Development Strategy, Viability, and Economic Convergence

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Abstract

The paper argues that an economy's industry/technology structure is endogenously determined by the economy's endowment structure. For the convergence to occur, the government of an LDC should target the upgrading of endowment structure instead of the industry/technology structure in its development strategy. If the government chooses to pursue an industry/technology structure, which is inconsistent with the comparative advantage determined by the economy's endowment structure, the firms in the government's priority sectors will be nonviable and the government needs to suppress the function of market and distort all kinds of prices as a way to protect the nonviable firms. Convergence will fail to occur as a result. Regression results from cross-country panel data are consistent with the predictions of the above arguments.

Key words: Economic Development, Development Strategy, role of government, Institution.

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Non-Technical Summary

Potentially, a less-developed country could narrow its income gap with the developed countries by a higher rate of capital accumulation and by obtaining a faster rate of technological innovation than developed countries through borrowing technology from developed countries. However, such convergence has occurred in only a small number of less-developed economies in East Asia. I will argue that the industry/technology structure of an economy is endogenously determined by the structure of its factor endowment and the government's development strategy about the industry/technology choice in a less-developed country is an important determinant about whether the convergence will occur or not. If the government's priority is to promote an industry/technology structure, which is inconsistent with the economy's comparative advantage determined by the economy's endowment structure, the firms in the priority sector will be nonviable in a competitive market. In order to set up and to maintain the survival of nonviable firms, the government needs to subsidize the firms with distorted prices of capital, foreign exchanges, and other inputs, and to use an administrative method to allocate the price-distorted resources to the firms. The functions of market will be suppressed. Rent seeking will be widespread. As a result, the performance of the economy will be poor and the convergence will fail to occur. Only if the government in a less-developed country follows the economy's comparative advantage as the basic principle for promoting the economy's industrial development, will the economy have a well function of market, borrow technology easily from developed countries, maintain a high rate of capital accumulation, achieve a rapid upgrading of its endowment structure, and result in the convergence. Empirical analyses of cross-country data show that the strategy of following or defying comparative advantages in the choices of technology/industries is an important factor in explaining a country's success or failure to converge with the developed countries. A less-developed country's government should therefore take the upgrading of the economy's endowment structure as the development target and improve the function of market and encourage the firms to exploit the economy's comparative advantages in the firm's choices of industry/technology.

I. Introduction

Since the industrial revolution in the 18th century, countries in the world can be divided into two groups. The first group includes the rich, industrialized, developed countries (DCs). The second group includes the poor, agrarian, less developed countries (LDCs). Countries in the first group extensively use modern, capital-intensive technologies for production, whereas countries in the second group mainly uses outdated technologies. The wealth of developed countries results from their industrial and technological advantages. How to industrialize their nations and catch up with developed countries has interested not only political leaders but also many intellectuals in the LDCs since the 19th century (Gerschenkron 1962, Lal 1985). After World War II, many governments in the LDCs adopted various policy measures to industrialize their economies. However, only a small number of economies in East Asia have actually narrowed the gap and converged to the level of per capita income with DCs.[1]

I will argue that the failure of most LDCs to converge with DCs can be largely explained by their government's inappropriate development strategies. Most governments in LDCs after World War II pursued the development of certain capital-intensive industries as the priorities of their development plan. However, the optimal industrial structure of an economy is endogenously determined by the economy's endowment structure. The firms in a government's priority industries are not viable in an open, competitive market because these industries do not match the comparative advantage of the particular economy. As such, the government introduces a series of distortions in its international trade, financial sector, labor market, and so on in order to support the non-viable firms. Through distortions it is possible to establish capital-intensive industries in developing countries. However, the economy becomes very inefficient due to misallocation of resources, rampant rent seeking, macro instability, and so forth. Consequently, convergence fails to occur. The government of an LDC should make the upgrading of its endowment structure instead of the upgrading of its industry/technology structure as its development goal, because once the endowment structure is upgraded, the firms induced by profit motives and competitive pressures will spontaneously upgrade their technologies and industries spontaneously. The upgrading of the endowment structure means faster accumulation of capital, both

[1] Starting from very low levels, Japan's per capita income, measured in current US dollars, exceeded that of the US in 1988, and Singapore's per capita income exceeded that of the US in 1996. Taiwan,

physical and human, than the growth of labor and natural resources in the economy. Capital accumulation depends on the economic surplus (or alternatively the profits) and the saving propensity in the economy. If an LDC develops its industries along the line of its comparative advantages, its economy will have the largest possible economic surplus and the highest savings propensities and will therefore achieve the highest possible upgrading of its endowment structure. Following this strategy, an LDC could achieve a faster upgrading of endowment, technology, and industry structures than the DCs and realize convergence. A firm's choice of industry/technology depends on the relative prices of capital, labor, and natural resources in the economy. Therefore, only if the price structure of the economy can reflect the relative abundances of capital, labor, and natural resources will the firm in the economy choose its industry/technology according to the comparative advantages of the economy. The price structure will reflect the relative abundance of each factor only if the prices are determined in competitive markets. Therefore, the government's primary function for economic development is to maintain well functioning markets.

