PEKING UNIVERSITY
Institute of New Structural Economics

Working Paper Series of New Structural Economics

No. E2020005 **2020-05-04**

Distance to Frontier and Optimal Financial Structure*

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Keywords: distance to frontier; diversity of opinion; financial institutions; Schumpeterian growth model; comparative advantage

JEL Classification: E22, G14, G21, L16, O31, O33, O4.

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1 Introduction

There is a long-stand debate on the relative importance of financial markets and financial intermediaries, or direct and indirect financial institutions, in economic development (Goldsmith, 1969). Some economists argue that intermediaries-dominate financial structure is better while some others insist that markets-dominate is superior. Allen and Gale (2000) conclude that there is no definitive answer to the question that which of the two financial institutions is better and hence the key point is to understand the trade-off of these two financial institutions. This paper investigates how the stage of economic development affects the optimal financial structure.

The above debate focuses on the question that which financial institution is superior. However, there is a large literature that shows the answer to this question depends on the stage of economic development. Using a large cross-country, time-series data set on the mixture of financial markets and intermediaries across 150 countries for the period 1960-1995, Demirguc-Kunt and Levine (2001) find that as countries become richer, financial markets become more active and efficient relative to banks. There is a tendency for national financial systems to become more market-based as they become richer. Tadesse (2002) show that while market-based systems outperform bank-based systems among countries with developed financial sectors, bank-based systems are far better among countries with underdeveloped financial sectors. These evidence suggests that the optimal financial structure depends on the stage of economic development.

We construct a Schumpeterian endogenous growth model in a stochastic environment. In the model, the main driving force of economic growth is the degree of technological change which takes two forms: imitation and invention. Imitation is easier and can be acquired from the world technological frontier, and thus the return of imitation is low. Invention is more difficult and must be developed from the knowledge level of local countries, and thus the return of invention is much higher than that of imitation. Imitation is more important for technological progress when the economy is far away from the world technological frontier, while invention is more essential as the economy approaches to the frontier. Agents with innovative projects (could be imitative or innovative) have to seek fundings from investors to launch the projects. Imitation and invention are uncertain ex ante, that is, initially, investors do not know the real type of the project. However, the real type of the project will be revealed ex post by paying a lump-sum cost. We show that, under some conditions, financial intermediaries (indirect financing institutions) are more conductive to imitation while financial markets (direct financing institutions) are more conducive to invention. We conclude that indirect financing institutions are more appropriate for countries that are in the early stage of economic development and direct financing institutions are more appropriate for countries that are in the advanced stage of economic development.

This paper is closely related to several strands of literature. First, this paper is related to the new structural economics. Lin, Sun and Jiang (2013) argue that the optimal financial structure of an economy has to be conducive to economic structure such as industrial structure. Lin, Cai and Zhou (1994) and Ju, Lin and Wang (2015) show that the stage of economic development of an economy measured by the factor endowment structure determines the industrial structure. These new structural economics literature conclude that the structure of an economy's factor endowments determines the comparative advantages and optimal industrial structure of the economy and, in turn, determines the features of riskiness and scale of financial needs of firms in the industries as well as the financial institutions appropriate for those features. With the changes of an economy's endowment structure in the process of economic development, the industrial structure and financial structure of the economy change accordingly. While the new structural economics describes the intuition of the optimal financial structure verbally, we develop a theoretical model to investigate how the optimal financial structure is determined and how it changes as the economy develops.

Second, our paper is related to the literature that studies how the behavior of firms changes as the economy grows. Acemoglu, Aghion and Zilibotti (2006) develop a model where firms from countries at early stages of development tend to imitate the existing technology. Closer to the world technology frontier, firms switch to an innovation-based strategy. Our model studies the optimal financing strategy of firms from countries at different stages of development. We show how the optimal financial strcuture depends on the strategy that firms select their technology.

Third, our paper is also related to the debate on the relative importance of direct and indirect financial institutions. Stiglitz (1985), Shleifer and Vishny (1997), Rajan and Zingales (1998), among others, point out that the advantages of financial intermediaries, such as information collection, corporation control, saving mobilization, etc, allow them to facilitate resources allocation and economic development. On the other hand, Hellwig (1991), Rajan (1992), Boot and Thakor (2000), Black and Moersch (1998), among others, argue that the financial intermediaries, under intermediaries-dominate financial structure, were precautionary and had great influence on corporations which may become negative effects on innovation and development of corporations and thus the whole economy. Moreover, they show that financial markets could provide more service in risk management which may encourage innovation. Allen and Gale (1995, 1997) find that financial intermediaries could provide more effective intertemporal risk sharing whereas financial markets provide more effective crosssectional risk sharing. Allen and Gale (1999) compare the effectiveness of financial markets and financial intermediaries in financing new industries and technologies and emphasize that financial markets tend to be superior when there is significant diversity of opinion and information is expensive. Our paper differs from this literature by considering how the stage of development affects the relative importance of direct and indirect financial institutions.

