IMF Working Paper

WP/99/34

INTERNATIONAL MONETARY FUND

Monetary and Exchange Affairs Department

Institutions, Innovations, and Growth

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March 1999

Abstract

The fundamental importance of economic institutions for economic growth through their impact on technological change has been argued, reconfirmed by recent empirical studies, but not examined theoretically. This paper tries to fill that gap. In the model proposed, economic growth is affected by the efficiency and riskiness of research and development (R&D), which are endogenized through financial institutions. The theory and its results shed lights on the debate of convergence versus divergence; the "East Asia miracle" versus the East Asia financial crisis; and the rise and fall of centralized economies.

JEL Classification Numbers: E20, G28, O31, O40

Keywords: Financial Institutions, Technological Innovations, Economic Growth

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[1] Paper presented to the American Economic Association Annual Meetings, New York, January 1999, and forthcoming in the *American Economic Review, Papers and Proceedings*. We thank Philippe Aghion, Eric Maskin, and Gerard Roland for discussions and Nancy Hearst for editorial assistance.

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I. Introduction

The fundamental importance of economic institutions for economic growth through their impact on technological change has long been argued by Schumpeter and others. Recent empirical studies have reconfirmed such arguments. Barro (1997) finds that economic and political institutions are the most important factors to explain differences in growth across economies. A major implication of the debate on the 'East Asia miracle' and the East Asia financial crisis concerns the nature of institutions in the East Asian economies and the role of institutions in technological change. The rise and fall of centralized economies is another important indication that institutions greatly affect R&D (research and development) and growth. However, our understanding of the impacts of economic institutions on R&D and the consequences for growth is still far from satisfactory.

New growth theory (Aghion and Howitt, 1992; Lucas, 1988; Grossman and Helpman, 1991; and Romer, 1990) has made major breakthroughs in endogenizing technological changes. Although some insightful and inspiring discussions of institutional impacts on innovation are provided, there is little attempt in these models to explain what, aside from capital, labor inputs, and knowledge accumulation, determines innovation. Technological change is modeled essentially as a function of inputs while taking the institution as a given.

Another strand of literature examines the relationship between finance and growth (Greenwood and Jovanovic, 1990; King and Levine, 1993; Obstfeld, 1994; and Rajan and Zingales, 1998). However, in this literature economic growth is essentially determined by labor and capital inputs which are allocated more (or less) efficiently through better (or worse) financial means; no attempt is made to analyze how finance affects growth through its impact on innovation.

In this paper we attempt to fill the gap by examining how financial institutions affect technological innovation and thus affect growth. Our theory is based on the literature on soft-budget constraints (Kornai, 1980; Dewatripont and Maskin, 1995; and Qian and Xu, 1998) and the literature on endogenous growth.

The rest of the paper is organized as follows. Section II sets up a simple endogenous growth model with risk-free conventional production and risky R&D, while treating R&D activities as a reduced form. Section III incorporates informational and incentive problems of R&D activities into the growth model and shows how institutions affect equilibrium R&D activities. Finally, Section IV shows how institutions affect growth.

II. A Simple Endogenous Growth Model

In the model, consumers (and investors) live for infinite periods of time. In every period a small proportion of the consumers generates innovative ideas following an identical and independent stochastic process. That is, some consumers randomly become entrepreneurs but none of them continues to be an entrepreneur for more than one period. Moreover, entrepreneurs lack sufficient wealth to finance their ideas. For simplicity, we normalize the total population size to be 1.

The outputs of firms are from two activities – (conventional) production and R&D. Conventional production has no risk, and there are no informational problems involved between banks and firms. Thus banks play no particular role in conventional production, except to provide capital. This makes production in our model the same as that in most growth models. However, we model the important roles of banking institutions in R&D and growth.

Specifically, the production of a representative firm has an AK technology:

$$y_t = \left[\bar{A}\left(1-\alpha_t\right)+\widetilde{A}_t\alpha_t\right]k_t, \tag{1}$$

where $\bar{A}$ and $\widetilde{A}_t$ are productivity coefficients for production and R&D respectively; α_t is the share of investment in R&D and $0 \leq \alpha_t \leq 1$; k_t is the capital to labor ratio (that is K/L). In this one good economy, capital can be consumed or invested. Moreover, depreciation is impounded into the productivity coefficient.