The rest of my lecture will be organized as follows: I will first present a brief overview of recent theoretical developments and debates on economic growth and convergence. I will then discuss the determinants of a firm’s viability and an economy’s comparative advantages and their relations to the economy’s factor endowments. This discussion is followed by analyses of a government’s alternative development strategies, the statistical measurement of a development strategy, and the econometric estimation of the impact of the development strategy on convergence. The policy implications of the analyses are provided in my concluding remarks.

II. Growth Theories: An Overview

When the field of development economics started to take shape in the post-war period, the development economists encouraged LDC governments to adopt interventional policies to accelerate capital accumulation and to pursue an "inward-looking" heavy-industry-oriented or an import-substitution strategy that directly aimed to close the industry/technology gap with DCs (Chenery 1961, Warr 1994). These economists were strongly influenced by the Soviet Union's initial success in nation building, by the pessimism about the export of primary products formed during the Great Depression, by the lack of confidence on markets, and by the neoclassic growth

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Korea, Hong Kong have all significantly narrowed the income gap with the DCs.

theory (Rosenstein-Rodan 1943, Prebisch 1959). Since the 1950s, most LDCs, in both the socialist and capitalist camps, have adopted a variant of these strategies (Krueger 1992).

According to the seminal work by Robert Solow (1956) and others, the neoclassical growth theory has suggested that the LDCs should grow faster than the DCs and that the gap in per capita income between DCs and LDCs would narrow due to the diminishing returns to capital in DCs and to the similar available technology among DCs and LDCs. However, empirical evidences show that, while the convergence occurred within the different states in the United States and among the DCs (Barro and Sala-I-Martin 1992; Baumol, 1986), most LDCs failed to narrow the gap in per capita income with the DCs (Pearson et al. 1969; Romer 1994).

Unsatisfied with the neoclassic growth theory's inability to explain the continuous growth of DCs and the failure of most LDCs' to converge with DCs, Romer (1986, 1990) and Lucas (1988) pioneered a new growth theory, which treats technology innovation as endogenously determined by the accumulation of human capital, research and development (R&D), learning by doing and so on. The new growth theory is insightful for explaining the continuous growth of the DCs, which use the most advanced technologies. However, the new growth theory cannot easily explain the extraordinary growth and convergence of the newly industrialized economies (NIEs) in Asia, which includes South Korea, Taiwan, Hong Kong, Singapore and recently China, during the last three decades of the twentieth century (Pack 1994, Grossman and Helpman, 1994).

LDCs generally use technologies that are inside the technology frontier of DCs (Caselli and Coleman, 2000). Technological innovation in a DC that adopts technology on the new frontier can only be obtained through R&D or other knowledge-generating mechanisms. However, for an LDC, technological innovation can be a result of technology transfer or imitation of existing technology of the DCs. Obviously, the costs of technological innovation through R&D are much higher than the costs of imitation or other ways of technological borrowing. Therefore, technology diffusion from DCs to the LDCs will facilitate the growth of LDCs. It is futile in understanding the convergence between LDCs and DCs to focus primarily on mechanisms that generate new technology.

However, the technological gap between DCs and LDCs is filled with a whole spectrum of different technologies. An LDC is faced with the question of which

technology is appropriate to imitate or borrow.

The idea of appropriate technology was first introduced in neoclassic trade theory by Atkinson and Stiglitz (1969), who formalized "localized learning by doing." A similar argument in development economics was made by Schumacher (1973). The study of appropriate technology has been recently revived by Diwan and Rodrick (1991), Basu and Weil (1998), and Acemoglu and Zilibotti (1999).[2]. But the models based on the idea of appropriate technology are inconclusive about the issue of convergence. Basu and Weil (1998) consider the relatively low capital stock in a LDC as a barrier for adopting the advanced technology of DCs. They conclude that an LDC will experience a period of rapid growth by raising its savings rate to take advantage of the advanced technology. However, their arguments cannot explain why governmental interventions to improve the savings rate in Latin America, Africa, and Asia excluding "Four little dragons" failed to speed up the growth rate. Rodrick(2000) in a cross-country study shows that causality runs from growth to savings, not vice versa. And, it would be quite difficult to take a rise in the savings rate as the trigger of rapid growth. By contrast, Acemoglu and Zilibotti (1999) stressed the disadvantages of importing technology. In their framework, technology in DCs is used with skilled workers. When the technology is transferred to an LDC, the technology is used by unskilled workers. This mismatch between labor skill and technology can lead to sizable differences in output per capita and total factor productivity (TFP). To Acemoglu and Zilibotti, improving the skill base and human capital of workers, the same argument made by Lucas(1993), is critical to income convergence. The assumption adopted by Acemoglu and Zilibotti was too strong. They assume that LDCs always adopt DCs' frontier technologies rather than some technologies inside the frontier.

The appropriate technology argument does not answer the question about what the appropriate role of LDC government is in the process of economic growth. Although the linkage of knowledge diffusion with an appropriate technology suggests an alternative development path that differs from the development practices followed by many LDCs, it is not clear if the government's intervention matters to economic growth, and if governments should adopt policies to improve the savings rate and

[2] There are also other economists who hold a similar idea about appropriate technology. Drawn from the lessons of the East Asia Miracle, some economists, such as Takatoshi(1998), suggested the "flying geese pattern" metaphor, to describe the characteristics of industrial structure and technological diffusion during different development stages. But distinct policy proposals cannot be obtained from this metaphor.

human capital stock of the private sector, or if they should subsidize the adoption of high technology industries directly.

