Emulation-Based Growth: Technology and Institutions

Jian Tong
University of Southampton

Chenggang Xu
LSE, HKUST and Tsinghua University

October 2, 2006

Abstract

This paper develops a new growth theory and provides new evidence on economic development in the world. The theory characterizes an emulation-based growth mechanism. We explain why (more) market-based financial institutional structures prevail in the advanced economies whereas many later developed and successful developing economies embrace the (more) bank-based institutional structures. Economies of emulation in R&D financing and the level of legal development are found to hold the answer.

Key words: economies of emulation, growth inertia, governance, financial institutions, asset pricing

1 Introduction

Numerous historical accounts of economic development suggest that successful developments are associated with active R&D, even when most technologies used in the development process are adopted from abroad. Examples include the catching up of the continental Europe and Japan in the late 19th century and early 20th century, 'newly industrialized countries' after the WWII (Gerschenkron 1962, Odagiri and Goto 1993, Kim 1993, Hou and Gee 1993), and the rise of China and India in the recent two decades (according to the latest statistics almost one third of China's exports are high tech products; India already becomes a leadinng software exporter in the world). However, not much work has been done to relate R&D-based growth models to developing countries. One reason for this probably lies in the perception that the R&D-based growth models are less relevant to the developing world that does not make much innovation (for example, see Jones 1995a, pp501). That is because except for a few technologically leading countries, most economies in the world apply technologies that were invented somewhere else. In this sense, technology is exogenous from the domestic productive system. This observation is tempting to suggest that the Solow neoclassical growth theory is a better approximation of what drives growth in developing economies. This has been the spirit of some influential cross-country empirical researches (Mankiw, Romer and Weil, 1992, and Evans 1996, 1998).[1]

In this paper we provide empirical evidence to show that there are important cross country regularities which cannot be explained by Solow model. We then develop a R&D-based growth model, which can better explain cross-country differences in per capita income and growth. The key aspect of our theoretical argument concerns mechanisms of imitative R&D activities.[2] We divide R&D activities into inventive and imitative R&D respectively. And we interpret most R&D activities of the developing economies as "imitative R&D". In our theory we will consider a whole continuum between pure invention and pure imitation, and countries vary in this dimension. Our theoretical argument builds on the following three ingredients: (1) The stock of opportunities for (domestic) imitation grows when the world technological frontier moves relatively further ahead. For an economy which is not at the frontier, this is one of the essential sources of technological progress and economic growth. (2) Fundamentally, economies grow by creation and exploration of "new" ideas, which are pursued by entrepreneurs with significant economic costs. (3) Investing in inventing and exploiting "new" ideas through R&D is risky and involves a high degree of informational asymmetry between entrepreneurs and external investors. This requires appropriate corporate governance to provide right incentives to entrepreneurs, and to encourage external investors' participation.[3]

A consensus among different growth theories is that without technical progress, the growth of per capita income simply can not sustain. As an empirical im-

[1] Citing Howitt (2000): "Cross-country evidence on income differences has been used in recent years to cast doubt on endogenous growth theory".

[2] Cohen and Levinthal (1989) convincingly argue that R&D not only generates new information, but also enhances a firm's ability to assimilate and exploit existing information; in short, there are "two faces of R&D".

[3] We follow the assumption usually made in the R&D literature that entrepreneurs who have the right ideas do not have the personal wealth to finance the R&D projects entirely.

plication, the dynamics of per capita income should reflect the dynamics of the technological progress. If technological progress is exogenous, then the dynamics of per capital income will mainly be determined by the convergence effect due to diminishing returns to capital accumulation. Hence, by comparing dynamics patterns of per capital income with this neoclassical theoretical prediction, it is empirically possible to establish whether technological progress displays any pattern of endogenous determination.

By studying economic growth of 168 countries in the world (the Penn World Table panel data of the period 1950-2000), most of which are developing economies, we find that the typical pattern of long run growth displays a fair amount of positive autocorrelation. The correlation coefficient between real per capita GDP and its one year laggard is a statistically highly significant 0.126. Furthermore, even when the country-specific steady state level is controlled for the autocorrelation still remains positive and significant. We believe that this residual positive autocorrelation can not be accounted for by the neoclassical growth theory. Thus, it reflects a new property of the process of technological progress yet to be explained.

Table 1 list the empirical results in some detail. It shows the regressions of the growth rate of per capita GDP on lagged growth rate, with or without controls over the conditional convergence effect. Column (3) is the preferred specification, which uses the fixed effect regression to control country-specific steady state levels. The coefficient of the per capita GDP level has the expected sign according to the prediction of conditional convergence. If the positive autocorrelation in growth rate is merely the familiar conditional convergence in disguise, one should expect the autocorrelation to become insignificant in regression (3). To make sure this result is not driven by short run business cycles, we use the Hodrick-Prescott filter to remove the business cycle components. The results with HP filtered data reported in columns (4)-(6) strengthen the original finding of the residual positive autocorrelation. The evidence clearly suggests that the positive autocorrelation in growth can not be fully accounted for by the conditional convergence effect. Then there must be some other economic force that is responsible for this residual positive autocorrelation in growth rates. The question is what are these factors.

In this paper we develop a theory of emulation-based growth to explain the residual positive autocorrelation of growth rates. The central idea of our theory is to examine the relationship between the residual positive autocorrelation in growth rate and the dynamics of endogenous technological progress, which is a function of intentional investment in R&D, and links closely with the dynamics

	OLS (1)	OLS (2)	FE (3)	HP, OLS, (4)	HP, OLS (5)	HP, FE (6)
one-year lagged growth rate	.12622***	.1246082***	.0680614***	.9787603***	.9806255***	.9571616***
	(.0139917)	(.014001)	(.0142296)	(.0038439)	(.0039648)	(.0046162)
one-year lagged per capita GDP		4.62e-07**	-2.18e-06***		-.0001549	-.0021873***
		(1.79e-07)	(3.68e-07)		(.0000814)	(.0002117)
constant	.0179866***	.0155004***	.0310072***	.0004066***	.0001736	.0195618***
	(.001046)	(.0014208)	(.0310072)	(.0001099)	(.0001645)	(.001835)
observation	5103	5101	5101	2450	2450	2450
R^2	0.0157	0.0170	n.a.	0.9636	0.9637	n.a.

Table 1: Regression of growth rate of per capita GDP
(Note: *, ** and *** indicate statistical significance at 10%, 5% and 1% levels respectively)

of asset pricing for intellectual properties. The theory is motivated by the observation that the technological progress of a developing economy is a joint product of international knowledge spillover and internal R&D investments. Developing economies could be beneficiaries of the positive externalities of the technological inventions and innovations made by the developed economies. But to reap the full benefit of these positive externalities, the developing countries have to exert sufficient own efforts in investing in learning, adapting the imported technologies. The stock of these positive externalities is a stock of opportunities of emulation. The more laggard a country is behind the world technological frontier, the bigger is its stock of emulation opportunity. However, this opportunity can never be materialized automatically. A country's economic growth hinges on how well it puts its stock of opportunities into action, particularly emulation based R&D activities.

In our model we investigate the role of financial institutions play in R&D investment. We argue that the inability of entrepreneurs to pledge the entirety of the returns of investments to the external investors due to agency problems or other contractual problems leads to credit rationing and underinvestment in R&D and technological progress. An example is venture capital financing. It typically involves performance-contingent stage financing, therefore further external financing remains essential and the entrepreneur gives numerous costly concessions besides cash flow rights to the venture capital financier. The ability of this kind of private contracting to address the credit rationing problem depends on legal protection of investors.

In principle, governance services can be provided both by government and private agents. The ideal structure of governance provision should feature that government providing effective impartial rule of law and contract enforcement, protection of property rights, respect to civil liberty, and keeping an arm's length relationship with the markets; meanwhile allowing private governance provisions by institutions such as private law firms, accounting firms, financial institutions, press and media firms, or by associations[4] of civil society to develop in accordance to civil liberty, professionalism, the rule of law, and market forces. With this kind of structure, the private provision of governance services supplements the public provision, and generates a significant multiplier effect. The development of many of these examples of private provision of governance services clearly relies on solid public provision of fundamental governance services, such as impartial rule of law, civil liberty, and protection of property rights. The fact this "ideal" structure is the reality of the most advanced economies speaks of its virtue. We call the measurement in this dimension the 'legal development'. Unfortunately the perfect 'legal development' is far from the reality of the developing countries for various reasons. For instance, historically predetermined legal, political conditions may deviate from impartial rule of law, respect to civil liberty and commitment to protect property rights. As a result the otherwise potentially well functioning (supplementary) private provision of governance service is underdeveloped. These inevitably affect both public provision and private provision of governance services, and equilibrium private contracting.

Our analysis of the financial institutional structure and its determinants depends the following assumptions. First, the lesser the legal development, the less adequate the set of feasible contractual and financial instruments available to help private contracting to improve external investor protection. Second, the more economies of emulation the better the external investor protection available (other things being equal). Among the contractual/financial instruments that can be used to provide external investor protection in connection to R&D investments, it is useful to distinguish whether and to what degree the contractual instruments rely on stock market based performance assessments, e.g., stock price contingent cash flow rights and control rights. On the one end of the spectrum along this dimension is market-based financial institutional structure, which hinges on stock market valuation. On the other end of the spectrum is the (purely) bank-based financial institutional structure, where bank loan and the associated liquidation rights are at the heart of the system. In between we have the hybrid type between the (pure) market-based and the (pure) bank-

[4] These should include professional bodies and academia.

based structures. The other two substantial assumptions of our analysis are that the effectiveness of the less market-based structures is less sensitive to the level of legal development; and that it is more sensitive to the effect of emulation economies. For example, the since bank-based financial institutional structure does not rely on stock market-based performance measurements, its effectiveness is less affected by lesser legal development and the inadequacy of governance services that support the stock market. The cost of using the (pure) bank-based structure is that the liquation rights associated with bank loans make the normal entrepreneurial business process vulnerable to the interventions of non-experts of the business. This intervention cost is lower if the technology is easier to understand/explain to the external investors due to the abundance of positive externality (emulation economies). Based on these four assumptions we show that the comparative advantages (disadvantages) of the various financial institutional structures depend on the legal development and the position of relative economic development. We also show that in steady state, both the endogenous financial institution structure and the position of relative economic development depend on the parameter of legal development. This last prediction is tested and supported empirically in the empirical section of the paper.