In this economy, banks and firms are owned by consumers. The role of the banks is to select and finance projects on behalf of consumers and we rule out informational problems between consumers and banks. The sizes of banks are exogenously given and each bank is wealthy enough to finance at least one innovation in each period. Because banks do not play any particular role in conventional production, investments in production and R&D are two separate assets. We suppose that successful technological innovations will be sold at the end of each period to conventional production. Moreover, Schumpeterian "creative destruction" is involved in updating and replacing conventional technologies (Aghion and Howitt, 1992).

The capital invested in conventional production has a constant gross return, $1+\bar{A}$, per unit invested. Equating the marginal product of capital with r, we have $r=\bar{A}$. The capital invested in R&D has a risky return, $1+\widetilde{r}_t = 1+\widetilde{A}_t$, for each unit of capital invested at t. $\widetilde{r}_t$, to be determined below, has a mean $E_t[\widetilde{r}_t] > r$. In this economy, capital goods can move freely between risky and safe investment.

Assume that a representative consumer's preference is $U_t = E_t\left\{\sum_{s=t}^{\infty}\beta^{s-t}\ln C_s\right\}$. Since capital is the only source of income for each consumer, a representative consumer's budget constraint for consumption and investment in production and R&D is $K_{t+1} = [(1-\alpha_t)(1+r) + \alpha_t(1+\widetilde{r}_t)]\, K_t - C_t$, where K_t is the total amount of capital accumulated to $t-1$, including both R&D and production investments.

The Euler equation of the consumer's program with respect to investment in R&D is $u^{'}(C_t) = \beta E_t(1+\widetilde{r}_{t+1})u^{'}(C_{t+1})$, or,

$$1 = \beta E_t\left[(1+\widetilde{r}_{t+1})\frac{C_t}{C_{t+1}}\right], \tag{2}$$

given $u(C_t) = \ln C_t$.

The dynamic programming problem of the representative consumer is $V(K_t) = \max_{C_t}\left[\ln C_t + \beta E_t V(K_{t+1})\right]$. Solving it leads to the growth rate:

$$1+\overline{g} = \frac{K_{t+1}}{K_t} = \frac{C_{t+1}}{C_t} = \beta[1+r+\alpha(\widetilde{r}_{t+1}-r)], \tag{3}$$

where $\overline{g}$ is the steady state growth, and α denotes the equilibrium α_t. For $\widetilde{r}_{t+1}$ being i.i.d., α_t is a constant in equilibrium.

Linearizing the Euler equation (2) around the steady state, using $\frac{C_{t+1}}{C_t} = \beta[1+r+\alpha(\widetilde{r}_{t+1}-r)]$, and denoting variance by σ^2, we get

$$\alpha = \frac{E_t(\widetilde{r}_{t+1}-r)}{(1+r)\beta^2\sigma_t^2(\widetilde{r}_{t+1}-r)}. \tag{4}$$

Substituting (4) for (3), we reach the expected gross rate of growth in the following result (for the proof see Huang and Xu, 1998b).

Lemma 1 *The growth rate is*

$$E_t\left[\frac{C_{t+1}}{C_t}\right] = \frac{[E_t(\widetilde{r}_{t+1}-r)]^2}{(1+r)\beta\sigma_t^2(\widetilde{r}_{t+1}-r)} + (1+r)\beta. \tag{5}$$

From this lemma it is obvious that if the expected return of R&D investments increase or if the variance of R&D investments decrease, the growth rate goes up. Here R&D is treated as a reduced form. In the following, we are going to endogenize $\widetilde{r}_t$, innovation, and economic growth via the banking institutions. In a sense, some finance and growth models can be viewed as special cases of our model when the financial institution, $\widetilde{r}_t$, and r are all fixed (e.g. Obstfeld, 1994).

III. Financial Institutions and Innovation

A critical role of financial institutions in R&D is to solve informational and incentive problems related to R&D activities. We argue that because the uncertainties associated with R&D projects can only be reduced when a project is carried out, ex-post selection is more effective than ex-ante selection. However, an ex-post screening mechanism requires a commitment that a bad project must be stopped even when refinancing the bad project is ex-post profitable. We show that some financial institutions facilitate this screening mechanism, thus better promoting innovation and economic growth.