III. Viability, Comparative Advantage, and Endowment Structure

The per capita income in a country is a function of the technologies/industries that are found in the country. If two countries have an identical technology/industry structure, the two countries should have a similar per capita income. To understand how the income of a LDC converges to that of DCs, we need to understand how an LDC can narrow the technology/industry gap between it and DCs. I will first define the meaning of a firm's viability and the relationship between a firm's viability and its industry/technology choice.

I define the term viability with respect to the expected rate of profit of a firm in an open, free, and competitive market. If a firm through normal management is expected to earn a socially acceptable normal profit in a free, open, and competitive market, the firm is viable. Otherwise, the firm is nonviable. It is obvious that no one will invest in a firm, if it is not expected to earn a socially acceptable normal profit. Such a firm will come to exist only if the government gives it support.

In a competitive market, the management of a firm will affect its profitability, which is a known proposition. The expected profitability of a firm also depends on its industry/technology choice.

The isoquant shown in Figure 1 represents the different technologies of production or combinations of capital and labor required to produce a given amount of a certain product. The technology represented by A is more labor intensive than that of B. C, C_1, D, D_1 are isocost lines. The slope of an isocost line represents the relative prices of capital and labor. In an economy where capital is relatively expensive and labor is relatively inexpensive, as represented by isocost lines, C and C_1, the adoption of technology A to produce the given amount of output will cost the least. When the relative price of labor increases, as represented by the isocost lines by D and D_1, production will cost least if technology B is adopted.

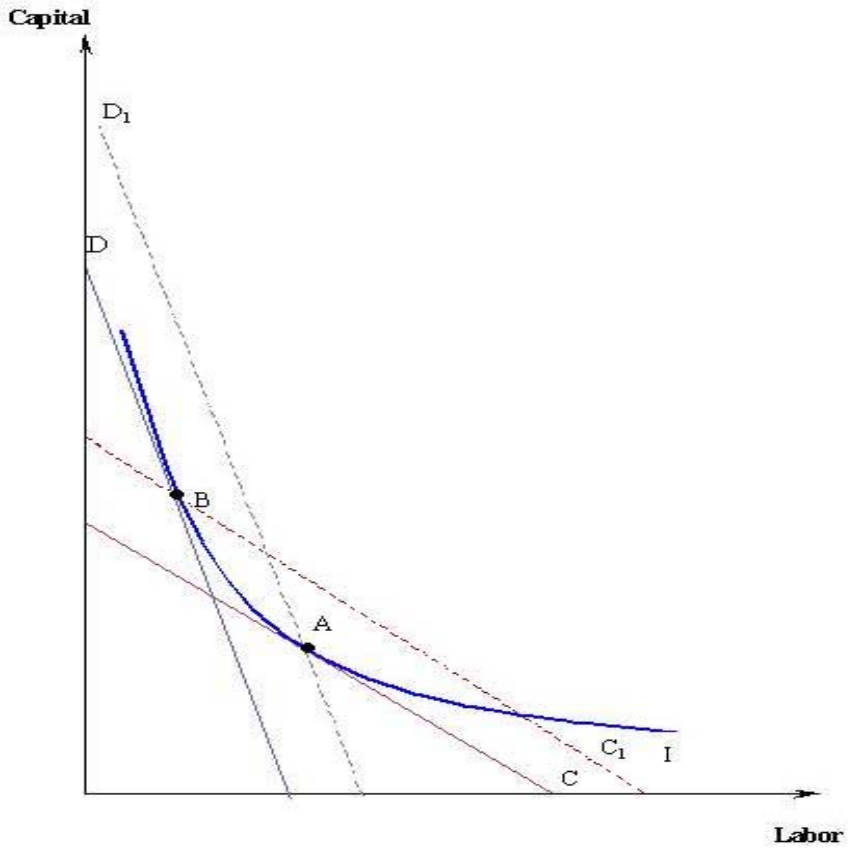


Figure 1: Relative Price of Production factors and Techique Choice

In a free, open, and competitive market economy that produces only one product as illustrated in Figure 1, a firm will be viable only if it adopts the least-cost technology in its production. In Figure 1, if the relative prices of capital and labor can be presented by C, the adoption of technology A costs the least. The adoption of any other technology, such as B, will have a higher cost. The market competition will make firms that adopt technologies other than A nonviable. Therefore, in a competitive market with given

relative prices of labor and capital, the viability of a firm depends on its technology choice.

In a competitive market, the relative prices of capital and labor are determined by the relative abundance/scarcity of capital and labor in the economy's factor endowments. When labor is relatively abundant and capital is relatively scarce, the isocost line will be something like that of line C in Figure 1. When capital becomes relatively abundant and labor relatively scarce, the isocost line will change to something like line D in Figure 1. Therefore, the viability of a firm in a competitive market depends on whether its choice of technology is on the least cost lines determined by the relative factor endowments of the economy.