We organize this paper as follows. Section 2 presents the model with distance to frontier and diversity of opinion. The model is characterized in section 3. Section 4 provides concluding remarks.

2 The Model

In this section, we construct a schumpeterian endogenous growth model with information acquisition, diversity of opinion, and distance to technology froniter. (Aghion and Howitt, 1992, 1998; Allen and Gale, 1999; Acemolgu, Aghion and Zilibotti, 2006).

2.1 Agents and Production

The model economy is populated by overlapping generations of two-period lived risk-neutral agents. The population is constant and each generation consists of a mass of $N+K$ agents. Young agents are endowed with one unit labor and have no wealth. All of the young agents can be workers and supply their labor endowment inelastically to earn wages and are equally productive in production tasks. A measure K of young agents can come up with entrepreneurial ideas, i.e. innovation projects in terms of higher quality of intermediate goods (Schumpeter, 1912, Aghion and Howitt, 1992), in each period, and they can become entrepreneurs if they successfully acquire the fundings from the old generation. The old generation does not act as workers and entrepreneurs. They consume the unique final good and invest in projects run by entrepreneurs using their wages earned when they are young.

The unique final good is produced competitively by aggregating K intermediate goods through an aggregator with a constant elasticity of substitution $\epsilon \in [0, \infty)$:

$$y_t = \left(\sum_{i=1}^{K} \lambda(i) y_t(i)^{\frac{\epsilon-1}{\epsilon}} \right)^{\frac{\epsilon}{\epsilon-1}}, \tag{1}$$

where $\sum_{i=1}^{K} \lambda(i) = 1$.

We take this final good as the numeraire so that its price, p_t, is normalized to one at all time points:

$$1 \equiv p_t = \left(\sum_{i=1}^{K} \lambda(i)^{\epsilon} p_t(i)^{1-\epsilon} \right)^{\frac{1}{1-\epsilon}}, \tag{2}$$

where $p_t(i)$ is the price of the $y_t(i)$ goods and it can be obtained as:

$$p_t(i) = \lambda(i) \left[\frac{y_t(i)}{y_t} \right]^{-\frac{1}{\epsilon}}. \tag{3}$$

Intermediate good i is produced competitively by labor and a continuum of mass 1 input goods through the production function below:

$$y_t(i) = \frac{1}{\alpha} N_t(i)^{1-\alpha} \left(\int_0^1 A_t(v,i)^{1-\alpha} x_t(v,i)^{\alpha} dv \right), \tag{4}$$

where $A_t(v,i)$ is productivity in input sector v which is used by intermediate sector i at time t. $x_t(v,i)$ is the flow of input good v used in intermediate sector i again at time t. $N_t(i)$ is the number of production workers in intermediate sector i at time t and $\alpha \in (0,1)$.

In input sector v used by intermediate sector i, one production site has access to the most productive technology, $A_t(v,i)$, hence this "leading firm" will enjoy monopoly power. Each leading firm has access to a technology to transform one unit of the final good into one unit of input good of productivity $A_t(v,i)$. A fringe of additional firms can imitate this technology, and produce the same intermediate good, with the same productivity $A_t(v,i)$, without using the production site or an entrepreneur. But this fringe faces higher costs of production, and needs χ units of the final good to produce one unit of the input good, where $1 < \chi < 1/\alpha$ (obviously, the imitating firms will not be active in the equilibrium).[1] The existence of the imitators forces the innovator to charge a limit price,

$$q_t(v,i) = \chi. \tag{5}$$

[1]The detail economic description of variable χ can be seen in the paper, Acemolgu, Aghion and Zilibotti (2006).

The final good sector is competitive, so each input good producer v at date t faces the inverse demand schedule: $q_t(v,i) = [A_t(v,i)\,N_t(i)/x_t(v,i)]^{1-\alpha}$. This equation together with (4) gives equilibrium demands: $x_t(v,i) = \chi^{-\frac{1}{1-\alpha}} A_t(v,i)\,N_t(i)$, with monopoly profits equal to:

$$\pi_t(v,i) = (q_t(v,i) - 1)\,x_t(v,i) = \delta A_t(v,i)\,N_t(i), \tag{6}$$

where $\delta \equiv (\chi - 1)\,\chi^{-\frac{1}{1-\alpha}}$.

Equation (4) gives aggregate output of the intermediate sector i as $y_t(i) = \alpha^{-1}\chi^{-\frac{1}{1-\alpha}} A_t(i)N_t(i)$, where $A_t(i) \equiv \int_0^1 A_t(v,i)\,dv$, is the average level of technology in the economy at time t. The market clearing wage level is equal to the marginal product of labor in production:

$$w_t = \alpha^{-1}(1-\alpha)\,\chi^{-\frac{1}{1-\alpha}} p_t(i)A_t(i), \tag{7}$$

where $p_t(i)A_t(i) = p_t(j)A_t(j)$ for any $i,\ j$ from $\{1,\cdots,K\}$. Then combining the production function of the intermediate sector i and its pricing equation (3) yields the following equation:

$$\frac{N_t(i)}{N_t(j)} = \left(\frac{\lambda(i)}{\lambda(j)}\right)^{\epsilon}\left(\frac{A_t(i)}{A_t(j)}\right)^{\epsilon-1}, \tag{8}$$

which implies:

$$N_t(i) = \frac{\lambda(i)^{\epsilon}A_t(i)^{\epsilon-1}N_t}{\sum_{i=1}^{K}\lambda(i)^{\epsilon}A_t(i)^{\epsilon-1}}, \tag{9}$$

where $N_t = \sum_{i=1}^{K} N_t(i)$. Without loss of generality, we assume there is no population growth and thus we have the number of workers $N_t = N$ for all t.

