannot be calculated analytically, D is numerically calculated. An asymptotic confidence interval is constructed by

$$\left[\tilde{c}_t - c_\alpha \cdot \left[\frac{1}{n} D \Sigma_z D' \right]^{1/2}, \tilde{c}_t + c_\alpha \cdot \left[\frac{1}{n} D \Sigma_z D' \right]^{1/2} \right],$$

where c_α is a critical value.

3. DATA AND PARAMETERIZATION

3.1. Data

Macroeconomic variables except capital stock are obtained from *National Accounts 1990*, and *Economic Statistics Yearbook* by the Bank of Korea. Government consumption, private consumption, GDP, and gross capital formation are in the 1985 constant prices. The ratio of compensation of employees to value added to calculate TFP (total factor productivity) is also obtained from the same sources.³ In the estimation, trade deficit, government consumption, and an increase of stocks as a transaction cost are assumed to be exogenous to focus on the optimal allocation policy between (private) consumption and investment.⁴ Thus,

$$\begin{aligned} C_t + I_t &= GDP_t - (G_t + M_t - X_t + \Delta S_t), \\ &\equiv Y_t \end{aligned}$$

where G_t is government consumption, M_t is import, X_t is export, and ΔS_t is a change of stocks.

Population is obtained from *Korean Statistical Yearbook* by National Statistical Office. The growth rate of population was nearly 3 percent in 1960, and fell to almost 1 percent in the late 1980s. The growth rate of population is assumed to be a function of per capita capital stock and be deterministic for simplicity. The function is nonparametrically smoothed by cubic spline toward 0.4 percent at the deterministic steady state.

Capital stock is obtained from Pyo (1992). This paper uses real gross capital stock (gross fixed reproducible assets) with the total of nine industries.⁵ The disposal rate δ is assumed to be 0.02 from

³The primary sector is excluded from calculation, because of the unreliably low rate of compensation of employees. Compensation of employees in 1970 is applied for 1960–69 because of lack of the data.

⁴In terms of financial account, the deficit of total spending from income must be financed by external borrowing. In this paper, I implicitly assume that the government controlled international capital flow, including direct foreign investment (DFI). This seems to be a reasonable assumption for Korea, because foreign loans required governmental approval (Jones and Sakong, 1980), and direct foreign investment has been strictly regulated; DFI was consistently less than 1 percent in Korea, while other Newly Industrialized Countries in East Asia accepted a DFI of more than 5 percent GDP.

⁵A problem of this estimation is that estimated capital retirement is negative. Pyo (1992) explains “that the capital formation data in national income accounts are underestimated, and that the capital gains accrued are reflected only in latter national wealth survey.” There seems to be an inconsistency between the 1977 and 1987 National Wealth Survey, because the capital stock data from the late 1970s to the early 1980s could be distorted by high inflation. Therefore, a further adjustment on real gross capital stock is made.

Table 3.1: Average Annual Growth Rate (%)

GDP	Capital(K)	Population(N)	TFP
8.34%	8.04%	1.42%	3.86%

the disposal rate of tangible fixed assets in the manufacturing sector between 1984–90 from *Report on Mining and Manufacturing Survey* (various years) by the Korea Statistical Association and *Report on Industrial Census* (1988) by the Economic Planning Board.

3.2. Production Technology

This section provides the estimation result of the production technology (Step 1 in Section 2.2) using the annual data. For the convenience of calculating productivity, the aggregate production technology is assumed to be

$$Y_t = \theta_t \cdot A_t \cdot F(K_t, N_t),$$

where $F(K_t, N_t)$ is constant returns to scale.⁶

STEP 1: CALCULATE TFP. TFP growth (TFPG) is calculated by

$$TFPG = \frac{\Delta GDP}{GDP} - w \cdot \frac{\Delta N}{N} - (1 - w) \cdot \frac{\Delta K}{K},$$

where w is the ratio of compensation of employees to GDP , and Δ indicates a change. Table 3.1 reports the average annual growth rates of GDP , capital stock, population, and TFP .⁷ Set $TFP = 1.0$ in the initial year, and calculate the sequence of TFP and per capita GDP/TFP as an estimate of $f(k) = F(K, N)/N$.