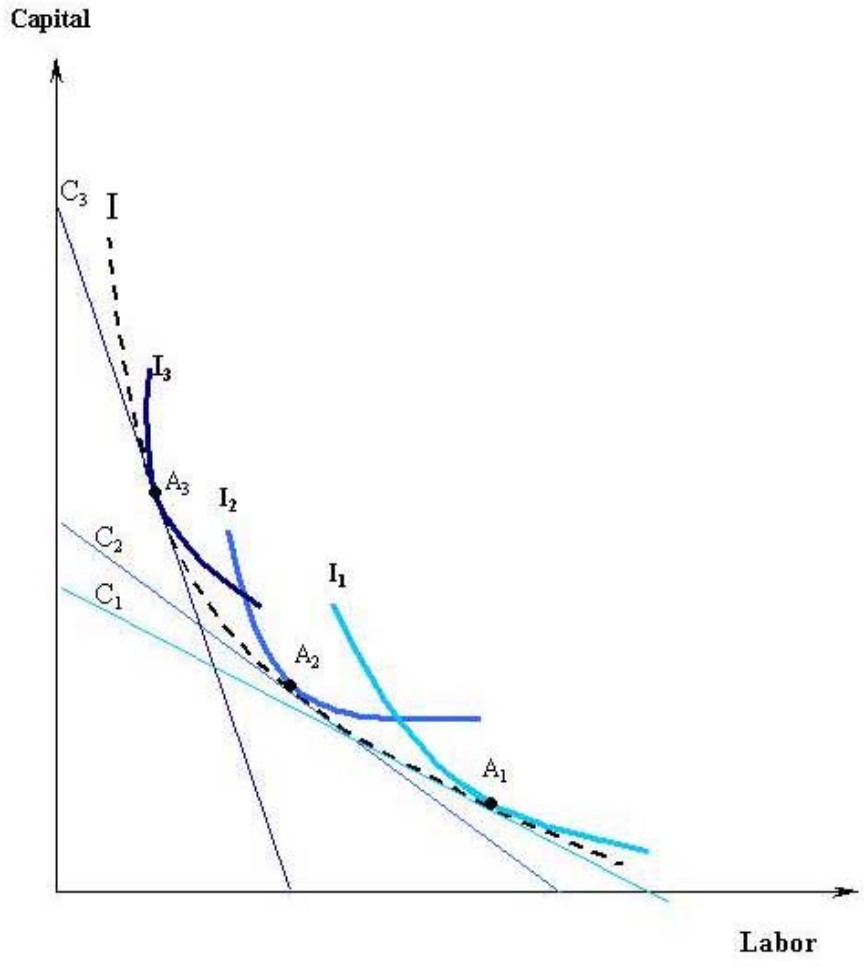


Figure2: Product Choice in an Industry

The above discussion can be extended to an industry that has many different products and an economy that has many different industries. As shown in Figure 2, lines I_1, I_2, and I_3 represent the isoquants of three different products that have the same output value in industry I. The average relative capital intensity of the three products is increasing from I_1 to I_3. As shown in Figure 2, the viability of a firm is determined by whether or not its product and technology choices are on the least cost line, which is determined by the relative factor endowments of the economy.

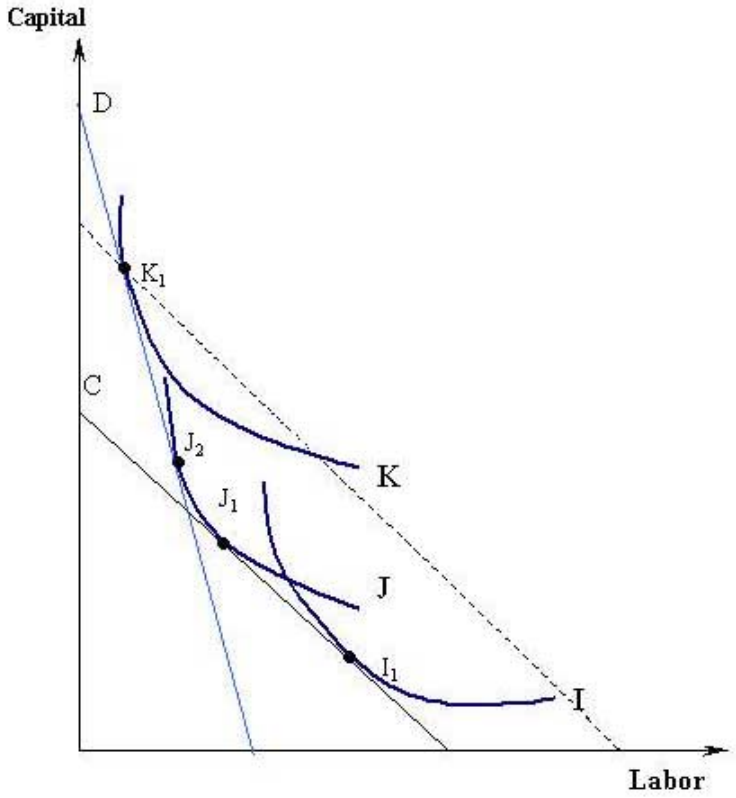


Figure3: Industry and Product Choices in an Economy

An industry can be represented by the envelope of the isoquants of all different kinds of products in the industry. On the isoquant of an industry, each point represents a specific product in the industry that is produced by a specific technology and has the same value as any other product in the same isoquant. As shown in Figure 3, an

economy that has three different industries, represented by the three industrial isoquants I, J, and K, will have the same output value. If labor is relatively abundant and the isocost line is indicated by C, the economy has a comparative advantage in industries I and J and a firm will be viable if it enters industry I (or J) and adopts a corresponding technology to produce product I_1 (or J_1). Supposedly, as the relative abundance of capital increases, the isocost line changes to line D. The comparative advantage of the economy will change accordingly and a firm will be viable if it upgrades its product/technology from J_1 to J_2 in industry J or it migrates to industry K and produces K_1. The firm that produces I_1 in industry I will become nonviable.