The remainder of the paper is organized as follows: Section 2 develops a model of emulation-based R&D and growth, with endogenous financial institutional structure. In Section 3 we test the predictions of the model empirically. Section 4 further relates our findings to the literature, and discusses their robustness before we conclude in Section 6.

2 Model

Our model economy exists for an infinite number of periods labelled $t = 0, 1, 2, \cdots, \infty$. There are L identical risk-neutral consumers, who live forever, each has one unit of labour supply per period. Each consumer's utility maximization problem is:

$$\begin{array}{l} \max \sum_{t=0}^{\infty} \frac{c_t}{(1+\rho)^t} \\ s.t. : b_{t+1} = w_t + b_t\left(1 + r_t\right) - c_t, \end{array} \tag{1}$$

where c_t is consumption, w_t is wage income, b_t is the holding of risk-free debt contract[5] with interest rate r_t, ρ is the discount rate; in equilibrium, $r_t = r = \rho$,

[5] The financial claim against the physical capital stock is risk-free because there is no technological uncertainty, and the claim can be secured by taking the physical capital stock and the inventory of a borrowing firm as collateral. It does not matter whether the debt contract is publicly floated bond or bank loan.

implying an infinite elasticity of supply of physical capital.

2.1 Production

Production in this economy comprises a final good sector and an intermediate good sector. The final good sector is perfectly competitive, and it has a Cobb-Douglas technology with intermediate inputs x_{it}, labor input L_{1t}, and output:

$$Y_t = L_{1t}^{1-\alpha} \sum_{i=1}^{A_t} x_{i_t}^{\alpha},\ 0 < \alpha < 1, \tag{2}$$

where A_t is the number of varieties of intermediate goods, which is also a measure of domestic knowledge stock. The firm's maximization program is

$$\max_{x_{it}, L_{1t}} \left(L_{1t}^{1-\alpha} \sum_{i=1}^{A_t} x_{i_t}^{\alpha} - (1+r)\, p_{it} x_{it} - L_{1t} w_t \right), \tag{3}$$

where p_{it} is the price of intermediate good x_{it}, and w_t is the wage of labor at period t. The final good producers pay the intermediate goods producers at the beginning of each period to get the inputs, and sell their own products and pay their workers at the end of each period. The final good producer can finance the input of physical capital either by borrowing from a bank, or by issuing bond in the market; either way the financial claim can be secured by taking the physical capital stock and the inventory of a borrowing firm as collateral, hence is risk-free, and has no real effect on production decision. The optimal demands for intermediate goods and labor are:

$$x_{it} = \alpha \frac{Y_t}{(1+r)\, p_{it}} \frac{x_{it}^{\alpha}}{\sum_{i=1}^{A_t} x_{i_t}^{\alpha}}, \tag{4}$$

and

$$L_{1t} = \frac{(1-\alpha)\, Y_t}{w_t}. \tag{5}$$

The producer of intermediate good i is a monopolist with the following profit maximization program:

$$\begin{aligned} \max_{p_{it}, x_{it}} \pi_{it} &= \max_{p_{it}, x_{it}} \left(p_{it} x_{it} - x_{it} \right), \\ s.t. &: \alpha L_{1t}^{1-\alpha} x_{it}^{\alpha-1} = (1+r)\, p_{it} \end{aligned} \tag{6}$$

and its solution is

$$p_{it} = \frac{1}{\alpha}. \tag{7}$$

Even if a monopolist firm owns multiple (intermediate) products, the pricing of each product will not be affected because these products are neither substitutes or complements.

The solutions for all intermediate good producers are symmetric, so the subscript i can be dropped. Then we have,

$$x_t = \frac{\alpha^2 Y_t}{A_t (1+r)} = \alpha^{\frac{2}{1-\alpha}} (1+r)^{\frac{-1}{1-\alpha}} L_{1t}, \tag{8}$$

$$p_t = \frac{1}{\alpha}, \tag{9}$$

$$\pi_t = (1-\alpha)\, \alpha^{\frac{1+\alpha}{1-\alpha}} (1+r)^{\frac{-1}{1-\alpha}} L_{1t}, \tag{10}$$

$$w_t = \frac{(1-\alpha) Y_t}{L_{1t}}, \tag{11}$$

$$\frac{Y_t}{A_t} = \alpha^{\frac{2\alpha}{1-\alpha}} (1+r)^{\frac{-\alpha}{1-\alpha}} L_{1t}, \tag{12}$$

and

$$L_{1t} = \frac{(1-\alpha) Y_t}{w_t}. \tag{13}$$

Define $\bar{w} \triangleq \frac{w_t}{A_t}$, the ratio of wage vis-a-vis knowledge stock, we have

$$\bar{w} = \frac{w_t}{A_t} = \frac{(1-\alpha) Y_t}{L_{1t} A_t} = (1-\alpha)\, \alpha^{\frac{2\alpha}{1-\alpha}} (1+r)^{\frac{-\alpha}{1-\alpha}}, \tag{14}$$

$$w_t = A_t \bar{w} \text{ for } L_{1t} > 0,$$

and w_t is undefined when $L_{1t} = 0$.

Then, the profit for every intermediate firm in each period is,

$$\pi_t = \frac{\alpha \bar{w}}{1+r} L_{1t}. \tag{15}$$

We have assumed that physical capital stock depreciates completely after one period. This implies that in equilibrium, the saving of the final good at the end of period t should equal the demand for physical capital at the beginning of period $t+1$, which is $A_{t+1} x_{t+1}$. Since aggregate saving can not exceed the aggregate output, it ensues that $A_{t+1} x_{t+1} \leq Y_t$. This constraint must be satisfied and usually should not be binding; if it is binding, we can not guarantee the interior solution to the consumers' maximization problem (1), i.e., $r_t = r$.

Using eq. (8) and (12) to eliminate x_{t+1} and Y_t in the above constraint yields the following:

$$A_{t+1}\alpha^{\frac{2}{1-\alpha}}(1+r)^{\frac{-1}{1-\alpha}}L_{1t+1} \leq \alpha^{\frac{2\alpha}{1-\alpha}}(1+r)^{\frac{-\alpha}{1-\alpha}}L_{1t}A_t. \tag{16}$$

Denoting the steady state value of L_{1t} as L_1, then steady state values of x_t and π_t are

$$x = \alpha^{\frac{2}{1-\alpha}}(1+r)^{\frac{-1}{1-\alpha}}L_1, \tag{17}$$

and

$$\pi = \frac{\alpha\bar{w}}{1+r}L_1. \tag{18}$$

2.2 R&D, Finance and Corporate Governance

The number of new intermediate products introduced in period $t+1$ as results of R&D activities at t is determined by the productivity of the R&D sector, $\frac{\delta}{(a_t)^\eta}$, labor input in the R&D sector, L_{2t}[6], and the knowledge stock at the time, A_t, i.e.,[7]

$$A_{t+1} - A_t = \frac{\delta}{(a_t)^\eta}L_{2t}A_t. \tag{19}$$

Where, L_{2t} is determined by the labor market clearing condition:

$$L_{2t} = L - L_{1t}, \tag{20}$$

a_t is the position of relative development in the world, formally, $a_t \triangleq \frac{A_t}{A_{ft}}$, A_{ft} is the knowledge stock of the leading economy in the world, who is the target of emulation by all follower economies. The productivity of the R&D sector, $\frac{\delta}{(a_t)^\eta}$, decreases in a_t; this is due to emulation economies.

In each period there are a sufficiently large number of entrepreneurs, each of whom has an R&D project, needs to hire l workers to introduce new intermediate products. Each entrepreneur offers a contract $(\tilde{\omega}_{jt}, s_{jt})$ to external investors in the perfectly competitive capital market, where $\tilde{\omega}_{jt}$ is amount of investment funded by entrepreneurial (own) wealth ω_t ($\omega_t = \bar{\omega}A_t > 0$), thus $\tilde{\omega}_{jt} \leq \omega_t$; the request of external finance thus is $w_t l - \tilde{\omega}_{jt}$; s_{jt} is an index of external investor

[6] Here, we follow the standard Romer model by assuming R&D only needs labor inputs. Our main result will go through if we relax this assumption of extremely high labor intensity in the R&D technology, as long as we avoid assuming extremely high capital intensity in R&D.

[7] We have assumed that the R&D production function is linear in L_{2t} and A_t. These are not critical assumptions for any of our main results. We can have alternatively used Cobb-Douglas R&D production with moderate capital intensity, which gives similar results. Due to space limit, we do not report the analysis based on that more general specification.

protection provided by the corporate governance structure of the firm, $0 \leq s_{jt} \leq \theta(\sigma, a_t)$; $\theta(\sigma, a_t)$ is the upper limit of feasible external investor protection, which measures the availability and effectiveness of feasible contractual and financial instruments. One important reason for s_{jt} to be bounded above is that if the external investors are overly protected, e.g., by excessive liquidation rights, then their excessive intervention may jeopardize the normal entrepreneurial business process and the project may fail because of that.

Suppose the entrepreneur's human capital is the essential asset of the firm that is created by the R&D project. Consequently the entrepreneur has a private benefit, which is to quit the original firm, and start a new firm with the probability of success being $(1 - s_{jt})$; if the entrepreneur quits, then the firm is not viable, but the new firm can replace the original one if succeeds. Therefore the expected value of the private benefit for the entrepreneur equal $l\frac{\delta}{(a_t)^\eta} A_t V_t (1 - s_{jt})$, where $l\frac{\delta}{(a_t)^\eta} A_t V_t$ is the value of the new firm, V_t is asset value of each product, $l\frac{\delta}{(a_t)^\eta} A_t$ is the number of products. Due to the 'limited liability' constraint and the 'inalienability of human capital', the original firm does not have the legal/contractual right to stop the entrepreneur from quitting. To induce the entrepreneur's loyalty to the original firm, the stake for the entrepreneur in the original firm must at least equal the value of the private benefit, i.e.,

$$z_t \geq l\frac{\delta}{(a_t)^\eta} A_t V_t (1 - s_{jt}).$$

where z_t is the compensation for the entrepreneur. When this incentive compatibility constraint is binding, we have

$$z_t = l\frac{\delta}{(a_t)^\eta} A_t V_t (1 - s_{jt}), \tag{21}$$

and the pledgeable income for the external investors is $l\frac{\delta}{(a_t)^\eta} A_t V_t s_{jt}$.