We define $A_t = \sum_{i=1}^{K}\lambda(i)^{\epsilon}A_t(i)^{\epsilon-1}di$ as the aggregate productivity (or technology). Obviously the aggregate productivity, A_t, is the weighted average of all intermediate sectors' productivity. Equation (9) implies that the number of workers in intermediate sector i completely depends on the productivity of this sector relative to the aggregate productivity. For example, if all intermediate sectors have the same productivity, that is, $A_t(i) = A_t(j)$ for all i, j from $\{1,\cdots,K\}$, then the number of workers in sector i is completely determined by the parameter $\lambda(i)$. In addition, if all intermediate sectors have the same productivity growth rate despite their different initial technology level, then the number of workers in any intermediate sector is a constant, that is, $N_t(i) = N(i)$ for all t.

We assume that all input sectors in all intermediate sectors are the same and therefore the monopoly profit of each input sector in intermediate sector i is

$$\pi_t(i) = \delta A_t(i)\,N_t(i). \tag{10}$$

Here it should be noticed that input sectors' monopoly profit in different intermediate sectors could be different because both $A_t(i)$ and $N_t(i)$ are heterogeneous across sectors. Finally, each project must be operated by an entrepreneur who secures the idea and the total size of population is $N + K$.

2.2 Technology Progress and Productivity Growth

At the beginning of each period, some young agents can always come up with ideas of innovative projects in each intermediate good sector. These young agents, having no financial resources at their hands, must seek financing from investors who are of old generation. Once a project is financed by investors, the young agent who owns the project becomes an entrepreneur.

Firm productivity is determined by entrepreneurial skill (management or operation skill) and the size of the project that the entrepreneur operates. To simplify the analysis, we do not consider the entrepreneurial skill or entrepreneurial risk. We only consider the risk of technological innovation and assume that there are two possible project types, imitation and inventionḟootnoteAcemoglu, Aghion and Zilibotti (2006) consider the entrepreneurial risk and two specific possible project sizes. However, their definition of entrepreneurial skill is not the same to this paper Imitation is easier and can be acquired from the world technological frontier, and thus its return is low. Invention is more difficult and must be developed from the knowledge level of local countries, and thus its return is much higher than imitation.

Denote the growth rate of the world technology frontier in the intermediate sector i by $\overline{A}_t(i)$ which follows the following dynamics:

$$\overline{A}_t(i) = (1+g)^t\,\overline{A}_0(i). \tag{11}$$

Here we assume that all intermediate sectors have the same growth rate of technology frontier.

We will return to the determination of this growth rate below. All countries have a state of technology defined by $A_t(i) \equiv \int_0^1 A_t\,(v,i)\,dv$, which is lower than the frontier technology. In particular, for the representative country, we have $A_t(i) \leq \overline{A}_t(i)$. Lin, Sun and Jiang (2013) consider three kinds of risks in a firm, i.e. technological innovation risk, market demand risk and entrepreneurial risk, pointing out that entrepreneurial risk dominates in the early stage of development whereas technological risk and market demand risk dominate in the later stage of development of an economy. Since entrepreneurial risk is not so significant, we abstract from this risk and merely assume there is no risk in imitation which is captured by entrepreneurial level. Technological risk and market demand risk, on the contrary, are more essential in determinging the optimal financial institution. Therefore, the productivity of input good sector v in the intermediate sector i at time t is defined as follows:

$$A_t(v, i) = \eta \overline{A}_{t-1}(i) + \gamma_t(v) A_{t-1}(i), \tag{12}$$

where

$$\gamma_t(v) = \begin{cases} \overline{\gamma}_t(v) & \text{if successful, with } prob = \psi \\ \underline{\gamma}_t(v) & \text{if failed, with } prob = 1 - \psi \end{cases}. \tag{13}$$

η denotes the efficiency of imitation, which captures the entrepreneurial skill level of the country. $\overline{\gamma}_t(v) > \underline{\gamma}_t(v)$ denotes the efficiency of invention, which captures technological innovation proficiency of the economy. By imitating the existing technologies, firms benefit, in term of a higher productivity, from the state of world technology in the previous period, $\overline{A}_{t-1}(i)$. On the other hand, there is productivity growth due to invention building on the local knowledge level, $A_{t-1}(i)$, and the success in invention depends on technological innovation efficiency as captured by $\gamma_t(v)$. The parameter ψ is the ex post probability that a project is successful and all investors can not know this probability ex ante.