From the above discussion, we see that the concept of a firm's viability and the concept of an economy's comparative advantage are closely related and both are determined by the endowment structure of the economy. If a LDC wants to close its gap of industry/technology structure with that of a DC, it needs to close the gap of factor endowments first.

IV. Alternative Development Strategies

The government is the most important institution in any economy. Its economic policies shape the macro incentive structure that firms in the economy face. With the aim to explain the success or failure of convergence in an LDC, I will analyze the government's economic policies toward industrial development and group them into different development strategies. I will broadly divide the development strategies into two mutually exclusive groups: (i) the comparative advantage-defying (CAD) strategy, which attempts to encourage firms ignoring the existing comparative advantages of the economy in their entry/choice of industry/technology; and (ii) the comparative advantage-following (CAF) strategy, which attempts to facilitate the firms' entry/choice of industry/technology according to the economy's existing comparative advantages.[3] No countries in the world have followed either strategy consistently and without amendments. However, some countries have followed a strategy close enough to be a model of that strategy. A country that follows a particular strategy may also abandon it. The switch in strategy provides good opportunities for careful analysis of the impact of the strategy.

[3] Griffin (1999) classifies development strategies into six different alternatives: monetarism, open economy, industrialization, green revolution, redistribution, and socialist strategy.

IV.1: The Characteristics of Development Strategies

(i) The CAD strategy

Most LDCs are characterized by relative labor abundance and capital scarcity. Therefore, in a free, open, and competitive market, the firms in LDCs will enter relatively labor-intensive industries and adopt relatively labor-intensive technologies in their production.[4] However, political leaders and intellectuals in LDCs often equate industrialization, especially heavy industrialization, with modernization and push their countries to develop capital-intensive heavy industries and adopt the most advanced technologies in their production as quickly as possible, that is, they want the economy to develop some industry like K and produce product K_1 when the isocost line determined by their endowment structure is line C, as illustrated in Figure 3.[5] With the given endowment structure, a firm producing product K_1 will not be viable in a free, open, and competitive market. If a free, open, and competitive market is maintained, a firm following its government's strategy will incur a loss equivalent to the distance between isocost lines C and C_1. I will call this loss a policy burden on the firm. Because the government is responsible for the firm's entry/adoption of the industry/technology, the government is accountable for the firm's loss. Therefore, in implementing the CAD strategy, the government must give the firm a policy subsidy to compensate for the loss (Lin et al. 1998, 1999 and 2001).[6]

How large the subsidy is to compensate for the policy burden in the real world depends on how far away the promoted industry/technology is from the economy's comparative advantages. If the distance is small, the government can rely on tax incentives or direct fiscal transfer to subsidize the firm. However, this distance is often very large when the government in a LDC pursues a CAD strategy and special institutional arrangements are required for achieving the strategy goal.

When an LDC government pursues a CAD strategy, the most frequently used method is to suppress interest rates by regulation in order to reduce the project's capital costs. In addition, the equipment for the CAD project, in general, cannot be produced

[4] For simplicity, I neglect the endowment of nature resources in the discussion. The propositions derived from the discussion are also valid, if the nature resources are also considered.

[5] The heavy industry was the most advanced sector in the past. Nowadays, the priority of the CAD strategy in an LDC is focused on the information technology and other hi-tech industries, which are the most capital-intensive industries now.

[6] My focus in this discussion is on the development policies in an LDC. The government of a DC may adopt other forms of CAD strategy, i.e., protecting its firms in an old industry that has lost its comparative advantage due to the upgrading of the country's endowment structure often for the purpose of protecting jobs.

domestically in an LDC and needs to be imported from DCs and, therefore, access to foreign exchange is also required for the CAD project. However, foreign exchange in a LDC in general is scarce and expensive as well, because the LDC's exports are limited and consist mainly of low-value agricultural products and resources. To lower the costs of equipment imports for the CAD project, the government in general also overvalues the domestic currency and undervalues foreign exchange.[7]

The distortions in the interest rate and the foreign exchange rate on the one hand will stimulate firms, both in the priority and non-priority sectors, to demand more capital and foreign exchange and, on the other hand, suppress the incentive to save and to export and thus reduce the availability of capital and foreign exchange in the economy. Therefore, there will be shortages in capital and foreign exchange and the government will need to use administrative measures to ration capital and foreign reserves in order to guarantee that the CAD firms will have the resources to perform the strategic task. The resource allocation function of markets is thus constrained or even replaced by direct government rationing.[8]