STEP 2: ESTIMATE THE CES FUNCTION. $F(K, N)$ is parameterized as the CES production function. I avoid using the Cobb-Douglas

⁶Alternatively, labor-augmenting technological progress: $Y_t = \theta_t F(K_t, A_t N_t)$ may be considered. However, this form is not chosen due to estimation problem of productivity growth. In fact, if $F(K_t, A_t N_t)$ takes the Cobb-Douglas form, this form can be transformed to $\tilde{A}_t F(K_t, N_t)$.

⁷The estimated growth rate of 3.86 percent seems to be reasonable comparing to previous studies. Chen (1979) reports 4.99 percent (1955–70, country level), Nishimizu and Robinson (1984) report 3.71 percent (1960–77, manufacturing), Kwon (1986) reports 2.95 percent (1961–80, manufacturing), Dollar and Sokoloff (1990) report 6.1 percent (1963–79, manufacturing), and so forth.

Table 3.2: Production Technology

		Estimate	
CES Production function	a	0.7556 (0.0354)	
	b	0.5887 (0.0068)	
	τ	-0.2422 (0.0244)	$R^2 = 0.9998$
Productivity	$\ln A$	1.1007 (0.1162)	
	γ	0.8853 (0.3092)	
Stochastic shocks	ρ	0.8923 (0.0957)	$R^2 = 0.982$
	σ	0.0401	(D - W = 0.972)

Standard errors are in parentheses.

production function that fixes the ratio of labor compensation to output. The CES production function is parameterized as

$$f(k) = (ak^\tau + b)^{1/\tau}$$

Estimate (a, b, τ) by the nonlinear regression.

STEP 3: ESTIMATE STOCHASTIC SHOCKS. To evaluate the Euler equation (2.2), expectation scheme of productivity growth must be parameterized. TFP growth may be caused by various factors such as spillover effects of knowledge, learning by doing, or human capital accumulation by education. However, because the purpose here is not to seek the sources of the productivity growth and because productivity is given (whatever the sources of productivity growth) for an agent in the competitive economy, an arbitrary simple scheme that fits the actual productivity change is assumed. Productivity A_t is conventionally assumed to be related to the production experiences (without shocks for simplicity): $A_t \equiv \bar{A} \cdot \bar{y}_t^\gamma$, where $\bar{y}_t = \theta A_t f(k_t)|_{\theta=1}$.⁸ By simple manipulation, $A_t = \bar{A} \cdot f(k_t)^\gamma$ where $\gamma = \tilde{\gamma}/(1 - \tilde{\gamma})$ and \bar{A} is some constant. Estimate (\bar{A}, γ) and an AR(1) process of $\{\theta_t\}$

$$\ln y_t/\hat{f}_t = \ln \bar{A} + \gamma \cdot \ln \hat{f}_t + \ln \theta_t$$

$$\ln \theta_t = \rho \ln \theta_{t-1} + \epsilon_t,$$

where $\hat{f}_t = f(k_t; \hat{a}, \hat{b}, \hat{\tau})$.

Table 3.2 reports the results of estimation of the production technology. All of the estimates of parameters seem to be reasonable and p values are less than 1 percent. With these estimates,

⁸Other expectations scheme such as $A_t = \bar{A} \cdot y_t^\gamma$ or $A_t = \bar{A} \cdot k_t^\gamma$ were also tried, but did not affect the major result described later.

Table 4.1: Estimated μ

	$\hat{\mu}$
1960–90	0.9051 (0.1315)
1980–90	0.3857 (0.0084)

Standard errors are in parentheses.

per capita GDP in 1990 is yet almost half of the deterministic steady state.