Rearranging equation (6) and using the definition $A_t(i) \equiv \int_0^1 A_t(v, i)\, dv$, we derive the growth rate of aggregate technology in the intermediate sector i as follows:

$$\frac{A_t(i)}{A_{t-1}(i)} = \frac{\int_0^1 A_t(v, i)\, dv}{A_{t-1}(i)} = \int_0^1 \left(\eta \frac{\overline{A}_{t-1}(i)}{A_{t-1}(i)} + \gamma_t(v) \right) dv. \tag{14}$$

Equation (8) shows the importance of distance to frontier, as captured by the term $\frac{\overline{A}_{t-1}(i)}{A_{t-1}(i)}$. When this term is large, the country is far away from the world technology frontier, and the major source of growth is the imitation of already well-established technologies as captured by the term $\eta \frac{\overline{A}_{t-1}(i)}{A_{t-1}(i)}$. When $\frac{\overline{A}_{t-1}(i)}{A_{t-1}(i)}$ is close to 1, so that the country is close to the frontier, invention matters relatively more, and growth is driven by the $\gamma_t(v)$ term. Consequently, as the country develops and approaches the world technology frontier, invention and technological innovation efficiency becomes more important.

We assume, without loss of generality, that there exists a sunk cost for both imitation and invention, $\sigma \overline{A}_{t-1}(i)$ for all i from $\{1, \cdots, K\}$, in intermediate sector i in period t

2.3 Financing New Technologies

As we describe above, young agents who come up with ideas have no wealth to launch the projects. Hence, they must seek external financing from investors who are the old generation. The efficiency of invention is uncertain ex ante. That is, initially, investors do not know the true type of the project. More importantly, we assume that the investors have no common prior on the probability of success of the project. The common prior assumption is not appropriate when considering new industries such as biotechnology and new technologies. As Allen and Gale (1999) point out, there is a wide variation in views on the effectiveness and value of an innovation immediately after the innovation has occurred. Since the amount of data available based on actual experience with new products or technologies are nonexistent or small, such differences in views would appear to be due to differences in priors. In this case, there is diversity of opinion and people agree to disagree. Investors have heterogeneous beliefs and interpret information differently. Pessimistic investors think of that the project is bad and refuse to invest even if they are awere of detailed information about the project. Optimistic investors, in contrast, interpreting the same information in an opposite way, believe the project is good and choose to invest. We simplify the analysis by assuming that investors are ex ante identical, i.e. all the investors have the same probability of becoming optimists or pessimists. We assume that the opinions of investors are diverse. The importance of the heterogeneous priors assumption is not that it implies different beliefs about the profitability of the project ex ante, but rather that it allows investors to agree to disagree.

The timing and the details of decision-making process are as follows. Investors initially have symmetric beliefs about the profitability of the project's type. They can obtain more information about the profitability of the project before the investment decision by paying a cost. We assume the information cost is $C_t(i) > 0$, where $C_t(i) = c\overline{A}_{t-1}(i)$. After paying the cost, the investor is either in a state of optimism about the project and thinks the project will be successful, which has a positive expected return per unit of investment, or he is in a state of pessimism and thinks the project will be failed, which yields a negative return per unit of investment. The probability that an uninformed investor is an optimist is denoted by μ. If the investor does not pay the cost $C_t(i)$, he/she cannot find out whether the project is successful or failed until a later date after the investment decision has been made.

There are three subperiods in each period. At the beginning of each period, all investors symmetrically have asymmetric information about the detailed features of the new projects submitted by young agents who are endowed with ideas. During the second sub-period, incomplete information about the projects becomes available and investors have two possible actions to choose. One is paying a cost of $C_t(i)$ and acquiring the information relied on which they will know the type by their own interpretation and not necessarily the true type. The other is doing nothing and remaining uninformed about the project. Diversity of opinion implies that informed investors do not necessarily agree. Although the investors get the same information, they interpret it differently. As a result, they have heterogenegous beliefs and agree to disagree. In the third sub-period, innovation is completed, intermediate goods are produced, profits are realized and payment is allocated to the entrepreneurs and workers.

The measurement of the degree of diversity is the probability that a randomly selected informed investor will disagree with an optimist. Denote the conditional probability by:

$$\beta \equiv prob\,(Y \text{ is an optimist}|X \text{ is an optimist})\,. \tag{15}$$

Another related conditional probability is

$$\beta' \equiv prob\,(Y \text{ is an optimist}|X \text{ is an pessimist})\,. \tag{16}$$

Allen and Gale (1999) prove that the profitability of delegating the investment decision to an intermediary depends on whether the beliefs of investors are correlated ex post, and this requires $\mu \leq \beta \leq 1$. We can think of β as a measure of correlation among the investors' beliefs. Alternatively, we can think of $1-\beta$ as a measure of diversity of opinion. If the randomly chosen person is an optimist, then it is likely that the majority of the investors are optimists. Similarly, if a randomly chosen person is a pessimist, it is likely the majority are pessimists. We can also prove that these two probability have the relation that $\beta > \beta'$.