Theoretically, the government that adopts a CAD strategy will only be responsible for giving a subsidy to compensate for the loss arising from the policy burden. However, due to information asymmetry, the government cannot distinguish policy burden-induced losses from operations losses. The firms will use the policy burden as an excuse and use resources to lobby the government for *ex ante* policy favors, such as access to low-interest loans, tax reductions, tariff protection, legal monopolies, and so on in order to compensate for the policy burdens. In addition to policy favors, if the firms still have losses, they will again request that the government offer some *ex post*, ad hoc administrative assistance, such as more preferential loans. The economy will be full of rent-seeking activities.[9] Because the firms can use the policy burdens as an excuse to

[7] The distortions in the interest rate and the foreign exchange rate are universal for an LDC that pursues a CAD strategy. In the socialist countries and other LDCs that adopted the heavy-industry-oriented development strategy, the prices of raw materials and living necessities along with wages were often distorted as well (Lin et al. 1996).

[8] The government that adopts a CAD strategy can also ration capital to the firms that are not in the priority industries. This in fact is the practice in the socialist planned economy. Certainly, the firms in the non-priority industries will receive less capital than if the government does not adopt this strategy. Alternatively, the government can allow the market to allocate capital after the firms in the priority industries have been guaranteed rations. The interest rate will consequently be higher than it is when all capital is allocated by the market. On the contrary, the wage rate in the market will be lower because of the low labor absorption of the firms in the priority industries. Therefore, the firms in the non-priority industries will adopt a more labor-intensive technology in their production than if there is no government intervention. The above analyses are also applicable to the allocation of foreign exchange to firms in non-priority industries.

[9] The loss from rent seeking is estimated to be much larger than the loss from misallocation (Kruger

bargain for more government support and because it is hard for the government to shun such responsibility, the firm's budget constraints become soft (Lin and Tan 1999). When the soft budget constraint exists, the manager of the firm will not have pressure to improve productivity and will have more on-the-job consumption, and other moral hazards. The subsidies could actually be much higher than the cost of the policy burdens.

(ii) The CAF Strategy

The government in an LDC could adopt the alternative CAF strategy to encourage firms to enter the industries for which the country has comparative advantages and to adopt the technology in production that will make these firms viable. As discussed, the industries for which the economy has comparative advantages and the technologies that are appropriate for production are all determined by the country's relative factor endowments. However, the managers of firms, as micro agents, will have no knowledge or concern of the actual endowments. Their only concerns are the prices of their outputs and the costs of their production. They will enter the industry and choose the technology of production appropriately only if the relative factor prices reflect correctly the relative factor abundances, which can be achieved only if the markets are competitive. Therefore, when the government in an LDC adopts a CAF strategy, its primary policy is to remove all possible obstacles for the function of free, open, and competitive product and factor markets.

In the above discussions, I assume that the information about the product markets, industries, and production technologies is freely available to the firms in the economy. Therefore, when the factor endowment structure of the economy is upgraded, the firms can upgrade its products/technologies or upgrade from a less capital-intensive industry to a relatively more capital-intensive industry smoothly. However, the information may not be available. Therefore, it is necessary to invest resources to search for, collect, and analyze the industry, product, and technology information. If a firm carries out the activities itself, it will keep the information private, and other firms will also need to make such investment to obtain the same information. There will be repetition in the information investments. However, the information has a public good nature. The cost of information dissemination is close to zero, after the information has been gathered and processed. Therefore, the government can collect the information about the new industries, markets, and technology, and make it available in the form of an industrial

1974).

policy to all firms.

The upgrading of technology and industry in an economy often requires coordination of different firms and sectors in the economy. For example the human capital, or skill requirements, of new industry/technology may be different from the old industry/technology. A firm may not be able to internalize the supply of the new requirements and needs to rely on outside sources for the supply. Therefore, the success of a firm's industry/technology upgrading also depends on the existence of an outside supply of the new human capital. In addition to human capital, the upgrading may also require new financial institutions, trading arrangements, marketing, and distribution facilities, and so on. Therefore, the government may also use the industrial policy to coordinate between firms in different industries and sectors for the upgrading of industry/technology in the economy.

The upgrading of industry/technology is an innovation and it is risky by nature. Even with the information and coordination provided by the government's industry policy, a firm's attempt to upgrade its industry/technology may fail due to the upgrade being too ambitious, the new market being too small, the coordination being inadequate, and so forth. The failure will indicate to other firms that the industrial policy is not appropriate and therefore they can avoid the failure by not following the policy. That is, the first firm pays the cost of failure and produces valuable information for other firms. If the first firm succeeds, the success will also provide externality to other firms, prompting the other firms to engaging in similar upgrading and dissipating the possible rents that the first firm may enjoy. Therefore, there is an asymmetry between the costs of failure and the gains of success that the first firm may have. To compensate for the externality and the asymmetry between the possible costs and gains, the government may provide some forms of subsidy, such as tax incentives or loan guarantees, to the firms that initially follow the government's industrial policy.