In estimating stochastic shocks, autocorrelation still remains with assuming an AR(1) process. However, it becomes quite difficult to obtain a numerical solution by using a model with higher order serial correlation including $\{\theta_{t-1}, \theta_{t-2}, \dots\}$ in addition to k_t (θ_t) as state variables, because of the “curse of dimensionality.” Moreover, an introduction of higher order models may not be meaningful, because the annual time series data are limited to 31 samples (1960–90). Bearing these limitations in mind, I chose an AR(1) process instead of seeking higher order process.

4. RESULT

4.1. Optimizing Behavior

Due to the difficulty in obtaining convergence of the nonlinear regression,⁹ β is fixed to 0.95 from 10 percent interest rate of 1-year time deposit between 1984 November and 1988 December when the average annual inflation rate of CPI was 4.54 percent in Korea.¹⁰ Therefore, the inverse of the intertemporal elasticity of utility μ is only one estimator included in \mathbf{x} .

With $\beta = 0.95$, Table 4.1 reports estimates of μ ,¹¹ and its asymptotic standard errors for 1960–90 and 1980–90, respectively. Figures 1 and 2 compare actual and predicted (simulated) investment rate ($\equiv I/(I + C)$), i.e., the government consumption is excluded)

⁹A change of β causes a change of the deterministic steady state; consequently, a change of the range of the state space of capital stock is inevitable (a change of μ does not cause this problem). The nonlinear regression may bid up β while hunting for the best fit for β in the iteration, which may disastrously expand the state space.

¹⁰Source: Bank of Korea, *Economic Statistic Yearbook*, 1992.

¹¹The values of $\hat{\mu}$ seem to be quite small, but the values vary depending on the assumption of β . If β is bigger than 0.95, $\hat{\mu}$ becomes bigger.

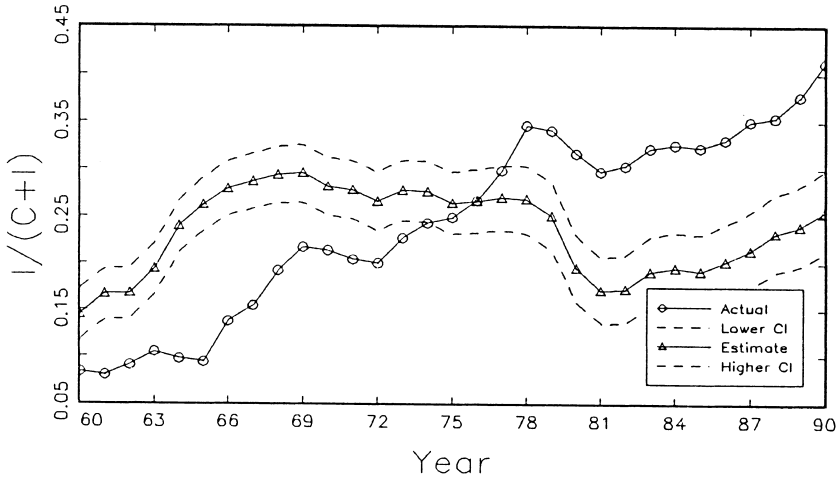


Figure 1. Investment behavior 1960–90.

with 95 percent asymptotic confidence intervals arising from estimation errors of production technology and stochastic shocks.

During the period 1960–90, actual investment rates steadily rose, while predicted investment rates are rather stable throughout the period. The actual path clearly crosses the interval as illustrated in Figure 1. The simulation with a numerical solution predicts investment rates higher for the 60s and for the early 70s, and lower for the late 70s and for the 80s than actual. Focusing on the 1980s, however, the simulated path seems to predict the actual path pretty well except 1990, as shown in Figure 2. The estimation result suggests that the model explains investment decision in 1980s well, but that the model fails to explain the rise in investment rates in the 1960s and 1970s. This result is robust by changing some of the parameterization. By changing β , a simulated path shifts parallel rather than rotating. Bigger β results in a higher investment rate throughout the periods. A change of expectation scheme of A_t does not affect the predicted behavior, either. For example, parameterization such as $A_t = k_t^\alpha$, which assumes that productivity is raised by spillover effects of knowledge generates the similar predicted path. The result is also robust using active labor as N_t for production instead of population, or changing the population growth rate at the deterministic steady state.