Each entrepreneur's objective is to maximize the expected entrepreneur surplus, i.e.,

$$\max_{(\tilde{\omega}_{jt}, s_{jt})} \Pr(\text{winning external finance}) \left(l\frac{\delta}{(a_t)^\eta} A_t V_t (1 - s_{jt}) - \tilde{\omega}_{jt} \right) \tag{22}$$

subject to:

$$l\frac{\delta}{(a_t)^\eta} A_t V_t s_{jt} \geq w_t l - \tilde{\omega}_{jt}. \tag{23}$$

$$\tilde{\omega}_{jt} \leq \omega_t \tag{24}$$

$$s_{jt} \leq \theta(\sigma, a_t) \tag{25}$$

where condition (23) is the external investor participation constraint, which implies the external investment can not exceed pledgeable income for the external investors; condition (24) is the entrepreneurial wealth constraint, which says that internal funding can not exceed the entrepreneurial net worth; condition (25) is the corporate governance constraint, which states that the credible external investor protection the corporate governance structure provides can not exceed its feasible upper limit, which depends on broader legal institutions and the position of relative development. We make the following assumption regarding this upper limit.

Assumption 1 (Essential external financing)

$$\theta\left(\sigma, a_t\right) < 1 - \frac{\bar{\omega}}{\bar{w}l}. \tag{26}$$

Where the right hand side is the proportion of the investment that is externally financed, thus the assumption implies that external financing need is sufficiently strong relative the upper limit of feasible external investor protection.

Lemma 1 (Zero external investor surplus) *Due to perfect competition in the capital market, the external investors' participation constraint must be binding in equilibrium, i.e.,*

$$w_t l - \tilde{\omega}_{jt} = l \frac{\delta}{\left(a_t\right)^{\eta}} A_t V_t s_{jt}. \tag{27}$$

Assumption 1 and the above lemma imply the following equilibrium property:

Proposition 1 (Barriers to entry) *In equilibrium, the entrepreneurial surplus for those who get external finances is strictly positive, i.e.,*

$$l \frac{\delta}{\left(a_t\right)^{\eta}} A_t V_t \left(1 - s_{jt}\right) > \tilde{\omega}_{jt}, \tag{28}$$

and there exist 'barriers to entry' to the intermediate good sector, namely, intermediate good producers enjoy strictly positive net profits, i.e.,

$$l \frac{\delta}{\left(a_t\right)^{\eta}} A_t V_t - w_t l > 0. \tag{29}$$

Proof. Conditions (25), (26) and (24) imply respectively the following:

$$\frac{1 - s_{jt}}{s_{jt}} \geq \frac{1 - \theta\left(\sigma, a_t\right)}{\theta\left(\sigma, a_t\right)},$$

$$\frac{1-\theta(\sigma,a_t)}{\theta(\sigma,a_t)} > \frac{\frac{\bar{\omega}}{\bar{w}l}}{1-\frac{\bar{\omega}}{\bar{w}l}}$$

and

$$\frac{\frac{\bar{\omega}}{\bar{w}l}}{1-\frac{\bar{\omega}}{\bar{w}l}} \geq \frac{\frac{\tilde{\omega}_{jt}}{w_t l}}{1-\frac{\tilde{\omega}_{jt}}{w_t l}},$$

which by transitivity implies

$$\frac{1-s_{jt}}{s_{jt}} > \frac{\frac{\tilde{\omega}_{jt}}{w_t l}}{1-\frac{\tilde{\omega}_{jt}}{w_t l}}. \tag{30}$$

Then the above condition and eq. (27) jointly imply

$$l\frac{\delta}{(a_t)^{\eta}}A_t V_t (1-s_{jt}) > \tilde{\omega}_{jt}$$

and

$$l\frac{\delta}{(a_t)^{\eta}}A_t V_t > w_t l.$$

■

Corollary 1 (Credit rationing/denial) *Credit denial occurs in equilibrium, i.e., not all entrepreneurs who want to, can get external finances.*

Proof. Suppose all entrepreneurs who want to can get external finances, then given that there are sufficient potential entrepreneurs in the economies, the entrepreneurial surplus should drop to zero in equilibrium, which contradicts Proposition 1. ■

Credit rationing in the form of (random) credit denial and 'barriers to entry' arise jointly in equilibrium[8]. As a result, the entrepreneurs have to compete for external financing intensively, and this pushes them in the direction of devoting all entrepreneurial wealth into the investment and offering the maximal feasible external investors protections.

We are interested in analyzing the equilibrium where all the entrepreneur offer the identical contract $(\tilde{\omega}_t, s_t)$ and ex ante each entrepreneur's chance of getting external financing is equal; off equilibrium path, the external investors always give priority to a contract that offers higher external investor surplus.

Proposition 2 (Binding wealth constraint and corporate governance) *In equilibrium, both internal funding and external investor protection are at maximal, i.e.,*

$$\tilde{\omega}_t = \omega_t \tag{31}$$

[8] For a more elaborate disscussion about the relationship between equilibrium credit rationing and endogenous 'barriers to entry', see Tong (2006).

and

$$s_{jt} = \theta(\sigma, a_t).$$

Proof. Suppose otherwise, then it is possible to increase either $\tilde{\omega}_t$ by $\varepsilon_1 \to 0$ or s_{it} by $\varepsilon_2 \to 0$. Either of these can increase the external investors' surplus, and hence increase the probability of winning external financing by a finite number, which is a profitable deviation, and therefore contradicts the supposition. ■

Lemma 1 and the above proposition imply the following binding external investor participation constraint:

$$l \frac{\delta}{(a_t)^\eta} A_t V_t \theta(\sigma, a_t) = w_t l - \omega_t. \tag{32}$$

2.3 Financial Institutional Structure

Consider the upper limit of feasible investor protection $\theta(\sigma, a_t)$ is determined by

$$\theta(\sigma, a_t) = \max(\theta_M(\sigma, a_t), \theta_H(\sigma, a_t), \theta_B(\sigma, a_t), \theta_I(\sigma, a_t)), \tag{33}$$

where σ is the legal development parameter: smaller σ means lower legal cost and hence better instruments for protecting external investors; $\theta_M(\sigma, a_t)$ stands for (security) market-based investor protection instruments, $\theta_B(\sigma, a_t)$ stands for bank-based investor protection instruments, $\theta_H(\sigma, a_t)$ stands for a hybrid (of market-based and bank-based) investor protection instruments, and $\theta_I(\sigma, a_t)$ stands for (other) informal-institution-based investor protection instruments.

Assumption 2 ((Determinants of the upper limit of external investor protection))

$$\theta_j(\sigma, a_t) = \beta_{j0} - \beta_{j1}\sigma - \beta_{j2}a_t \text{ and } \beta_{jk} > 0 \text{ for, } j = M, H, B, I \text{ and } k = 0, 1, 2 \tag{34}$$

This assumption basically allows linearity and assures that for each financial institutional structure j, $\frac{\partial \theta_j(\sigma, a_t)}{\partial \sigma} < 0$ and $\frac{\partial \theta_j(\sigma, a_t)}{\partial a_t} < 0$, and thereby implies:

Lemma 2 *Better legal development enhances external investor protection, i.e.,* $\frac{\partial \theta(\sigma, a_t)}{\partial \sigma} < 0$ *and there exist economies of emulation in institution, i.e.,* $\frac{\partial \theta(\sigma, a_t)}{\partial a_t} < 0$.

Proof. These results follow immediately from the fact that $\frac{\partial \theta_j(\sigma, a_t)}{\partial \sigma} = -\beta_{j1} < 0$ and $\frac{\partial \theta_j(\sigma, a_t)}{\partial a_t} = -\beta_{j2} < 0$. ■

This assumption is to capture two ideas: (i) better legal development, i.e., smaller σ, provides better choice set of instruments for external investor protection; (ii) when there is a bigger stock of opportunity for emulation (positive externality), i.e., smaller a_t, the instruments available for external investor protection are also richer, e.g., information disclosure, writing and enforcing contracts are easier, hence the upper limit of external investor protection is higher.

Assumption 3 (Comparative institutions) *The parameters* β_{jk} *for* $j = M, H, B, I$ *and* $k = 1, 2, 3$*, satisfies the following ranking conditions:*

$$\beta_{M1} > \beta_{H1} > \beta_{B1} > \beta_{I1}, \tag{35}$$

$$\beta_{M2} \leq \beta_{H2} \leq \beta_{B2} \leq \beta_{I2}, \tag{36}$$

$$\frac{(\beta_{H0} - \beta_{M0})}{(\beta_{H1} - \beta_{M1})} < \frac{(\beta_{B0} - \beta_{H0})}{(\beta_{B1} - \beta_{H1})} < \frac{(\beta_{I0} - \beta_{B0})}{(\beta_{I1} - \beta_{B1})} \tag{37}$$

and

$$0 < \frac{(\beta_{H0} - \beta_{M0}) + (\beta_{M2} - \beta_{H2})}{(\beta_{H1} - \beta_{M1})} < \frac{(\beta_{B0} - \beta_{H0}) + (\beta_{M2} - \beta_{B2})}{(\beta_{B1} - \beta_{H1})} < \frac{(\beta_{H0} - \beta_{M0}) + (\beta_{M2} - \beta_{H2})}{(\beta_{H1} - \beta_{M1})} \tag{38}$$

Conditions (35) and (36), respectively, imply that the more market-based institutional structure is more sensitive to legal development, i.e., parameter σ, but not more sensitive to the position of relative development, i.e., a_t. For a country with lesser legal development and at backward position of relative economic development, the less market-based institutional structure avoids the weakness in legal development, and better takes the advantages of economies of emulation. Conditions (37) and (38) are the additional (technical) parametric conditions that ensure the following comparative advantages (disadvantages) of the various financial institutional structures:

Proposition 3 (Financial institutional structure) *There exist functions* $\sigma_0(a_t) < \sigma_1(a_t) < \sigma_2(a_t)$ *such that* $\sigma_0'(a_t) \geq 0$*,* $\sigma_1'(a_t) \geq 0$*,* $\sigma_2'(a_t) \geq 0$*, and*

$$\theta_t(\sigma, a_t) = \begin{cases} \theta_M(\sigma, a_t) & \text{if} \quad \sigma \leq \sigma_0(a_t) \\ \theta_H(\sigma, a_t) & \text{if} \quad \sigma_0(a_t) < \sigma \leq \sigma_1(a_t) \\ \theta_B(\sigma, a_t) & \text{if} \quad \sigma_1(a_t) < \sigma \leq \sigma_2(a_t) \\ \theta_I(\sigma, a_t) & \text{if} \quad \sigma > \sigma_2(a_t) \end{cases}.$$

Proof. Define $\sigma_0(a_t)$, $\sigma_1(a_t)$, $\sigma_2(a_t)$ as follows:

$$\begin{aligned}
\sigma_0(a_t) &\triangleq \frac{(\beta_{H0}-\beta_{M0})}{(\beta_{H1}-\beta_{M1})}+\frac{(\beta_{M2}-\beta_{H2})}{(\beta_{H1}-\beta_{M1})}a_t\\
\sigma_1(a_t) &\triangleq \frac{(\beta_{B0}-\beta_{H0})}{(\beta_{B1}-\beta_{H1})}+\frac{(\beta_{M2}-\beta_{B2})}{(\beta_{B1}-\beta_{H1})}a_t\\
\sigma_2(a_t) &\triangleq \frac{(\beta_{I0}-\beta_{B0})}{(\beta_{I1}-\beta_{B1})}+\frac{(\beta_{B2}-\beta_{I2})}{(\beta_{I1}-\beta_{B1})}a_t
\end{aligned}$$

it is easy to verify that

$$\begin{aligned}
\theta_M(\sigma_0(a_t),a_t) &\equiv \theta_H(\sigma_0(a_t),a_t),\\
\theta_H(\sigma_1(a_t),a_t) &\equiv \theta_B(\sigma_1(a_t),a_t),\\
\theta_B(\sigma_2(a_t),a_t) &\equiv \theta_I(\sigma_2(a_t),a_t),\\
\sigma_0(a_t) &< \sigma_1(a_t)<\sigma_2(a_t),\\
\sigma_0'(a_t) &= \frac{(\beta_{M2}-\beta_{H2})}{(\beta_{H1}-\beta_{M1})}\geq 0,\\
\sigma_1'(a_t) &= \frac{(\beta_{M2}-\beta_{B2})}{(\beta_{B1}-\beta_{H1})}\geq 0,\\
\sigma_2'(a_t) &= \frac{(\beta_{B2}-\beta_{I2})}{(\beta_{I1}-\beta_{B1})}\geq 0
\end{aligned}$$

follows from Assumption 3.[9] ■

This result is illustrated graphically by Figure 1. It shows that the comparative advantages (disadvantages) of the various financial institutional structures depend on the legal development, i.e., parameter σ, and the position of relative economic development, i.e., a_t. In the region between the $\sigma_0(a_t)$ and the horizontal axis, the market-based financial institutional structure can provide the highest feasible level of external investor protection (controlling the complexity level of the R&D projects). In the region between $\sigma_1(a_t)$ and $\sigma_0(a_t)$ the hybrid structure is chosen endogenously. In the region between $\sigma_2(a_t)$ and $\sigma_1(a_t)$ the bank-based financial institutional structure is optimal. When the legal development is so poor such that $\sigma > \sigma_2(a_t)$, then the informal financial institutional structure arises in stead of any formal financial institutional structures.

2.4 Growth

From eq. (32) it follows that the asset value of an intermediate product is given by:

[9] A numerical example $\theta_j(\sigma, a_t)$ is given in Appendix A, which satisfies Assumptions 2 and 3, and verifies this proposition.

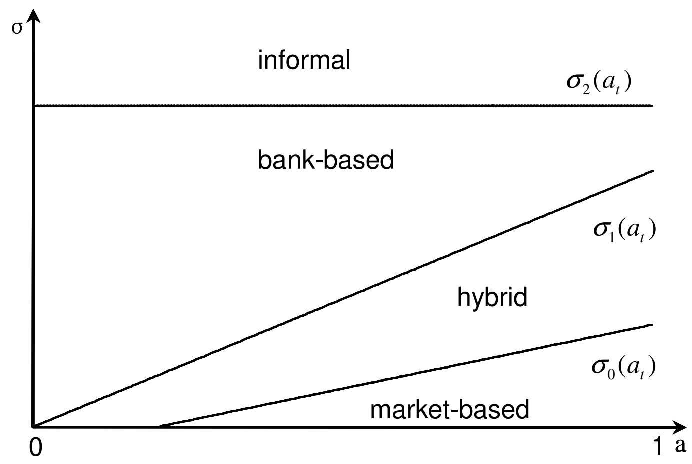

Figure 1: Determinants of financial institutional structure

$$V_t = \frac{(\bar{w} - \bar{\omega}/l)\,(a_t)^{\eta}}{\theta\,(\sigma, a_t)\,\delta}. \tag{39}$$

From eq. (19) and (20) it follows that

$$g_t \triangleq \frac{A_{t+1} - A_t}{A_t} = \frac{\delta}{(a_t)^{\eta}} L_{2t}$$

and

$$L_{1t} = L - \frac{g_t\,(a_t)^{\eta}}{\delta}. \tag{40}$$

Suppose the external investors can trade their cash flow rights over the intermediate good firms freely in the asset market, which gives rise to the following non-arbitrage condition:

$$rV_t = \pi_{t+1} + (V_{t+1} - V_t)\,. \tag{41}$$

From eq. (15), (39), (40) and (41) we can derive the following growth equation:

$$g_{t+1} = \frac{\delta L}{(a_{t+1})^{\eta}} + \frac{(1+r)\left(1 - \frac{\bar{\omega}}{l\bar{w}}\right)}{\theta\,(\sigma, a_{t+1})\,\alpha} - \frac{(1+r)^2\left(1 - \frac{\bar{\omega}}{l\bar{w}}\right)}{\theta\,(\sigma, a_t)\,\alpha}\frac{(a_t)^{\eta}}{(a_{t+1})^{\eta}}. \tag{42}$$

Using the growth identity

$$a_{t+1} = a_t \frac{1+g_t}{1+g_f} \tag{43}$$

to eliminate a_{t+1} in eq. (42) results in

$$g_{t+1} = \frac{\delta L}{\left(a_t \frac{1+g_t}{1+g_f}\right)^{\eta}} + \frac{(1+r)\left(1-\frac{\bar{\omega}}{l\bar{w}}\right)}{\theta\left(\sigma, a_t \frac{1+g_t}{1+g_f}\right)\alpha} - \frac{(1+r)^2\left(1-\frac{\bar{\omega}}{l\bar{w}}\right)}{\theta\left(\sigma, a_t\right)\alpha} \frac{1}{\left(\frac{1+g_t}{1+g_f}\right)^{\eta}}. \tag{44}$$

Putting eq. (43) and (44) together, we have the following system of difference equations, which determines the dynamics of the economy completely when the initial condition (a_0, g_0) is given.

$$\begin{cases} a_{t+1} = a_t \frac{1+g_t}{1+g_f} \\ g_{t+1} = \frac{\delta L}{\left(a_t \frac{1+g_t}{1+g_f}\right)^{\eta}} + \frac{(1+r)\left(1-\frac{\bar{\omega}}{l\bar{w}}\right)}{\theta\left(\sigma, a_t \frac{1+g_t}{1+g_f}\right)\alpha} - \frac{(1+r)^2\left(1-\frac{\bar{\omega}}{l\bar{w}}\right)}{\theta(\sigma, a_t)\alpha} \frac{1}{\left(\frac{1+g_t}{1+g_f}\right)^{\eta}}. \end{cases} \tag{45}$$

A benchmark of the model is the economy where legal development is the most advanced, as indicated by $\sigma = 0$, and that the knowledge stock is at the world frontier, i.e. $a_t = 1$; and the benchmark knowledge stock A_{ft} grows at a constant growth rate g_f,

$$A_{ft} = A_{f0}\left(1+g_f\right)^t. \tag{46}$$

2.5 Steady State

By definition, in a steady state, $g_{t+1} = g_t$ and $a_{t+1} = a_t = a^* > 0$, where a^* is time-invariant. Applying these definitions to eq. (45), we have $g_t = g^* = g_f$ and

$$a^* = \left(\frac{\delta L}{g_f + \frac{(1+r)r\left(1-\frac{\bar{\omega}}{l\bar{w}}\right)}{\theta(\sigma, a^*)\alpha}}\right)^{\frac{1}{\eta}}. \tag{47}$$

Proposition 4 (Steady state position of relative development) *In steady state $a_t = a^*$ and a^* decreases in σ, i.e., $\frac{\partial a^*}{\partial \sigma} < 0$.*

Proof. Differentiation of the logarithm of both sides of eq. (47) with respect to σ and reorganizing yield the following:

$$\frac{\partial a^*}{\partial \sigma} = \frac{\frac{(1+r)r\left(1-\frac{\bar{\omega}}{l\bar{w}}\right)\frac{\partial \theta(\sigma,a^*)}{\partial \sigma}}{\alpha g_f \theta(\sigma,a^*)+(1+r)r\left(1-\frac{\bar{\omega}}{l\bar{w}}\right)}}{\frac{\eta\theta(\sigma,a^*)}{a^*} - \frac{(1+r)r\left(1-\frac{\bar{\omega}}{l\bar{w}}\right)\frac{\partial \theta(\sigma,a^*)}{\partial a_t}}{\alpha g_f \theta(\sigma,a^*)+(1+r)r\left(1-\frac{\bar{\omega}}{l\bar{w}}\right)}} < 0 \text{ since } \frac{\partial \theta(\sigma, a^*)}{\partial \sigma} < 0 \text{ and } \frac{\partial \theta(\sigma, a^*)}{\partial a_t} < 0.$$