3 Market versus Intermediary

3.1 Financial Institutions

To compare financial markets with financial intermediaries, we must clearly define these two different financial institutions.

Definition 1 ***Direct or Market finance*** *is identified with a situation in which investors become informed and then decide individually whether to contribute to the funding of the project.*

Definition 2 ***Indirect or intermediary finance*** *is identified with a situation in which investors form a consortium. One of the investors in this consortium is designated as the manager who becomes informed and decides whether to invest in the project on the basic of that information, while the rest of the investors remain uninformed.*[2]

The fact that there is a positive correlation between the manager's opinion and the opinions of the other members of the consortium, which is guaranteed by the assumption $\mu \leq \beta \leq 1$, means that, on average, the manager makes a representative decision for the consortium.

3.2 Equilibrium

To define the equilibrium, we first introduce the notation

$$a_t(i) \equiv \frac{A_t(i)}{\overline{A}_t(i)} \tag{17}$$

as the proximity to the technological frontier, or in other words, as inverse measure of the country's distance to frontier in the intermediate sector i. This measure summarizes the state of development stage of the economy. The key decision of investors in this economy is to choose the optimal financial institution for their investment, in the sense of maximizing the expected profit earned through the investment. Denote the choice of financial institution by $F_t(v) \in \{I, M\}$, where $F_t = I$ denotes the intermediary (indirect) financing institution and $F_t = M$ denotes the market (direct) financing institution. The static and dynamic equilibrium of our model is defined below.

Definition 3 *A* ***static equilibrium*** *(given the state of the economy, $a_t(i)$) is a set of intermediate good prices $q_t(i)$, that satisfy (5), profit levels, $\pi_t(i)$, given by (10), a wage rate, w_t, given by (7), and the choice of financial institution, F_t.*

[2]The assumption that only one member of the consortium becomes informed is clearly special. But as Allen and Gale (1999) arguing that this is the limiting case when monitoring costs are high. Hence, to simplify the analysis, assume that only one manager exists in the consortium.

Definition 4 *A* ***dynamic equilibrium*** *is obtained by piecing together static equilibrium through the law of motion of aggregate productivity for any intermediate sector i as given by (14). The equilibrium law of motion will be determined in greater detail below.*

3.3 Comparison of Market and Intermediary

The investors compare market and intermediary financing institutions to decide which institution to be put in place. The criterion of the comparision is the expected profit of the project. Hence, we first determine the payoffs of all agents. Workers are paid its marginal product since they are in a competitive labor market. Entrepreneurs must be paid at least the same to what is paid to workers, i.e. competitive wages. The reason is that if the payment of entrepreneurs is less than the competitive wages then the agents with ideas will not submit the project and be a worker to earn a higher income than the payment to entrepreneurs. In other words, investors must satisfy a participation constraint when they maximize their expected income. Competition among entrepreneurs due to the lack of wealth allows the investors to set the payment at precisely the competitive wage. Thus, the participation constraint must be binding. Investors obtain the net profit.

To determine the profits of investors, we first examine the returns of projects launched by imitating and inventive entrepreneurs respectively. When the project is low-type, which means the invention will be failed, according to equations (5), (11) and (12), the return on average is determined by[3]

$$R_t^f(i) \equiv \delta\left(\eta_{t-1}(i) + \underline{\gamma} A_{t-1}(i)\right) - \frac{w_t + \sigma \overline{A}_{t-1}(i)}{N_t(i)}. \tag{18}$$

While the project is high-type, which means the invention is successful, from the some equations as above, the per capita return of investors is

$$R_t^s(i) \equiv \delta\left(\eta \overline{A}_{t-1}(i) + \overline{\gamma} A_{t-1}(i)\right) - \frac{w_t + \sigma \overline{A}_{t-1}(i)}{N_t(i)}. \tag{19}$$

Obviously, the return of investors if the project is successful is larger than that if the project is failed, that is, $R_t^s(i) > R_t^f(i)$. Moreover, we assume that $R_t^s(i) > 0 > R_t^f(i)$.

[3]Since, in the equilibrium, all sectors are the same, we can only consider a representative intermediate sector.

Consequently, investors who do not finance receive a net return of 0, denoting by $V^O = 0$. An uninformed investors expects the project on earn a net return of

$$V_t^U(i) \equiv \mu R_t^s(i) + (1-\mu)\, R_t^f(i). \tag{20}$$

Even if this return is positive, the investor may be able to do better by becoming informed.