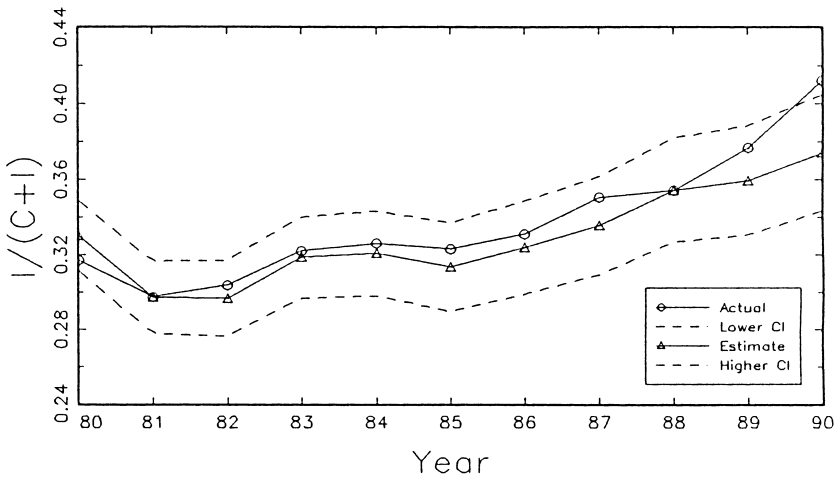


Figure 2. Investment behavior 1980–90.

4.2. Structural Change

During the period 1973–79, the Korean government intensively push the heavy and chemical industries (HCI Project) by heavily borrowing from abroad. Thanks to the project, manufacturing shifts from the light industry in the 1960s to the heavy industry in the 1980s. Therefore, it is not impossible that the transformation of production technology changed investment behavior.

Table 4.2 presents the estimation result of production technology for the period 1973–90¹² during and after the structural change. With these new estimates of production technology and previous estimate of μ , Figure 3 shows the actual path and the simulated paths for 1960–90¹³ and 1973–90. Investment rates slightly shift upward with the new production technology, but again, it is not enough to explain the rise in investment rates in the 1970s.

4.3. Externalities Effects

So far, it has been assumed that a representative agent takes the productivity growth as given. However, recent literature on

¹²Because of the convergence problem of the nonlinear estimation, AR(1) process is separately estimated.

¹³Because estimation for the early periods (such as 1960–79) fails to obtain meaningful result, the new path is compared to the path for the result on the whole period.

Table 4.2: Estimation for Alternative Models

	Structural change	Externalities ($\alpha = 0.2$)
CES Production function		
a	0.581 (0.0569)	0.7566 (0.0354)
b	0.5626 (0.0096)	0.5887 (0.0068)
τ	-0.0977 (0.0492)	-0.242 (0.0244)
	$R^2 = 0.9997$	$R^2 = 0.9998$
Productivity		
$\ln A$	1.0389 (0.0418)	0.6042 (0.1125)
γ	1.0251 (0.1166)	0.4644 (0.3087)
	$R^2 = 0.818$	
Stochastic shocks		
ρ	0.9232 (0.1569)	0.8897 (0.0951)
σ	0.0442	0.0405
	$R^2 = 0.684$ (D - W = 0.847)	$R^2 = 0.962$ (D - W = 0.982)

Standard errors are in parentheses.