■

Similarly, define $a_j^*(\cdot)$ such that

$$a_j^*(\sigma) \equiv \left(\frac{\delta L}{g_f + \frac{(1+r)r\left(1-\frac{\bar{\omega}}{l\bar{w}}\right)}{\theta_j\left(\sigma, a_j^*(\sigma)\right)\alpha}} \right)^{\frac{1}{\eta}} \tag{48}$$

for $j = M, H, B, I$, and then

Lemma 3 *In steady state, conditional on the financial institutional structure is j, then $a_t = a_j^*(\sigma)$, and $a_j^*(\sigma)$ decreases in σ, i.e., $a_j^{*\prime}(\cdot) < 0$.*

Define $(\hat{\sigma}_0, \hat{a}_0)$ such that

$$a_M^*(\hat{\sigma}_0) = a_H^*(\hat{\sigma}_0) = \hat{a}_0 \text{ and } \sigma_0(\hat{a}_0) = \hat{\sigma}_0 \tag{49}$$

Similarly, define $(\hat{\sigma}_1, \hat{a}_1)$ such that

$$a_H^*(\hat{\sigma}_1) = a_B^*(\hat{\sigma}_1) = \hat{a}_1 \text{ and } \sigma_1(\hat{a}_1) = \hat{\sigma}_1; \tag{50}$$

define $(\hat{\sigma}_2, \hat{a}_2)$ such that

$$a_B^*(\hat{\sigma}_2) = a_I^*(\hat{\sigma}_2) = \hat{a}_2 \text{ and } \sigma_2(\hat{a}_2) = \hat{\sigma}_2. \tag{51}$$

The uniqueness of $(\hat{\sigma}_k, \hat{a}_k)$ for $k = 0, 1, 2$ is guaranteed by the downward slope of $a_j^*(\sigma)$ and the (weakly) upward slope of $\sigma_k(a)$ in the (a, σ) space.

Proposition 5 (Steady state institutional structure and position of relative development) *The steady state financial institutional structure is*

$$\begin{cases} M & \text{if} \quad \sigma \leq \hat{\sigma}_0 \\ H & \text{if} \quad \hat{\sigma}_0 < \sigma \leq \hat{\sigma}_1 \\ B & \text{if} \quad \hat{\sigma}_1 < \sigma \leq \hat{\sigma}_2 \\ I & \text{if} \quad \sigma > \hat{\sigma}_2 \end{cases}$$

and the steady state position of relative development is

$$a^*(\sigma) = \begin{cases} a_M^*(\sigma) & \text{if} \quad \sigma \leq \hat{\sigma}_0 \\ a_H^*(\sigma) & \text{if} \quad \hat{\sigma}_0 < \sigma \leq \hat{\sigma}_1 \\ a_B^*(\sigma) & \text{if} \quad \hat{\sigma}_1 < \sigma \leq \hat{\sigma}_2 \\ a_I^*(\sigma) & \text{if} \quad \sigma > \hat{\sigma}_2 \end{cases}$$

and $a_t(\sigma)$ is decreasing in σ.

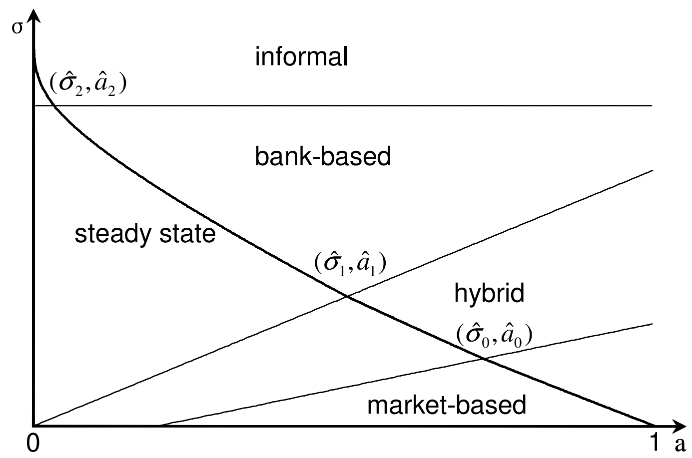

Figure 2: Determinants of steady state position and financial institutional structure

This result is illustrated graphically by Figure 2. The steady state financial institutional structure and the position of relative economic development are jointly determined by the level of legal development. Under high level of legal development, i.e., $\sigma < \hat{\sigma}_0$, the market-based financial institutional structure prevails in steady state and high level relative development is achieved, i.e., $\hat{a}_i^* > \hat{a}_0$. Under intermediate level of legal development, i.e., $\hat{\sigma}_0 < \sigma < \hat{\sigma}_1$, the hybrid structure is chosen in steady state and the intermediate level of relative development is achieved. When legal development is low, i.e., $\hat{\sigma}_1 < \sigma < \hat{\sigma}_2$, then the bank-based structure prevails and a low level of relative economic development sustains in steady state. If the legal development is extremely poor, then the informal financial institutional structure dominates and the economy remains the poorest in steady state. Overall the less market-based financial institutional structure is associated with the lower relative economic development level. Nevertheless, controlling the level of legal development (which is taken as exogenous), the endogenous financial institutional structure is optimal for steady state economic development position, as is stated in the following lemma.

Corollary 2 (Maximization of steady state development position) *The steady state financial institutional structure maximizes the steady state relative* *development position, i.e.,*

$$a^*(\sigma) = \max\left(a_M^*(\sigma), a_H^*(\sigma), a_B^*(\sigma), a_I^*(\sigma)\right). \tag{52}$$

Proof. Suppose otherwise, then there exist values of σ and j, denoted by $\tilde{\sigma}$ and $\tilde{j}$ such that $a^*(\tilde{\sigma}) < a_{\tilde{j}}^*(\tilde{\sigma})$. Given that

$$a^*(\tilde{\sigma}) = \left(\delta L / \left(g_f + \frac{(1+r)\, r \left(1 - \frac{\bar{\omega}}{l\bar{w}}\right)}{\theta(\tilde{\sigma}, a^*(\tilde{\sigma}))\, \alpha}\right)\right)^{\frac{1}{\eta}}$$

and

$$a_{\tilde{j}}^*(\tilde{\sigma}) = \left(\delta L / \left(g_f + \frac{(1+r)\, r \left(1 - \frac{\bar{\omega}}{l\bar{w}}\right)}{\theta_{\tilde{j}}\left(\tilde{\sigma}, a_{\tilde{j}}^*(\tilde{\sigma})\right) \alpha}\right)\right)^{\frac{1}{\eta}}$$

it follows

$$\theta_{\tilde{j}}\left(\tilde{\sigma}, a_{\tilde{j}}^*(\tilde{\sigma})\right) > \theta(\tilde{\sigma}, a^*(\tilde{\sigma})).$$

Since

$$\theta(\tilde{\sigma}, a^*(\tilde{\sigma})) \geq \theta_{\tilde{j}}(\tilde{\sigma}, a^*(\tilde{\sigma}))$$

by definition, then

$$\theta_{\tilde{j}}\left(\tilde{\sigma}, a_{\tilde{j}}^*(\tilde{\sigma})\right) > \theta_{\tilde{j}}(\tilde{\sigma}, a^*(\tilde{\sigma}))$$

and it follows from the fact $\frac{\partial \theta_{\tilde{j}}(\tilde{\sigma}, a^*(\tilde{\sigma}))}{\partial a_t} < 0$ that $a_{\tilde{j}}^*(\tilde{\sigma}) < a^*(\tilde{\sigma})$, which contradicts the supposition. ■

R&D intensity is the most commonly used measurement of R&D activity of an economy. The stylized fact about R&D intensity is that the economically more developed economies also have the highest R&D intensity. This stylized fact can be explained by the following proposition:

Proposition 6 (R&D intensity) *The steady state R&D input level (or intensity) increases in a^* and decreases with σ, i.e.,* $\frac{\partial L_2}{\partial a^*} > 0$ *and* $\frac{\partial L_2}{\partial \sigma} < 0$.

Proof.

$$L_2 = \frac{g_f (a^*)^\eta}{\delta}$$

$$\frac{\partial L_2}{\partial a^*} = \frac{\eta g_f (a^*)^{\eta - 1}}{\delta} > 0,$$

$$\frac{\partial L_2}{\partial \sigma} = \frac{\eta g_f (a^*)^{\eta - 1}}{\delta} \frac{\partial a^*}{\partial \sigma} < 0.$$

■

This proposition also points out that both steady state relative economic development and R&D intensity are jointly determined by the level of legal development.

2.6 Emulation Economies and Off-steady-state Dynamics

In this subsection we study the off-steady-state growth paths. Its main objective is to identify a novel hallmark of the emulation-based growth mechanism. Linearizing the growth equation (44) around the steady state point (a^*, g_f) yields the following linear equation:

$$(g_{t+1} - g_f) \approx -\mathfrak{B}_1 (a_t - a^*) + \mathfrak{B}_2 (g_t - g_f), \tag{53}$$

where

$$\mathfrak{B}_1 \triangleq \left(\frac{(1+r) r \left(1 - \frac{\bar{\omega}}{l\bar{w}}\right)}{\theta(\sigma, a^*) \alpha} \left(\eta - \frac{\partial \theta(\sigma, a^*)}{\partial a_t} \frac{a^*}{\theta(\sigma, a^*)} \right) + \eta g_f \right) \frac{1}{a^*} \tag{54}$$

and

$$\mathfrak{B}_2 \triangleq \left(\left(\frac{(1+r)\left(1 - \frac{\bar{\omega}}{l\bar{w}}\right)}{\theta(\sigma, a^*) \alpha} \eta - \frac{\partial \theta(\sigma, a^*)}{\partial a_t} \frac{a^*}{\theta(\sigma, a^*)} \right) - \eta g_f \right) \frac{1}{1 + g_f} \tag{55}$$

Equation (53) neatly decomposes the source of the excess growth of the next period $(g_{t+1} - g_f)$ into the 'convergence effect': $-\mathfrak{B}_1 (a_t - a^*)$ and the 'growth inertia effect': $\mathfrak{B}_2 (g_t - g_f)$. The existence of the 'growth inertia effect', as measured by a residual positive autocorrelation in growth rate (after controlling the convergence effect), is an identifying feature of our discrete-time emulation-based growth model. In the introduction of the paper, we have provided some empirical evidence of this effect. (For a more comprehensive empirical study of this effect, see Tong (2006b).) If $\eta = 0$ and $\frac{\partial \theta(\sigma, a_t)}{\partial a_t} = 0$, then $\mathfrak{B}_1 = \mathfrak{B}_2 = 0$, and the economy will always be in steady state, as in the original Romer (1990) model. What make the growth dynamics richer are the emulation economies; and clearly there are two sources of emulation economies: one in technology, one in (financial) institutions.