Under market finance, each individual who wishes to become informed must pay the cost $C_t(i)$. After becoming informed, an investor will change his probability that he believes the project is successful, denoting by ϕ. And an investor will invest in the project if and only if he is optimistic. Thus, the payoff to becoming informed is

$$V_t^M(i) \equiv \phi R_t^s(i) + (1-\phi)\, 0 - C_t(i). \tag{21}$$

Simplifying equation (15) obtains

$$V_t^M(i) \equiv \phi R_t^s(i) - C_t(i). \tag{22}$$

Information is valuable to the intermediary only if the investment decision depends on the outcome of obtaining information. Since we assume that $\beta > \beta^{'}$, we have the following inequalities by continuity:

$$\beta^{'} R^s(i) + \left(1-\beta^{'}\right) R^f(i) < 0 < \beta R^s(i) + (1-\beta)\, R^f(i). \tag{23}$$

If it is worthwhile forming an intermediary at all, the return conditional on the manager being optimistic is positive and everyone agrees to invest in the project if and only if the manager and investors are optimistic and if the manager and investors are pessimistic. Under this decision rule, the payoff is

$$\begin{aligned} V_t^I(i) &\equiv \phi\left(\beta R_t^s(i) + (1-\beta)\, R_t^f(i)\right) + (1-\phi)0 - \frac{C_t(i)}{N_t(i)} && \text{(24a)} \\ &\equiv \phi\left(\beta R_t^s(i) + (1-\beta)\, R_t^f(i)\right) - \frac{C_t(i)}{N_t(i)} && \text{(24b)} \end{aligned}$$

since the manager is optimistic and decides to invest with probability ϕ and, given that the manager is optimistic, the expected return to a randomly selected investor is $\beta R_t^s(i) + (1-\beta)\, R_t^f(i)$. With probability the manager is pessimistic and does not invest. In each case the investor has to pay his or her share $\frac{C_t(i)}{N_t(i)}$ of the information costs.

Since what we are interested in is which financial institution to choose, we do not consider the case investors do not finance. In addition, we assume that the prior probability, μ, the cost of information, $C_t(i)$, are low enough so that $V_t^U < V_t^M$ and $V_t^U < V_t^I$, with $V_t^M > 0$, $V_t^I > 0$ and $V_t^U < 0$. Then quation (19), (20) and (22) imply that the investor will not keep uninformed and pay the cost to become informed. According to the continuity of the value functions, and the fact $R_t^s(i) > R_t^f(i)$, there exist some prior probabilities and costs which make investors better off if they become informed[4].

To summarize, if the investors choose intermediary as their financial institution, i.e. $F_t = I$, then the manager will choose to become informed while all the investors can not and if the investors choose market as the financial institution, i.e. $F_t = M$, then all the investors will decide to be informed. In the intermediary financing system, since investors and the manager may have different opinion in the type of the project and the decision maker is the manager, investors do not know exactly whether the manager will invest or not. Therefore, the expected gross return of investors under intermediary financial institution depends on the opinion of the manager, which leads to a low return. In the market financing system, however, investors decide to invest based on their own beliefs. Thus, the expected return of investors under the market financing institution depends on their own beliefs. Consequently, the expected gross return of investors under direct financing institution is larger than that under the indirect financing system.

We can conclude that the primary distinctions between the direct and indirect financing institution are that 1) the gross revenue is larger under the direct financing institution than the indirect one; and 2) the cost is lower under the indirect one than the direct one. Both differences are consequences of the fact that decision makers are all investors under direct financing institution while the manager is the only decision maker under indirect financing system. Equations (17), (18), (20) and (22) imply the following lemmas.

Lemma 1 *A project is more likely to be regarded as a high-type one under direct financial institution than indirect one.*

Lemma 2 *The relative magnitude of expected value under two financial institutions is not unambiguous.*

Lemma 3 *Efficiency of imitation under direct financial institution is equal to that*

[4] The proof is just some simple and direct algebra.

under indirect financial institution, while efficiency of invention under direct financial institution is larger than that under indirect financial institution. Market has comparative advantage in promoting efficiency of invention while intermediary has comparative advantage in driving efficiency of imitation.

Proof. *From equations (10), (11), (17), (18), (20) and (22) and the definition $\delta \equiv (\chi - 1)\,\chi^{-\frac{1}{1-\alpha}}$, we derive the explicit expression of $R_t^s(i)$, $R_t^f(i)$, $V_t^I(i)$, $V_t^M(i)$ as follows:* ■

$$R_t^s(i) = \left(\eta\theta_t(i) - \frac{\sigma}{N_t(i)}\right)\overline{A}_{t-1}(i) + \overline{\gamma}\theta_t(i)A_{t-1}(i),$$

$$R_t^f(i) = \left(\eta\theta_t(i) - \frac{\sigma}{N_t(i)}\right)\overline{A}_{t-1}(i) + \underline{\gamma}\theta_t(i)A_{t-1}(i),$$

$$V_t^M(i) = \phi\left(\left(\eta\theta_t(i) - \frac{\sigma}{N_t(i)}\right)\overline{A}_{t-1}(i) + \overline{\gamma}\theta_t(i)A_{t-1}(i)\right) - C_t(i),$$

and

$$V_t^I(i) = \phi\left((\eta\theta_t(i) - \frac{\sigma}{N_t(i)})\overline{A}_{t-1}(i) + \theta\left(\beta\overline{\gamma} + (1-\beta)\underline{\gamma}\right)A_{t-1}(i)\right) - \frac{C_t(i)}{N_t(i)},$$