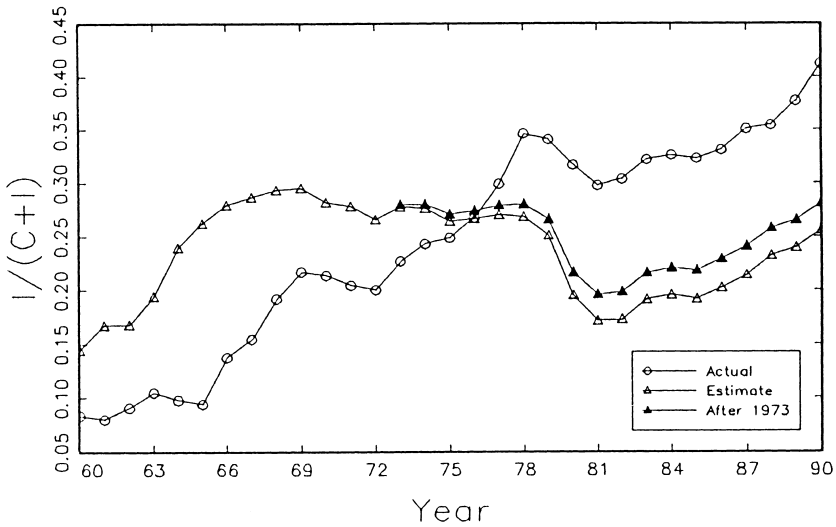


Figure 3. Structural change.

endogenous growth models has found that (human or physical) capital could be underinvested in the competitive equilibrium compared to a social optimum, because each agent behaves without considering externalities of her investment (e.g., Romer, 1986; Lucas, 1988). Also, effects of productive public services on growth can be considered in addition to private capital in production (Barro, 1990).

If part of the productivity growth is expected to be raised by externalities of investment and if the government is capable to control investment to some extent, investment rates could be higher than the previous results. For example, effects of investment in infrastructure and public enterprises of heavy industries on productivity growth might be considered in public investment decisions. The close relationship between the government and business groups in Korea might also help the governmental promotion of investment. Then, taking into the policy effects on investment, consider production technology is

$$y_t = \theta_t \cdot A_t \cdot g(k_t) \cdot f(k_t)$$

where $g(k) = k^\alpha$, which is a part of productivity, and $\partial y/\partial k = \theta A(g'(k)f(k) + g(k)f'(k))$ in the Euler equation (2.2).

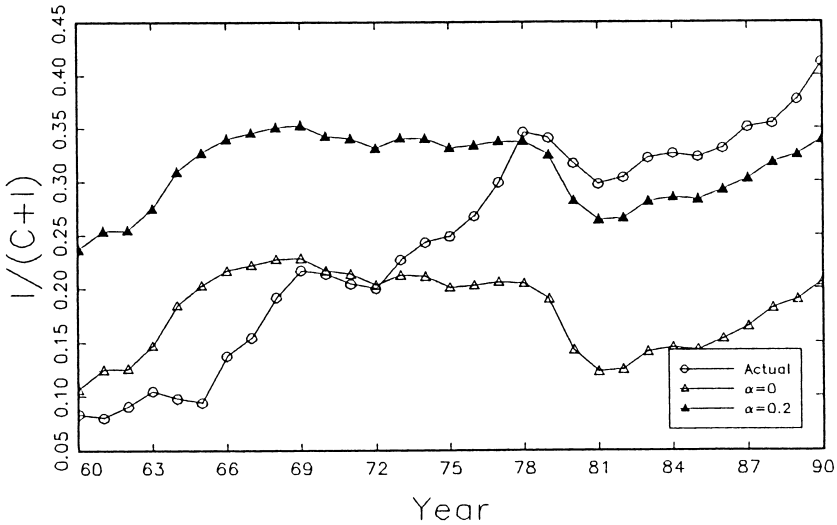


Figure 4. Externalities.