3 Empirical Evidence

In this section we present evidence pertaining to the key predictions of the emulation-based growth theory. In order to match the theoretical terms with observable variables, the main predictions are expressed in the following three hypotheses.

3.1 Hypotheses to be Tested

1. The estimated stead-state position (as measured by per-capita GDP level as a percentage of the US level) is positively correlated with measurements

of accounting standard, contract enforceability and law and order (which are proxies of the quality of legal institutions).

2. The financial institutional structure indicator (as measured by the relative activity level of stock market against private bank credit provision) is positively correlated with measurements of accounting standard, contract enforceability and law and order.

3. The estimated stead-state position is positively correlated with financial institutional structure indicator; but the correlation becomes insignificant or has ambiguous signs when the measurements of accounting standard, contract enforceability or law and order are controlled for.

3.2 Data Sources

The position of relative development is measured by a country's per capita GDP as a percentage of the US level. The growth rate is measured by the annual growth rate of per capita GDP.[10] The source of data is Penn World Table 6.1 (by Heston, Summer and Aten). There are up to 168 countries in this data set, which spans up to 51 years between 1950-2000.

Measurements of accounting standard is from the Center for International Financial Analysis & Research, Inc.; contract enforceability is from Knack and Keefer (1995), using data from Business Environmental Risk Intelligence (BERI); law and order is from International Country Risk Guide (ICRG).

The measurement of financial institutional structure is calculated using data from the (World Bank) Data Set on Financial Development and Structure (by Beck, Demirguc-Kunt and Levine). It is the average over the period 1980-95.

3.3 Estimation of steady state Positions

Linearizing equation (43) implies the following linear equation

$$a_{it+1} - a_{it} \approx \frac{a_i^*}{1+g_f}\left(g_{it} - g_{ft}\right), \tag{56}$$

which is useful for estimating the steady state position a_i^*. We specify the regression equation :

$$\Delta a_{it} = \theta_0 + \theta_1 \tilde{g}_{it} + \sum_j \theta_{2j} d_{ij} \tilde{g}_{it} + u_{it}, \tag{57}$$

[10] Since these measures are imperfect proxies for a_t and g_t of our theory, measurement errors are inevitable. The magnitude of the measurement errors diminishes as the economy approaches to its steady state.

where $\Delta a_{it} = a_{it+1} - a_{it}$, $\tilde{g}_{it} = g_{it} - g_{us,t}$, $g_{us,t}$ is the rate of per capita GDP growth of the U.S., which is a proxy of g_{ft}, d_{ij} is the dummy variable for country i ($d_{ij} = 0$ if $j \neq i$; $d_{ii} = 1$). u_{it} is assumed to have auto-correlation and heteroskedasticity. We estimate the equation by FGLS allowing for auto-correlation and heteroskedasticity in the error structure. Once θ_1 and θ_{2i} are estimated, the following can be used to estimate a_i^*:

$$a_i^* = (1 + \bar{g}_{us})(\theta_1 + \theta_{2i}) \tag{58}$$

where $\bar{g}_{us} = \frac{1}{T}\sum_{t=1}^{T} g_{us,t}$. Since the dynamic analysis is based on linear approximation around steady state values, the accuracy of the estimation of the steady state position will be higher if we use the data of the period in which the economies are closer to their steady states. If we are willing to assume that the dynamic system for most countries are at least asymptotically stable, then most economies are closer to their (long-term optimal) steady states[11] in the period between 1980-1999 than that between 1950-1979. For this reason, we use the data of period of (1980-1999) to estimate the steady state values. The results for 116 countries which have data for at least 30 years are reported in Table 5 in Appendix B. Further calculation (which we omit) confirms that average positions in the period: 1950-1979 are further away from the estimated steady state positions than those of the period: 1980-1999.

3.4 Determinants of steady state Position

The OLS regressions reported in Table 2 and the associated scatter plots in Figure 3 confirm Hypotheses 1: The estimated stead-state position is positively correlated with accounting standard, contract enforceability, and law and order measurements.

The positive correlations, however, tell us nothing about causality between the variables. It is equally plausible to argue for a causal relationship running either way. Since discussing the determination of σ_i is beyond the scope of this paper, our theory is only capable to capture the causality that runs from σ_i to a_i^*.

[11] It is possible that an economy's structure of financial institutions is exogenously determined, or its optimal structure entails switching between different modes depending on the position of relative development; thereby its current financial institutional structure can be different from its long-term optimal structure, in which case the economy is far away from its long-term optimal steady state.

	OLS (7)	IV (8)	OLS (9)	IV (10)	OLS (11)	IV (12)
account	1.122285***	1.053896**				
	(.2662299)	(.39307)				
contract			39.23486***	38.18953***		
			(3.288194)	(5.148729)		
law					15.65663***	19.76464***
					(1.002662)	(2.091236)
constant	-18.19407	-13.58874	-54.21989***	-51.45628***	-21.99666***	-35.99325***
	16.53709	(24.07758)	(3.288194)	(12.8562)	(3.835424)	(7.455103)
observation	40	39	46	45	84	83
R^2	0.3186	0.3247	0.7639	0.7651	0.7483	0.7084

Table 2: Regression of steady-state position

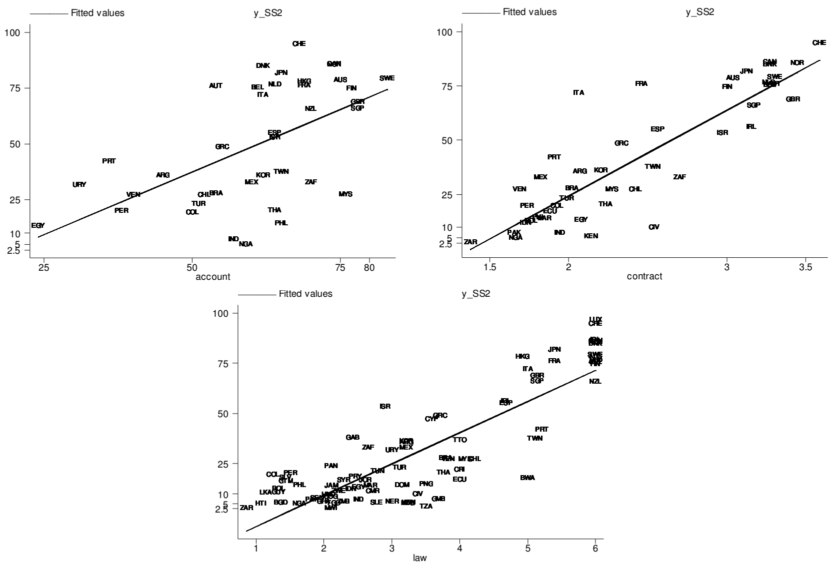

Figure 3: Steady-state positions vis-a-vis measures of accounting standard, contract enforceability and law and order

	OLS (13)	IV (14)	OLS (15)	IV (16)	OLS (17)	IV (18)
account	.0582151***	.0389439*				
	(.0139972)	(.0202599)				
contract			.9361102**	1.06616*		
			(.3537976)	(.5403881)		
law					.426728***	.3763675
					(.1214446)	(.2384386)
constant	-5.417628***	-4.307462***	-4.433478***	-4.817129***	-4.16358***	-4.012942***
	(.8694481)	(1.241021)	(.9073543)	(1.361318)	(.5013446)	(.9236837)
observation	40	39	45	44	65	64
R^2	0.3128	0.2916	0.1400	0.1447	0.1639	0.1543

Table 3: Regression of financial institutional structure

To estimate the strength of these causal relations, we use instrument variables to help identify the exogenous components of accounting standard, contract enforceability, law and order. Following the literature, we choose the legal origin (dummies) as instruments (data source: La Porta, de Silances, Shleifer and Vishny (1998)). The results are also reported in Table 2, which show that the IV estimators are very similar to the OLS estimators, and all the key coefficients are statistically and economically significant.

3.5 Determinants of Financial Institutional Structure

The OLS regressions reported in Table 3 and the accompanying scatter plots in Figure 4 confirm Hypothesis 2: The financial institutional structure indicator (as measured by the logarithm of the ratio of the total value traded on the stock market against claims on private sector by deposit money banks) is positively correlated with accounting standard, contract enforceability and law and order measurements. Using the legal origin dummy variables as instruments, the IV estimators are positive and statistically significant except for law and order.