It is worthwhile to note that there is a fundamental difference between the industrial policy of the CAF strategy and that of the CAD strategy. The promoted industry/technology in the CAF strategy is consistent with the comparative advantage determined by the change in the economy's factor endowments whereas the priority industry/technology in the CAD strategy attempts to promote is not consistent with the comparative advantage of the economy. Therefore, the firms in the CAF strategy should be viable and a small, limited-time subsidy is enough to compensate for the information externality whereas the firms in the CAD strategy are not viable and their survival

depends on large, continuous policy favors/support from the government.[10]

A comparison of the successes and failures of industrial policies on automobile production in Japan, Korea, India, and China is a good illustration of the differences between the CAF and CAD industrial policies. The automobile industry is a typical capital-intensive heavy industry. The development of an automobile industry has been the dream of LDCs. Japan adopted an industrial policy to promote its automobile industry in the mid 1960s and achieved great success. Japan's experience is often cited as a supporting argument by advocates of an industrial policy for heavy industries in developing countries. Korea instituted an industrial policy for automobile production in the mid 1970s. Korea has also achieved a limited degree of success in automobile production. The automobile industries in China and India were started in the 1950s and the industry in both countries has required continuous protection from the government since that time. What explains the success or failure of a similar industrial policy? This will be clear once we compare the per capita income of these countries with the per capita income of the United States at the time when they initiated their policies (see Table 1).

Table 1: Level of Per Capita Income (Unit = 1990 Geary Khamis Dollars)

	US	Japan	Korea	India	China
1955	10,970	2,695	1,197	665	818
1965	14,017	5,771	1,578	785	945
1975	16,060	10,973	3,475	900	1250

Source: Maddison, Angus. Monitoring the World Economy, 1820-1992, Paris: OECD, 1995, pp. 196-205.

Per capita income is a good proxy for the relative abundances of capital and labor in an economy. Capital is abundant and wage rates are high in a high-income country. In a low-income country, the opposite holds true. Table 1 indicates that when Japan initiated its automobile production policy in the mid 1960s, its per capita income was more than 40 percent of that in the United States. The automobile industry was not the most capital-

[10] The dynamic comparative advantage is an often-used argument for the government's industrial policy and support to the firms (Redding 1999). However, in our framework it can be clearly seen the argument is valid only if the government's support is limited to overcoming information costs and the pioneering firms' externality to other firms. The industry should be consistent with the comparative advantage of the economy and the firms in the new industry should be viable, otherwise the firms will collapse once the government's supports are removed.

intensive industry at that time nor was Japan a capital-scarce economy. The Ministry of International Trade and Industry (MITI) only gave supports to Nissan and Toyota. However, more than ten firms, resisting MITI's persuasion of not to enter the industry, also started their automobile production and all of them were equally successful, even though they did not receive any supports from MITI. The above evidence indicates that the Japanese automobile firms were viable and MITI's promotion of automobile industry in the 1960s was a CAF strategy. When Korea initiated its automobile industry development policy in the 1970s, its per capita income was only about 20 percent of that of the United States and about 30 percent of that of Japan. This may explain why the Korean government needed to give its automobile firms much greater and longer support than the Japanese government did. Even with the support, two of the three automobile firms in Korea fell into bankruptcy recently. When China and India initiated their automobile industry development policies in the 1950s, their per capita incomes were less than 10 percent of that of the United States. The automobile firms in China and in India were not viable at all. Even up to today their survival still depends on heavy protection from the governments.[11]

IV.2: Human Capital and Economic Development

In the above discussion, our focus is on the accumulation of physical capital and its determining effect on an economy's industry/technology upgrading. The role of human capital in the process of development has received much attention in the development literature in recent years. The recent empirical works that attempt to explain cross-country income differences have included human capital as an explanatory variable in the production function and have found that human capital has a positive effect on economic growth (Mankiw, Romer and Weil 1992; Caselli, Esquivel and Lefort 1996; Klenow and Rodriguez 1997; Barro 1997).

What is the role of human capital accumulation in the development strategy of an LDC? If an LDC adopts a CAF strategy, the upgrading of its factor endowments will be very fast and consequently the upgrading of its industry/technology will also be

[11] Most big push attempts by the LDCs in the 1950s and 1960s failed. However, there is a renewed interest in the idea after the influential articles by Murphy, Shleifer, and Vishny (1989a, b). Their papers show that a government's coordination and support are required for setting up a key industry and that the demand spillovers from the key industry to other industries will enhance economic growth. However, for the "big push" strategy to be successful the pushed industry must be consistent with the comparative advantage, which is determined by the relative factor endowment of the economy, and the firms in the pushed industry must be viable after the push. Deviance from comparative advantage is the reason why so many big-push attempts by the LDCs in the 1950s and 1960s failed.

very fast. The upgrading is an innovation by nature even though the process is an imitation of an existing industry/technology from more advance countries. The managers/workers will face and will need to handle uncertainty in skills, production, marketing and so on in the upgrading process. The managers/workers also need to make many adaptations of the borrowed technologies to fit them to the local conditions. Increasing the manager/worker's human capital will increase their ability to handle the uncertainty and to carry out necessary adaptations (Schultz 1975). When a developing country narrows its industry/technology gap with DCs, it will move from having mature industry/technology closer to newer, less mature, and more uncertain industry/technology, which will require more human capital. That is, human capital becomes increasingly complementary to the physical capital in the new, frontier industry/technology.[12] Because of the complementarity between the physical capital and human capital, it is necessary to accumulate human capital along with the accumulation of physical capital in the convergence process. However, human capital is not a substitute for physical capital. An over-accumulation of human capital will lead to the waste of a resource. After World War II, there were so many scientists and engineers migrating to the U.S. from India and Latin America and other developing countries. They made little direct contribution to the economic growth of their mother countries. These scientists and engineers are not to be blamed, however, because the low factor endowments structure in their mother countries made it impossible for many of them to find suitable positions that would utilize their human capital at home.