Simulation results using this formula indicates that investment rates become higher as externalities become bigger *throughout* the period. That means the model again fails to explain the change of investment behavior before 1980. However, if an economy shifts from the competitive economy toward socially planned economy, it is possible that investment rates are shifted up. Figure 4 illustrates the simulated paths with $\hat{\mu}$ in which the lower bound with $\alpha = 0$ and the higher bound with $\alpha = 0.2$ cover the actual path the best by the nonlinear regression. The result suggests that the shift from the lower bound to the upper bound occurs during the period 1973–78 that coincides with the period of the HCI project. However, a few shortcomings must be notified for this explanation. First, the bound is not yet wide enough to cover the actual path, even assuming the externality effect as big as $\alpha = 0.2$. Second, the lower bound does not predict the actual path for the period 1960–68 well. Third, investment behavior does not seem to shift back toward the competitive economy (i.e., the lower bound with $\alpha = 0$) in spite of economic liberalization effort in the 1980s in Korea.

5. CONCLUDING REMARKS

The purpose of this paper has been to quantitatively investigate whether or not investment behavior in Korea can be explained

by market forces. The estimation result suggests that market forces do not explain the rise in investment rates in the 1960s and 1970s, although investment behavior in the 1980s coincides with optimized investment behavior.

Two alternative models have been examined to investigate why the hypothesis of market forces is rejected in the 1960s and 1970s. Structural change from light industries to heavy industries in the 1970s also does not help to explain the rise of investment rates. On the other hand, effects of externalities of investment may help to explain the transition of investment behavior better than other models, while it is also possible that, for example, underdeveloped financial market bothered investment in early periods.

As previously studied, there are rich circumstantial evidences that governments could play an important role in driving economic growth in Korea. It is quite possible that the government intervention was one of the sources to raise investment rates, although further analysis is required to prove the relationship between government interventions and investment behavior.

REFERENCES

- Amsden, A.H. (1989) *Asia's Next Giants: South Korea and Late Industrialization*. New York: Oxford University Press.
- Barro, R.J. (1990) Government Spending in a Simple Model of Endogenous Growth. *Journal of Political Economy* 98:S103–S125.
- Barro, R.J., and Sala-i-Martin, X. (1992) Convergence. *Journal of Political Economy*. 100:223–251.
- Barro, R.J., and Sala-i-Martin, X. (1995) *Economic Growth*. New York: McGraw-Hill.
- Benhabib, J., and Jovanovic, B. (1991) Externalities and Growth Accounting. *American Economic Review* 81:82–113.
- Chen, E. (1979) *Hyper-Growth in Asian Economies*. New York: Holmes & Meier Publishers.
- Christiano, L.J., and Fisher, J.D.M. (1994) Algorithms for Solving Stochastic Dynamic Models with Occasionally Binding Constraints. Working paper, Northwestern University and Western Ontario University.
- De Long, J.B., and Summers, L.H. (1991) Equipment Investment and Economic Growth. *Quarterly Journal of Economics* 106:445–502.
- den Haan, W.J., and Marcet, A. (1994) Accuracy in Simulations. *Review of Economic Studies* 61:3–17.
- den Haan, W.J., and Marcet, A. (1990) Solving the Stochastic Growth Model by Parameterizing Expectations. *Journal of Business & Economic Statistics* 8:31–34.
- Dollar, D., and Sokoloff, K. (1990) Patterns of Productivity Growth in South Korean Manufacturing Industries, 1963–1979. *Journal of Development Economics* 33:309–327.
- Jones, L.P., and Sakong, I. (1980) *Government, Business, and Entrepreneurship in Economic Development: The Korean Case*. Cambridge MA: Harvard University Press.