When we compare the R^2 values in Table 3 with those in Table 2, it becomes clear that the legal institutional quality indicators can explain the estimated steady state position better than than they do financial institutional structure. The highest value of R^2 is 0.7651 for Table 2 but only 0.3128 for Table 3. The

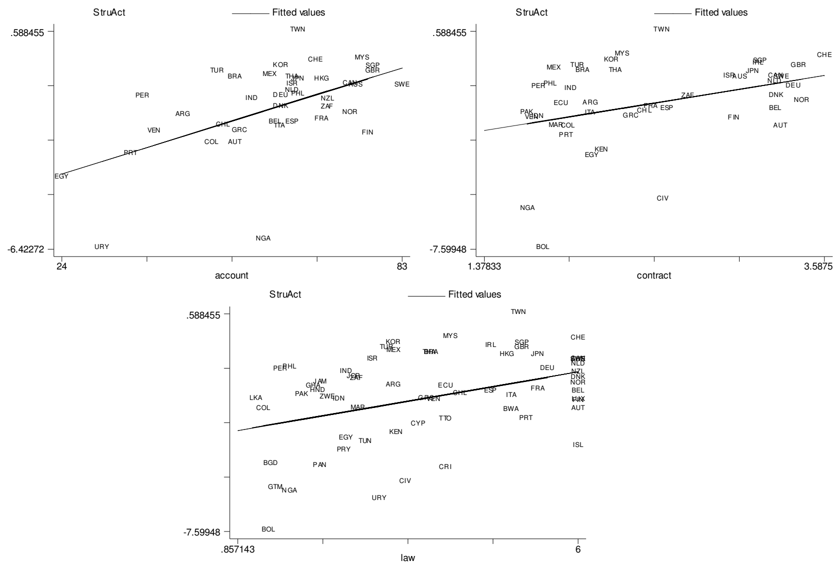

Figure 4: Determinants of financial institutional structure

conclusion we can draw from this comparison about the determination of financial institutional structure is that (1) it is indeed to some extent endogenous, and affected by the quality of legal institutions; (2) but there also exists some substantial exogenous component in it, which results in substantial deviation (disturbance) from the long-term optimal structure in either direction. The reason why the regressions in Table 2 fit much better is because the predicted positive correlation between legal institutional quality and steady state position does not rely on the assumption of endogenous structure of financial institutions, hence is more robust.

3.6 Financial Institutional Structure and steady state Position

Regressions (19) and (20) in Table 4 and Figure 5 show a significant positive correlation between the financial institutional structure indicator and the estimated steady state position. This suggests that those countries with more market-based financial system is likely to have higher steady state positions. It is not surprising that the R^2 value for regression (19) is rather small given that the actual financial institutional structures may substantially deviate from the long-term optimal values in either directions.

Having a more market-based financial system, however, is not the cause of a higher position of relative development because both variables are endogenous, and are jointly determined by some common fundamental parameters. In fact our theory predicts that an endogenous financial institutional structure should be an optimal response to the parameters of quality of legal institutions (Corollary **??**). If an economy deviates from its optimal financial institutional structure in either direction, it will suffer a lower steady state position. From the previous subsection we know that financial institutional structure is indeed endogenous (to some extent). Therefore the simple first order necessary condition[12] for optimization requires that the derivative of the steady state position with respect to financial structure (around the steady state position) should be zero. This prediction is examined by regressing the steady state position on the financial institutional structure measure while controlling for the effect due to accounting standard, contract enforceability or law and order.

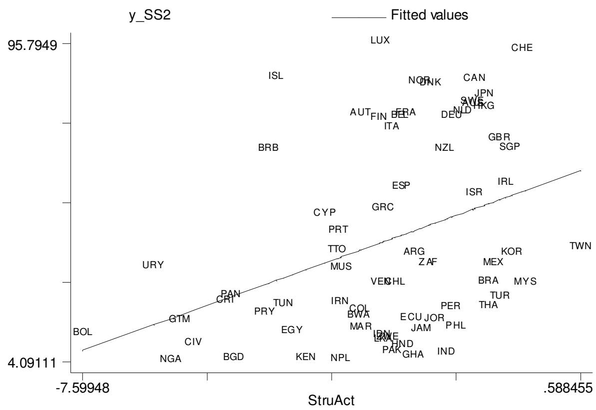

Figure 5: The correlation between financial structure and steady-state position

Regression (21) to (24) show that once accounting standard, contract enforceability or law and order is controlled for, financial institutional structure no longer has a predictable effect on the steady state position. In these regressions, we actually have controls over the optimal financial institutional structure. Thereby the coefficient of financial institutional structure is an estimator of the first order derivative of the steady state position with respect to financial institutional structure (around the optimal structure), which turns out to be, as

[12] Consider the financial institutional structure measure as a continuous variable, then when we can use the first order condition.

	OLS	IV	OLS	OLS	OLS	IV
	(19)	(20)	(21)	(22)	(23)	(24)
StruAct	6.329069***	17.49053**	-1.485322	1.596703	.564004	.4939223
	(1.942082)	7.170612	(3.117354)	(1.47927)	(1.117112)	(3.82675)
account			1.208753***			
			(.324475)			
contract				37.87084***		
				(3.700757)		
law					15.55038***	19.69382***
					(1.177624)	(2.736702)
constant	55.44137***	85.34086***	-26.24099	-47.51162***	-18.29652***	-33.79196*
	(5.986207)	(19.38886)	(23.7567)	(10.97627)	(6.433851)	(17.80697)
observation	69	68	40	45	65	64
R^2	0.1368	n.a.	0.3228	0.7596	0.7764	0.7325

Table 4: Regression of steady-state position

expected, not significantly different from zero.

In summary, the regression analysis provides evidence which supports Hypothesis 3: The estimated stead-state position is positively correlated with financial institutional structure indicators; and the correlation becomes insignificant or has ambiguous sign when accounting standard, contract enforceability or law and order measurements are controlled for. These support the view that financial institutional structure matters for growth and development, and financial institutional structure is (to some extent) endogenous.

4 Discussions

"Semi-endogenous" Growth? Jones (1995) observes that virtually all the first generation R&D-based growth models (Romer (1990), Grossman and Helpman (1991), Aghion and Howitt (1992)) predict a kind of "scale effects": if the level of resources devoted to R&D is doubled, then the per capita growth rate should also double. This kind of scale effects are not born out by data. Jones (1995) suggests how R&D-based models can be extended to avoid this unrealistic feature; but also finds that in the extended models growth becomes "semi-endogenous": economic growth is endogenous in the sense that it is driven by intentional R&D by profit-seeking firms; it is exogenous in the sense that steady state growth rate is no longer affected by traditional policy variables.

Our model does not have the feature of scale effects because of the presence of diminishing returns to emulation. It is consistent with the notion of semi-endogenous growth *a la* Jones (1995). Nevertheless, the quality of legal institutions (which is a kind of policy variables) does have impact on the steady state position of relative development.

Exogenous Legal/Political Institutions? Throughout the analysis presented in this paper, we have assumed that the quality of the legal and political institutions is completely exogenous and constant. One argument for this assumption is that this variable changes much more slowly than some other variables, e.g., per capita GDP, so this assumption makes a sensible first-order approximation; and also it simplifies the analysis significantly. Nevertheless, a caveat is in order in relation to the limitation of this assumption. Arguably, the quality of legal institutions, and perhaps even political institutions may be affected by economic development. For example, Lipset (1959) proposes that economic development and improvement in educational attainment increase the chance of establishing and maintain stable democracy. Adding this feedback: from economic performance to the deep components of institutions to the model will undoubtedly be an interesting extension of the current study.

4.1 Related Literature

Aghion, Dewatripont and Rey (2000), Tirole (2006) and Tong (2006a) show that when external financing need is strong, the entrepreneur is willing to make costly concessions, e.g., pledging collateral, inclusion of lender friendly debt covenants, disclosure of confidential information, accepting monitoring, relinquishing control rights (including voting rights, board rights, liquidation rights, which may or may not be state-contingent).

There are a few other papers that study technology diffusion-based endogenous growth. Barro and Sala-I-Martin (1997) pioneered this line of research by extending a continuous time version Romer model, incorporating the effect of international technological diffusion on R&D. Their analysis derives a conditional convergence effect, which is observationally equivalent to that predicted by a standard neoclassical growth model, e.g., the Solow model. Howitt (2000) extends the Aghion and Howitt (1992) 'growth by creative destruction' model, also derives a conditional convergence effect. As a previous incarnation of the current study, Tong and Xu (2004) is the first paper that develops a discrete time technology diffusion-based endogenous growth model, therefore is the first model that predicts a residual positive autocorrelation in growth rate after controlling the conditional convergence effect which is akin to that of Barro and Sala-I-Martin (1997). Tong (2006b) further explores the time series properties of the emulation-based endogenous growth mechanism both empirically and theoretically, which not only confirms the residual positive autocorrelation in growth rate, but also identifies low frequency growth cycles amid the process of long-run conditional convergence. The current paper (as in its predecessor Tong and Xu (2004)) is among the first to formally explore the effect of emulation economies on financial institutions.

Our research relates to the control theories of financial contracting. In an incomplete contract framework, Aghion and Bolton (1992) and Dewatripont and Tirole (1994) characterize financial contracts by the allocation of both cash flow rights and control rights between a wealth-constrained entrepreneur and external investor(s). Aghion and Bolton (1992) concern the optimality properties of governance structure induced by standard debt financing in terms of state-contingent allocation of control rights. They examine a setting where there are conflicting objectives between entrepreneurs and external investors, specifically, besides monetary benefit, the entrepreneur attaches to the control of the project a private benefit (which is not shared with the external investors). Debt contact allows the allocation of control to be contingent on a verifiable signal, i.e., default, hence gives external investors the necessary protection in default state while allows the entrepreneur to pursue the private benefit in non-default state. Dewatripont and Tirole (1994) aim to explain the coexistence debt and equity financing and the (partial) congruence between the entrepreneurial interests and the equity share holders' interests. In an important empirical study of venture capital financing contracts, Kaplan and Strömberg (2003) find venture capitalists separately allocate cash flow rights, voting rights, board rights, liquidation rights, and other control rights. These rights and future financing are frequently contingent on observable measures of financial and non-financial performance measures. Particularly, "if the company performs poorly, the VCs obtain full control. As company performance improves, the entrepreneur retains/obtains more control rights. If the company performs very well, the VCs retain their cash flow rights, but relinquish most of their control and liquidation rights. The entrepreneur's cash flow rights also increase with firm performance." In this paper we assume that the bank-based financial instruments grant the external investors strong liquidation rights, which may be suitable for financing projects with low level of novelty and uncertainty, but can be overly restrictive to the entrepreneurial process if novelty and uncertainty increase.