We suppose that in every period among all the projects proposed by entrepreneurs, λ percentage of them are of a good type, and the rest are of a bad type. Ex-ante, neither the entrepreneurs nor the banks know which project is good, but they are both aware of λ. A project takes three stages to finish, requiring a total investment of $I_1 + I_2 + I_3$. A good project generates an ex-ante profitable return, $Y > I_1 + I_2 + I_3$. A bad project, as it stands, generates no return. But it can be reorganized at the end of stage 2 and the best return a reorganized bad project can generate is $I_3 < X < I_2 + I_3$, that is, it is ex-ante unprofitable but can be ex-post profitable. The expected return of a project in the pool is greater than $(1 + r)$, i.e. $\frac{(1-\lambda)X+\lambda Y}{I_1+I_2+I_3} > 1 + r$.

We assume that if a project is financed, at stage 1 an entrepreneur will learn the type of her project, but the bank(s) still will not know the type. At stage 2, the bank(s) will know the type of the project, and if it is a bad one, a decision should be made either to liquidate or to reorganize.

We also assume that an entrepreneur gets a private benefit from working on a project. Specifically, if an entrepreneur quits a project at stage 1, she gets a low private benefit, $b_1 > 0$. At stage 2, if a bad project is liquidated, the entrepreneur gets an even lower private benefit b_{2b}, where $0 \leq b_{2b} < b_1$. At stage 3, if a bad project is reorganized and completed, it will generate $b_{3b} > b_1$ to the entrepreneur; in the case of a good project, it will generate $b_{3g} > b_{3b}$, to the entrepreneur.

When an entrepreneur proposes a project to a bank, the bank can either finance the project alone, or co-finance the project with other banks. We refer to the former as a case of single-bank financing, and to the latter as a case of multi-bank co-financing.[1] If a project is a good one, there is no efficiency difference between single-bank and multi-bank financing. Consequently, we will focus on the case of bad projects.

With respect to reorganizing a bad project, we assume that there are two strategies a and b to reorganize it during the third stage, but only one of these strategies can generate a profit ex-post. The right decision by the bank(s) in selecting a reorganization strategy depends on the information available to them: e.g. a is the right one if signal $s_A < s_B$ and vice versa. We suppose that in the case of multi-investor financing, investors A and B will observe signals s_A and s_B respectively.

We consider that there is a conflict of interests between the two banks. For example, a higher value of s_A may be more beneficial to bank A if the project is reorganized under strategy a than under strategy b; and vice versa. This implies that each bank J has a stronger incentive to use strategy j when it does not know the other's signal.

In the case of multi-bank financing, ex-post the two banks have to share their private information if they decide to reorganize a bad project. Given the private nature of the information, and the conflicts of interest between the two banks, Huang and Xu (1998a) show that under some specific efficiency and conflict of interest conditions, the cost of sharing information will be so high that liquidation is always better than reorganization. That is, multi-bank financing becomes an ex-post commitment device to stop bad projects. Moreover, this commitment to terminate bad projects can deter entrepreneurs from continuing a bad project after they privately learn its type.

In contrast, if a project is financed by a single bank, the bank will have all the information and will be able to use this information to choose an ex-post efficient strategy to reorganize the project. Therefore, the bank is not able to commit to terminating a bad project ex-post. Anticipating this result, when the entrepreneur at stage 1 discovers that her project is a bad one, she will always choose to continue. The following proposition summarizes the above discussion (see Huang and Xu, 1998a, for the proof).

Proposition 1 *All multi-bank-financed bad projects will be terminated by entrepreneurs at stage 1; however, all single-bank-financed bad projects will be continued.*

Following the above result, an economy with a dominance of R&D financing by single banks has soft-budget constraints (SBC), while an economy with a dominance of

[1] Single-bank financing refers to cases where financing decisions are made by a single agent, such as internal financing, government-coordinated financing, a principal bank system, etc. Multi-bank co-financing refers to cases where there are diversified and decentralized financial institutions and multiple banks/investors are involved in investment decisions. See Berglof and Roland (1998) for more interesting discussions.

R&D financing by multi-banks has hard-budget constraints (HBC). Denoting $I_\ell = I_2 + I_3$ and $Z = Y - X$, we summarize the statistical characterizations of the distributions of R&D investment returns under HBC and SBC economies.

