Institutions, Innovations, and Growth

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The fundamental importance of economic institutions for economic growth through their impact on technological change has long been argued by Joseph Schumpeter and others. Recent empirical studies have reconfirmed such arguments. Robert Barro (1997) finds that economic and political institutions are the most important factors in explaining 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, understanding of the impacts of economic institutions on R&D and the consequences for growth is still far from satisfactory.

New growth theory (Robert Lucas, 1988; Paul Romer, 1990; Gene Grossman and Elhanan Helpman, 1991; Philippe Aghion and Peter Howitt, 1992) has made major breakthroughs in endogenizing technological changes. However, 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.

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Another strand of literature examines the relationship between finance and growth (Jeremy Greenwood and Boyan Jovanovic, 1990; Robert King and Ross Levine, 1993; Maurice Obstfeld, 1994; Raghuram Rajan and Luigi 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 (János Kornai, 1980; Mathias Dewatripont and Eric Maskin, 1995; Erik Berglof and Gérard Roland, 1998; Huang and Xu, 1998a; Yingyi Qian and Xu, 1998) and the literature on endogenous growth.

I. 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 generate 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 (i.e., aggregate output is linear in capital):

$$y_t = [\bar{A}(1 - \alpha_t) + \tilde{A}_t\alpha_t]k_t \tag{1}$$

where $\bar{A}$ and $\tilde{A}_t$ are productivity coefficients for production and R&D, respectively; α_t is the share of investment in R&D, with $0 \leq \alpha_t \leq 1$; k_t is the capital-to-labor ratio (i.e., 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, $1 + \tilde{r}_t = 1 + \tilde{A}_t$, for each unit of capital invested at t; $\tilde{r}_t$, to be determined below, has a mean $E_t(\tilde{r}_t) > r$. In this economy, capital goods can move freely between risky and safe investment.

Assume that a representative consumer's preference is $U_t = E_t(\sum_{s=t}^{\infty} \beta^{s-t} \ln C_s)$. 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

$$K_{t+1} = [(1 - \alpha_t)(1 + r) + \alpha_t(1 + \tilde{r}_t)]K_t - C_t$$

where K_t is the total amount of capital accumulated by time $t - 1$, including both R&D and production investments.

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

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

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

The dynamic programming problem of the representative consumer is

$$V(K_t) = \max_{C_t} [\ln C_t + \beta E_t V(K_{t+1})].$$

Solving it leads to the growth rate:

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

where $\bar{g}$ is the steady-state growth, and α denotes the equilibrium α_t. For independently and identically distributed $\tilde{r}_{t+1}$, α_t is a constant in equilibrium.

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

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

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*

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

From this lemma it is obvious that, if the expected return to R&D investments increases or if the variance of R&D investments decreases, the growth rate goes up. Here R&D is treated as a reduced form. In the following section, we endogenize $\tilde{r}_t$, 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, $\bar{r}_t$, and r are all fixed (e.g., Obstfeld, 1994).

II. 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, a percentage λ 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 $1 + r$; that is,

$$\frac{(1 - \lambda)X + \lambda Y}{I_1 + I_2 + I_3} > 1 + r.$$

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 will 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 multibank cofinancing.[1] If a project is a good one, there is no efficiency difference between single-bank and multibank 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., strategy 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 interest 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 multibank 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 conflict of interest between the two banks, in Huang and Xu (1998a), we show that under some specific efficiency and conflict-of-interest condi-

[1] Single-bank financing refers to cases where financing decisions are made by a single agent, such as internal financing, government-coordinated financing, or a financing by a principal-bank system. Multibank cofinancing refers to cases where there are diversified and decentralized financial institutions and where multiple banks/investors are involved in investment decisions.

tions, the cost of sharing information will be so high that liquidation is always better than reorganization. That is, multibank 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 multibank-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's) while an economy with a dominance of R&D financing by multibanks has hard budget constraints (HBC's). 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, respectively,*

$$\bar{r}_h = \frac{\lambda Y}{I_1 + \lambda I_\ell} - 1$$

and

$$\bar{r}_s = \frac{(1-\lambda)X + \lambda Y}{I_1 + I_\ell} - 1$$

and the variations of R&D under HBC and SBC economies are, respectively,

$$\sigma_h^2 = \frac{\lambda(1-\lambda)Y^2}{(I_1 + \lambda I_\ell)^2}\left[\lambda + \frac{(1-\lambda)I_1^2}{(I_1 + I_\ell)^2}\right]$$

and

$$\sigma_s^2 = \frac{\lambda(1-\lambda)Z^2}{(I_1 + I_\ell)^2}.$$

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* $\hat{\lambda}$, *where*

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

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

III. Financial Institutions, Innovation, and Growth

We will now 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,*

$$E_t\left[\frac{C_{t+1}}{C_t}\right]_s$$

$$= \frac{[(1-\lambda)X + \lambda Y - (1+r)(I_1 + I_\ell)]^2}{(1+r)\beta\lambda(1-\lambda)(Y-X)^2}$$

$$+ (1+r)\beta$$

and

$$E_t\left[\frac{C_{t+1}}{C_t}\right]_h = \frac{[\lambda Y - (1+r)(I_1 + \lambda I_e)]^2}{(1+r)\beta\lambda(1-\lambda)Y^2\left[\lambda + \frac{(1-\lambda)I_1^2}{(I_1+I_e)^2}\right]} + (1+r)\beta.$$

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

PROPOSITION 3. *There exists a* λ^*, *where*

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

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

Our theory predicts that an HBC economy will promote R&D better and will achieve a higher growth rate than an SBC economy when the uncertainty of R&D projects is high (i.e., when $\lambda < \hat{\lambda}$), 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, an SBC economy may invest more in imitation and thus have a higher growth rate than an HBC economy. Finally, when the uncertainty of R&D projects is in the middle (i.e., $\hat{\lambda} < \lambda < \lambda^*$), an HBC economy invests less in R&D but still generates higher growth than an 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 Raphael LaPorta et al. (1997) and Rajan and Zingales (1998). 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 Rajan and Zingales's finding that external financing is high in pharmaceutical, electronics, computer industries (their table 1), particularly when companies are young (their table 1 and fig. 1).

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