Our findings have a close bearing on the debate on bank- vs. stock market-based financial system, in the voluminous and growing literature on law, finance and economic growth (King and Levine (1993), Rajan and Zingales (1998), Allen and Gale (1995), La Porta et al. (1998), Levine (2002)). Our theory and econometric evidence show that both financial structure and stead-state relative development positions are endogenous, and are positively correlated. The level of legal development fundamentally determines the country's steady state financial institutional structure and relative development position. Our study emphasizes on the finance of emulation-based R&D as the central mechanism through which finance and growth interact. This is a first step to jointly endogenizing financial institutional structure and economic growth (or technological progress). King and Levine (1993), Rajan and Zingales (1998) find systematic evidence that economic development is associated with financial development, and this relationship is not purely driven by that economic development may cause financial development. Allen and Gale (1995) survey a large and long-lasting literature on comparing the bank-based and stock market-based financial systems. La Porta et al. (1998) provide evidence to show that legal development determines financial development; legal origin has a bearing on financial development and financial institutional structure. More recently, Levine (2002) shows that legal development is associated with economic development, and identifies financial development as the channel through which legal development influences economic development; however, he reports a lack of evidence of financial structure (causally) affecting economic growth. Our findings suggest that there is a two-way causal relationship between financial institutional structure and economic development; because of this joint endogeneity problem, reduced-form regressions are unable to capture this relationship.

The empirical literature on economic growth has recently documented a growing body of evidence to establish that 'institutional quality' has a permanent effect on a country's level of per capita income (e.g., Hall and Jones (1999), Acemoglu, Johnson and Robinson (2001), Rodrik, Subramanian and Trebbi (2004)). The evidence appears in the form of strong positive correlation between the a set of measures of 'institutional quality' and per capita income, cum carefully chosen instrument variable approach to establish the causality within the relationship. Since these studies focus the exogenous components of institutions (because of the instrument variable approach), they are essentially concerned with the deep institutions. These studies are silent about which growth mechanism: the neoclassical or the R&D-based mechanism is the more important driving force of the growth process, and roles of some lesser deep institutions, such as financial institutions, in economic development. The central message delivered by these recent findings points to the ultimate importance of economic governance on growth performance. Our research complements these studies by investigating how the deep institutions, such as legal institutions, affect financial institution, R&D financing and investments, and economic growth. Therefore our research more directly addresses the "barriers to technology adoption and development" issue raised by Parente and Prescott (1994) and Prescott (1998).

5 Summary and Conclusion

In this paper, we characterize an emulation-based growth mechanism, which is particularly relevant to economic catching up or development. We start by establishing that intentional investments in technological progress, e.g., via R&D and learning, are an intrinsic part of the process of economic growth, even for developing economies. By examining the empirical dynamic properties of per capita income growth of a large majority of economies of the world, we identify a (novel) residual positive autocorrelation in per capita GDP growth rates after controlling for the conditional convergence effect which is more familiar to growth economists. This residual positive autocorrelation in growth rates, which we call the 'growth inertia' effect, relates to the fact that a technologically laggard economy typically (perhaps inadvertently) accumulates a stock of unexplored positive externalities (i.e., knowledge spillovers) due to the technological progress in more advanced industrial economies. This fact gives rise to the convenience (or advantage) for developing countries to base their intentional technological investments on emulation (as opposed to original invention or innovation). In other words, developing countries are in a vantage position to explore "economies of emulation" (note: emulation is cheaper than original invention or innovation). From a dynamic point of view, this advantage allows a developing country to catch up with the more advanced economies, but only to a limit. The limitation arises from another (related) fact that as an economy closes its gap with the more advanced economies, the stock of unexplored positive externalities shrinks, and the advantage diminishes. This is what we call "diminishing returns to emulation". The simple theory we develop in this paper unveils that these economic forces, when interacting with the more familiar market forces such as arbitrage activities, are responsible for the novel dynamic property - the 'growth inertia' effect.

The recognition of the emulation-based growth mechanism has significant institutional implications for growth in developing countries. It helps to understand why and how institutions matter for development; why the institutional "best practices" of the advanced economies, e.g., the (more) market-based financial institutional structures, some times fail to work for the developing world; and why some alternative institutions, e.g., the (more) bank-based financial institutional structures, some times generate outstanding growth performance. It also sheds new light on the issue as for whether alternative institutions can sustain good growth performance in the long run. First, bad quality of (deep) institutions, e.g., legal institutions, jeopardizes economic growth by failing technological progress foremost. It is technological progress and new market development that constantly place new demands for governance services and test the quality of institutions. Second, the reason why developing countries are poorer is because they are being penalized for having bad institutions, particularly at the level of deep political and legal institutions in the first place. This very reason prevents them from being able to adopt the institutional "best practices" of the advanced economies. Third, the fact that they are technologically underdeveloped means developing countries are typically in a vantage position to exploit a stock of yet-to-be-explored knowledge spillovers that have been accumulated thanks to the contributions of the more advanced economies. The most pro-growth institution in the context of a developing economy should be one that best exploits the economies of emulation to its advantage. That is why some alternative institutions (or policies) can possibly generate outstanding growth performance in some period of time. However, there may be limitations to this kind of institutions due to diminishing returns to emulation. While heterodox institutions and policies may facilitate a speedy catching up at an earlier stage, it may lose its advantage later as the economy closes its gap with the world frontier. Two possible outcomes are then lying ahead: If their institutions are on the track of converging toward the best practice of the most advanced economies, then the economic (financial) institutions as well as the long term economic performance can eventually converge to those of the world frontier. Otherwise, the economic (financial) institutions and the long term growth outcome will eventually stagnate at a position that is some distance away from the world frontier.

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A A Numerical Example of $\theta_j(\sigma, a_t)$

$$\begin{aligned}
\theta_M(\sigma, a_t) &= \beta_{M0} - \beta_{M1}\sigma - \beta_{M2}a_t = 1.592 - 1.5\sigma - 0.88a_t \\
\theta_H(\sigma, a_t) &= \beta_{H0} - \beta_{H1}\sigma - \beta_{H2}a_t = 1.6 - 1.4\sigma - 0.92a_t \\
\theta_B(\sigma, a_t) &= \beta_{B0} - \beta_{B1}\sigma - \beta_{B2}a_t = 1.6 - 1.3\sigma - a_t \\
\theta_I(\sigma, a_t) &= \beta_{I0} - \beta_{I1}\sigma - \beta_{I2}a_t = 1.5 - 1.2\sigma - a_t
\end{aligned}$$

$$\begin{aligned}
\sigma_0(a_t) &= \frac{(\beta_{H0} - \beta_{M0})}{(\beta_{H1} - \beta_{M1})} + \frac{(\beta_{M2} - \beta_{H2})}{(\beta_{H1} - \beta_{M1})}a_t = -0.08 + 0.4a_t \\
\sigma_1(a_t) &= \frac{(\beta_{B0} - \beta_{H0})}{(\beta_{B1} - \beta_{H1})} + \frac{(\beta_{M2} - \beta_{B2})}{(\beta_{B1} - \beta_{H1})}a_t = 0.8a_t \\
\sigma_2(a_t) &= \frac{(\beta_{I0} - \beta_{B0})}{(\beta_{I1} - \beta_{B1})} + \frac{(\beta_{B2} - \beta_{I2})}{(\beta_{I1} - \beta_{B1})}a_t = 1
\end{aligned}$$

B Estimated Steady State Positions of Relative Development

Country	Est. SS position	Country	Est. SS position	Country	Est. SS position
Luxembourg	95.79486	Brazil	26.76812	Comoros	8.48351
Switzerland	93.78139	Malaysia	26.37682	Honduras	8.43831
Iceland	85.56747	Venezuela	26.30657	Congo, Republic of	7.562485
Canada	85.01697	Chile	26.29844	Angola	7.357324
Norway	84.50031	Panama	22.68029	China	7.02423
Denmark	83.8786	Turkey	22.27551	Senegal	6.609795
Japan	80.75665	Namibia	21.41364	Gambia, The	6.532256
Sweden	78.40001	Algeria	21.30551	Pakistan	6.32049
Australia	77.83346	Costa Rica	21.13266	India	6.241665
Hong Kong	76.97074	Iran	20.86638	Mauritania	5.672306
Netherlands	75.6282	Tunisia	20.24347	Ghana	5.376215
France	75.1487	Thailand	19.47904	Lesotho	5.131199
Austria	74.9935	Romania	19.31273	Zambia	4.918089
Belgium	74.36121	Peru	19.10237	Central African Republic	4.915256
Germany	74.30521	Colombia	18.63084	Niger	4.865241
Finland	73.75047	Paraguay	17.519	Sierra Leone	4.783536
Italy	70.95229	Fiji	17.48144	Bangladesh	4.702587
United Kingdom	67.84731	El Salvador	17.14122	Kenya	4.675583
Singapore	65.14073	Botswana	16.88127	Mozambique	4.637321
Barbados	64.81126	Guinea	16.43364	Chad	4.611234
New Zealand	64.72637	Ecuador	16.16764	Madagascar	4.401875
Ireland	55.25398	Syria	16.08592	Togo	4.389935
Spain	53.98337	Jordan	15.83265	Nepal	4.216647
Israel	52.19148	Guatemala	15.51254	Haiti	4.185884
Greece	47.71455	Papua New Guinea	13.92681	Benin	4.176262
Cyprus	46.2253	Philippines	13.53502	Nigeria	4.091108
Portugal	41.18862	Dominican Republic	13.23293	Burkina Faso	3.371043
Puerto Rico	39.63076	Morocco	13.16635	Mali	3.265568
Hungary	38.50129	Jamaica	13.09235	Rwanda	3.184152
Gabon	36.83307	Egypt	12.44959	Guinea-Bissau	2.801957
Taiwan	36.68224	Nicaragua	11.85085	Tanzania	2.730271
Trinidad &Tobago	35.63553	Bolivia	11.83749	Burundi	2.64957
Korea, Republic of	35.09156	Indonesia	11.13349	Ethiopia	2.526114
Argentina	34.96124	Cape Verde	10.77601	Uganda	2.26605
South Africa	31.94386	Zimbabwe	10.45308	Malawi	2.224817
Mexico	31.81397	Cameroon	10.20655	Congo, Dem. Rep.	1.908483
Uruguay	30.90471	Guyana	9.979059		
Mauritius	30.71663	Sri Lanka	9.834751		
Seychelles	30.71392	Cote d'Ivoire	8.916863		
Poland	29.15185	Equatorial Guinea	8.677501		

Table 5: The estimated steady-state positions