where $\theta_t(i) = \left(\chi - 1 - \frac{1-\alpha}{\alpha N_t(i)}\right)\chi^{-\frac{1}{1-\alpha}}$. We can see clearly that efficiency of invention is larger under market than intermediary and efficiency of imitation is equivalent under two institutions. To see the comparative of the two financing systems, comparing the relative efficiencies of both invention and imitation, we secure

$$\frac{\left(\eta\theta_t(i) - \frac{\sigma}{N_t(i)}\right)}{\left(\eta\theta_t(i) - \frac{\sigma}{N_t(i)}\right)} < \frac{\overline{\gamma}\theta_t(i)}{\theta\left(\beta\overline{\gamma} + (1-\beta)\underline{\gamma}\right)},$$

that is,

$$1 < \frac{\overline{\gamma}\theta_t(i)}{\theta\left(\beta\overline{\gamma} + (1-\beta)\underline{\gamma}\right)},$$

from which we can obviously see the comparative advantage of each system.

The efficiency of imitation is assumed to be a constant and the efficiency of invention can not be determined by investors ex post. The ex post efficiency of invention is remain uncertain with the objective probability of success ψ. Therefore, we can immediately derive that the law of motion of technology (productivity) is uniform under both financial institutions. This is summarized in Proposition 1.

Proposition 1 *Both the direct and indirect financing institutions share the same law of motion of technological progress below:*

$$A_t^M(i) = A_t^I(i) = \eta \overline{A}_{t-1}(i) + \left(\psi\overline{\gamma} + (1-\psi)\underline{\gamma}\right) A_{t-1}(i), \tag{25}$$

3.4 Static Equilibrium

Since the main purpose of this paper is to determine which financial institution to choose is optimal in the stages of economic development, we focus on the equilibrium financial institutions in equilibrium.

Investors choose which institution to finance the project by maximizing their expected value at the beginning of each period. They will compare the expected value in the two institutions and choose the larger one. Lemma 2 guarantees the expected value can be smaller or larger under direct financing system than the indirect financing system. In equilibrium, all projects will be financed and all investors under market financing institution and the manager under intermediary financing system will pay the information cost to become informed. The ex ante expected value under the two financial institutions are as follows:

$$V_t^M(i) = \left(\phi(\eta\theta_t(i) - \frac{\sigma}{N_t(i)}) - c\right)\overline{A}_{t-1}(i) + \phi\overline{\gamma}\theta_t(i)A_{t-1}(i), \tag{26}$$

and

$$V_t^I(i) = \left(\phi(\eta\theta_t(i) - \frac{\sigma}{N_t(i)}) - \frac{c}{N_t(i)}\right)\overline{A}_{t-1}(i) + \phi\left(\beta\overline{\gamma} + (1-\beta)\underline{\gamma}\right)\theta_t(i)A_{t-1}(i) \tag{27}$$

noting that $C_t(i) = c\overline{A}_{t-1}(i)$.

Investors in each intermediate sector choose a financial institution at the beginning of each period by comparing equations (26) and (27). Obviously, the result relies on the distance to frontier, a_{t-1}. The cutoff value of the distance to frontier is

$$a_t^*(i) = \frac{c\left(1 - \frac{1}{N_t(i)}\right)}{\phi(1-\beta)\left(\overline{\gamma} - \underline{\gamma}\right)\theta_t(i)} \tag{28}$$

which is uniquely determined. The static equilibrium is summarized in Proposition 2:

Proposition 2 *There exists a unique threshold value of the distance to frontier for any intermediate sector i, $a_t^*(i)$. Moreover, given the distance to technology frontier, $a_{t-1}(i)$, there exists a unique equilibrium such that the intermediary financing institution is chosen by the manager, $F_t = I$, when $a_{t-1}(i) < a_t^*(i)$, and the market financing institution are chosen by investors, $F_t = M$, when $a_{t-1}(i) > a_t^*(i)$.*

The following comparative statics of the cutoff value $a_t^*(i)$ with respect to some subjective and institutional parameters provide some important and insightful results:

$$\frac{\partial a_t^*(i)}{\partial \phi} < 0,\ \frac{\partial a_t^*(i)}{\partial (1-\beta)} < 0,\ \frac{\partial a_t^*(i)}{\partial c} > 0,\ \frac{\partial a_t^*(i)}{\partial N_t(i)} < 0,$$

and

$$\frac{\partial a_t^*(i)}{\partial (\Delta\gamma)} < 0,$$

where $\Delta\gamma \equiv \overline{\gamma} - \underline{\gamma}$ is the efficiency difference. And the parameter of sunk cost σ will not influence $a_t^*(i)$.

The above comparative static results are very intuitive. A larger ϕ means a larger ex ante expected value of investors, which in turn means that market financing institution leads to larger revenues and should be chosen earlier in the stage of economic development. A small β or a large $1-\beta$ means the degree of diversity of opinion is larger, hence the expected value difference between two institutions is large, hence the investors want to adopt market financing institution earlier in the stage of economic development. The larger the information cost c, the smaller the difference between two institutions and then the investors are willing to dive in direct financing system is not so urgent. The same thing happens when the ex post efficiency difference becomes larger. Since both financial institutions pay a sunk cost before investment, the sunk cost has no effect on $a_t^*(i)$.