- Judd, K.L. (1992) Projection Methods for Solving Aggregate Growth Models. *Journal of Economic Theory* 58:410–452.
- Judd, K.L. (1991) *Numerical Methods in Economics*. Manuscript, Hoover Institution, Stanford University.
- Kwon, J.K. (1986) Capital Utilization, Economies of Scale and Technical Change in the Growth of Total Factor Productivity. *Journal of Development Economics* 24:75–89.
- Levine, R., and Renelt, D. (1992) A Sensitivity Analysis of Cross-Country Growth Regressions. *American Economic Review* 82:942–963.
- Lucas, R.E. (1993) Making Miracle. *Econometrica* 61:251–272.
- Lucas, R.E. (1988) On the Mechanics of Economic Development. *Journal of Monetary Economics* 22:3–42.
- Marcet, A. (1994) Simulation Analysis of Dynamic Stochastic Models: Applications to Theory and Estimation. In *Advances in Econometrics: Sixth World Congress Vol. II* (C.A. Sims, Ed.). Cambridge: Cambridge University Press.
- Mason, E.S., et al. (1980) *The Economic and Social Modernization of the Republic of Korea*. Cambridge MA: Harvard University Press.
- Nishimizu, M., and Robinson, S. (1984) Trade Policies and Productivity Change in Semi-industrialized Countries. *Journal of Development Economics* 16:177–206.
- Pack, H., and Westphal, L.E. (1986) Industrial Strategy and Technological Change: Theory versus Reality. *Journal of Development Economics* 22:87–128.
- Press, W., Flannery, B.P., Teukolsky, S.A., and Vetterling W.T. (1989) *Numerical Recipes: The Art of Scientific Computing*. Cambridge: Cambridge University Press.
- Pyo, H.K. (1992) *A Synthetic Estimate of the National Wealth of Korea, 1953–1990*. KDI Working Paper, No. 9212.
- Pyo, H.K. (1988) Estimates of Capital Stock and Capital/Output Coefficients by Industries: Korea (1953–1986). *International Economic Journal* 3:79–121.
- Quah, D. (1993) Empirical Cross-section Dynamics in Economic Growth. *European Economic Review* 37:426–434.
- Rebelo, S. (1991) Long Run Policy Analysis and Long Run Growth. *Journal of Political Economy* 99:500–521.
- Romer, P. (1986) Increasing Returns and Long Run Growth. *Journal of Political Economy* 94:1002–1037.
- Rust, J. (1995) Structural Estimation of Markov Decision Process. In *Handbook of Econometrics, vol. 4*, (R. Engle and D. McFadden, Eds.). Amsterdam: North Holland.
- Sheshinski, E. (1967) Test of the Learning by Doing Hypothesis. *Review of Economics and Statistics* 49:568–578.
- Summers, L.H. (1990) What Is the Social Return to Capital Investment? In *Growth/Productivity/Unemployment: Essays to Celebrate Bob Solow's Birthday* (P. Diamond, Ed.). Cambridge, MA: MIT Press.
- Summers, L.H. (1990) What Is the Social Return to Capital Investment? In *Growth/Productivity/Unemployment: Essays to Celebrate Bob Solow's Birthday* (P. Diamond, Ed.). Cambridge, MA: MIT Press.
- Summers, R., and Heston, A. (1991) The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950–1988. *The Quarterly Journal of Economics* 106:327–368.
- Taylor, J.B., and Uhlig, H. (1990) Solving Nonlinear Stochastic Growth Models: A Comparison of Alternative, Solution Methods. *Journal of Business & Economic Statistics* 8:1–17.
- Ueda, A. (1994) *Capital Allocation and Economic Growth in Korea*, unpublished Ph.D. Thesis, University of Wisconsin–Madison.

Wade, R. (1990), *Governing the Market: Economic Theory and the Role of Government in East Asian Industrialization*. Princeton: Princeton University Press.

World Bank (1993) *The East Asian Miracle: Economic Growth and Public Policy*. Washington, DC: World Bank.

World Bank, Operations Evaluation Department (1992) *World Bank Support for Industrialization in Korea, India, and Indonesia*. Washington, D.C.: World Bank.