Lemma 2 *The expected return rates of R&D under HBC and SBC economies are* $\overline{r}_h = \frac{\lambda Y}{I_1+\lambda I_\ell} - 1$ *and* $\overline{r}_s = \frac{(1-\lambda)X+\lambda Y}{I_1+I_\ell} - 1$ *respectively; and the variations of R&D under HBC and SBC economies are* $\sigma_h^2 = \frac{\lambda(1-\lambda)Y^2}{(I_1+\lambda I_\ell)^2}\left[\lambda + \frac{(1-\lambda)I_1^2}{(I_1+I_\ell)^2}\right]$ *and* $\sigma_s^2 = \frac{\lambda(1-\lambda)Z^2}{(I_1+I_\ell)^2}$ *respectively.*

Using Lemma 2 in (4), we obtain equilibrium investments for innovation in SBC and HBC economies (for the proof see Huang and Xu, 1998b).

Proposition 2 *There exists a* $\widehat{\lambda}$, *where*

$$\widehat{\lambda} = \frac{(1+r)I_\ell}{Y - [Y-(1+r)I_\ell]\left(\frac{Z}{Y}\right)^2},$$

such that when $\lambda \leq \widehat{\lambda}$, *i.e. the uncertainty of R&D projects is high, at equilibrium consumers in a HBC economy invest more in innovation than do consumers in a SBC economy; and vice versa.*

IV. Financial Institutions, Innovation, and Growth

Now, we analyze the effects of financial institutions on growth via their impact on innovation. Using Lemma 2 in (5), we obtain the growth rates for SBC and HBC economies, recorded in the following lemma (for the proof see Huang and Xu, 1998b).

Lemma 3 *The growth in SBC and HBC economies are respectively,*

$$\begin{aligned} E_t\left[\frac{C_{t+1}}{C_t}\right]_s &= \frac{\left[(1-\lambda)X + \lambda Y - (1+r)\left(I_1+I_\ell\right)\right]^2}{(1+r)\beta\lambda(1-\lambda)(Y-X)^2} + (1+r)\beta, \text{ and} \\ E_t\left[\frac{C_{t+1}}{C_t}\right]_h &= \frac{\left[\lambda Y - (1+r)\left(I_1+\lambda I_\ell\right)\right]^2}{(1+r)\beta\lambda(1-\lambda)Y^2\left[\lambda + \frac{(1-\lambda)I_1^2}{(I_1+I_\ell)^2}\right]} + (1+r)\beta. \end{aligned}$$

A comparison of the growth rate in a SBC economy with that in a HBC economy leads to the following result (for the proof see Huang and Xu, 1998b).

Proposition 3 *There exists a* λ^*, *where*

$$\lambda^* = \frac{\left\{ \frac{Z}{Y}\left[Y-(1+r)I_\ell\right] + \sqrt{(\frac{Z}{Y})^2\left[Y-(1+r)I_\ell\right]^2 + 4Z\left[(1+r)I_\ell - X\right]} \right\}^2}{4Z^2}.$$

such that when $\lambda \leq \lambda^*$, *i.e. the uncertainty of R&D projects is high, a HBC economy has a higher growth rate than a SBC economy; and vice versa. Moreover, in general* $\lambda^* > \widehat{\lambda}$.

Our theory predicts that a HBC economy will promote R&D better and will achieve a higher growth rate than a SBC economy when the uncertainty of R&D projects is high, i.e., $\lambda < \widehat{\lambda}$ (such as when an economy is at an advanced technological stage). However, when R&D projects have low uncertainties ($\lambda > \lambda^*$), such as when an economy is at a catching-up stage and R&D projects are characterized by imitation, a SBC economy may invest more in imitation and thus have a higher growth rate than a HBC economy. Finally, when the uncertainty of R&D projects is in the middle, i.e., $\widehat{\lambda} < \lambda < \lambda^*$, a HBC economy invests less in R&D but still generates a higher growth than a SBC economy.

Our theory has testable predictions which should lead to future empirical work. Many of our predictions are consistent with existing empirical findings, such as those of LaPorta et al. (1997) and Rajan and Zingales (1998, thereafter RZ). Specifically, we predict that external financing as a device to harden budget constraints should be more popular in successful industries involving intensive R&D, particularly at stages when uncertainty is high. This is consistent with RZ that external financing is high in pharmaceutical, electronics, computer industries (RZ Table 1), particularly when companies are young (RZ Table 1 and Figure 1).

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