Notice that the sector with higher technology level has a larger labor force according to equation (9). The result that $a_t^*(i)$ decreases with respect to $N_t(i)$ means that the sector with higher technology level tend to achieve its threshold sooner if all sectors have the same distance to the frontier and the same growth rate of technology. We will discuss this situation again later.

3.5 Dynamic equilibrium

We now characterize the dynamic equilibrium of the economy. Let us first determine the law of motion of $a_t(i)$ conditional on the financial institution decision, F_t. Using equations (19) and (20) and the fact that $\overline{A}_t(i)$ grows at the rate g, we obtain:

$$a_t(i) = \frac{\eta + \left(\psi\overline{\gamma} + (1-\psi)\,\underline{\gamma}\right) a_{t-1}(i)}{1+g}, \tag{29}$$

for both financial insitutions. Obviously, equation (29) implies that all intermediate sectors have the same growth rate of technology if the technology frontier grows at the same rate. Then, it can be shown that $N_t(i) = N(i)$ for all t by observing equation (9) and finally obtain $a_t^*(i) = a^*(i)$ for all t by observing equation (28). Proposition 3 summarizes these results.

Proposition 3 *Suppose the technology frontier grows at the same rate as equation (11) for all intermediate sectors. Then all intermediate sectors share the same growth rate of technology described by equation (29), and in addition, all intermediate sectors have the stable number of workers, that is,* $N_t(i) = N(i)$ *for all* t. *Furthermore, the threshold value of the distance to frontier is also stable for any intermediate sector* i, *that is,* $a_t^*(i) = a^*(i)$ *for all* t.

Equation (29) shows that the equilibrium dynamics are given by a linear first-order difference equation. When $a_t \leq a^*$, the intermediary financing institution emerges in equilibrium, whereas $a_t > a^*$, the economy switches to the market financing institution.

We can now characterize the growth rate of the world technology frontier. Since $a_t(i) = \frac{A_t(i)}{\overline{A}_t(i)}$, world technology frontier can be touched only when $a = 1$. Then, equation (29) evaluated at $a = 1$ gives the world technology growth rate as:

$$g = \eta + \left(\psi\overline{\gamma} + (1-\psi)\,\underline{\gamma}\right) - 1 \tag{30}$$

Proposition 4 summarizes the equilibrium dynamics.

Proposition 4 *Suppose all the assumptions hold. Denote the initial distance to frontier by the same* a_0 *for all intermediate sectors. The equilibrium dynamics of the optimal financing institutions are as follows:*

1. *If* $a_0 < \min\{a^*(i)\}$*, then all intermediate sectors start with the intermediary financing institution only. Then, the intermediate sector with the highest technology level switches to the market financial institution at period* t_1*, where* $t_1 = inf\{t : a_t \geq min\{a^*(i)\}\}$*. Since period* t_1*, the intermediary financing institution and the market financing institution coexist. Finally, all intermediate sectors switch to the market financing institution at period* t_2*, where* $t_2 = inf\{t : a_t \geq max\{a^*(i)\}\}$*. Since period* t_2*, only the market financing institution exists in the economy.*

2. *If* $\max\{a^*(i)\} > a_0 \geq \min\{a^*(i)\}$*, the economy begins with both the intermediary and market financing institutions. Then, all intermediate sectors switch to the market financing institution at period* t_2*. The economy converges to the world technology frontier with the market financing institution only since period* t_2*.*

3. *If* $a_0 \geq \max\{a^*(i)\}$*, only the market financing institution exists from the beginning.*

The economy eventually converges to the world technology frontier, $a = 1$*, in all three cases.*

The dynamic pattern of the optimal financing institution in Proposition 4 is consistent with empirical evidence documented in Demirguc-Kunt and Levine (2001) and Tadesse (2002), among others.

4 Concluding Remarks

There is no reason to think of that one financing institution will be optimal for all stages of economic development. Empirical evidence shows that financing institution endogenously changes as the economy develops. This paper studies endogenous changes of financial institutions in a Schumpeterian endogenous growth model with uncertain innovation outcome. The market financing system has comparative advantage in promoting efficiency of invention while intermediary financial institution has comparative advantage in encouraging efficiency of imitation. When the economy is at early stages of economic development, imitation is more important and the intermediary financial institution emerges in equilibrium. As the economy approaches the world technology frontier, invention becomes more significant and the intermediary financial institution will switch to the market financing system.

This paper takes the risk properties of firms as exogenously given. Lin, Cai and Zhou (1994); Lin, Sun and Jiang (2013), Ju, Lin and Wang (2015) argue that factor endowment determines the industrial structure which is a main driving force of the risk properties of firms. Hence, a promising further research direction is investigating how the optimal financial structure evolves as the factor endowment and industrial structure changes.

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