IV.3: CAF strategy and CAD strategy: Comparisons

The attempt to catch up with DCs is justifiable for any LDC. The CAD strategy is appealing to political leaders and the general public, including elite intellectuals, in LDCs because most people directly observe the differences between the industry/technology structure of DCs and their own countries and notice the correlation between the industry/technology structure and the per capita income. However, a CAF strategy will enable an LDC to catch up with DCs and a CAD strategy will in effect stifle an LDC's opportunity to catch up. Many other theories have also attempted to explain an LDC's success or failure in achieving sustained economic development. The

[12] In recent years, a variety of papers have argued that different technologies may display different degrees of skill-labor or unskill-labor bias (Katz and Murphy 1992; Berman, Bound and Griliches 1994; Acemoglu 1998; Caselli 1999). This idea of skill complementarity has been employed to explain the increase in wage inequality in the 1980s and 1990s in the United States.

CAF/CAD strategy framework provides a unified explanation.

(i) Capital Accumulation

An economy's industry/technology structure is endogenously determined by its endowment structure. Therefore, if an LDC wants to catch up DCs in its industry/technology structure, it needs to narrow the gap in its factor endowment structure with DCs first. The upgrading of the factor endowment structure means an increase in capital relative to labor. Capital accumulation depends on the size of surplus/profits accrued by firms and the rate of savings of economic agents in the economy. When a firm in an economy enters the industry in which that economy has a comparative advantage and adopts the least-cost technology in its production, as a result of the CAF strategy, the firm will be competitive, occupy the largest market share, and have the largest surplus/profits. Meanwhile, the capital in the economy will have the highest possible rate of return when the capital is employed in the industries of which the economy has comparative advantages. Therefore, the economic agents' incentives to save will be highest. Moreover, the government will not distort the prices of factors and products, nor will the government use administrative powers to create legal monopolies. Therefore, there will be no scope for wasteful rent-seeking activities. The firm will have a hard budget constraint and will need to earn the profits through improving management and competitiveness. The CAD strategy will result in just the opposite to the CAF strategy regarding the competitiveness, the rate of return to capital, the rent-seeking activities, and the softness of the budget constraints for the firms in the priority industries. Therefore, the upgrading of the endowment structure will be faster under the CAF strategy than under the CAD strategy.

(ii) Technology Transfer

The upgrading of the endowment structure in an economy will provide the basis for the upgrading of industry/technology structure in the economy (Basu and Weil, 1998). The industry/technology will be new to the firms in an LDC and will need to be transferred from DCs. The learning costs will be smaller under the CAF strategy than under the CAD strategy because the distance between the new industry/technology and the old industry/technology is smaller under the former strategy than under the latter strategy (Barro and Sala-i-Martin 1997). Moreover, the patent protections for many of the targeted technologies under the CAF strategy may have already expired.

Even if it is still under patent protection, the license fee will be lower with the CAF strategy than with the CAD strategy because the targeted technology for the CAF strategy is older than the CAD strategy *ceteris paribus*. In some cases, the firms under the CAD strategy will not be able to obtain the technology from DCs and will need to "reinvent the wheel" and invest in costly and risky R&D of technology by themselves. Therefore, the acquisition costs of the technology will be lower under the CAF strategy than under the CAD strategy.

(iii) Openness in international trade

A number of empirical studies show that more open countries exhibit stronger convergence tendencies than do closed countries (Harberger 1984, Dollar 1992, Warner 1992, Ben-David 1993, Sachs and Warner 1995, Harrison 1996, Michaely 1977, Frankel and Romer 1999). International trade is expected to facilitate technology diffusion among countries. Lee (1995) finds that countries importing more capital goods tend to grow faster, which means that new technologies may be embodied in the capital goods. However, Rodríguez and Rodrik(2000) argue that "methodological problems with the empirical strategies employed in this literature leave the results open to diverse interpretations". The role of the trade policies is not clear. If the importing of equipment facilitates technology transfer, should the government adopt measures to promote equipment importation or is it the best to pursue trade liberalization in the sense of lower tariffs and non-tariff barriers to trade?

In our framework, a country adopting a CAF strategy will rely on importation for products for which it does not have a comparative advantage and exportation the products for which it has comparative advantages. For this country, openness is endogenously determined by the country's factor endowment structure instead of an exogenously determined parameter. If the government in an LDC adopts the CAD strategy and attempts to substitute the importation of capital-intensive manufactured goods by domestic production, not only will the country's import trade be reduced but its export trade will also diminish. The latter is because resources will be shifted away from the industries for which the economy has a comparative advantage and the exchange rate may be overvalued to facilitate the development of priority industries, therefore, hampering the possibility of exports. The Socialist economies, India, and the Latin American countries belong to this case. The growth performance of these countries is miserable, compared with the countries that have adopted the CAF

strategy. The government in an LDC may adopt the CAD strategy and at the same time encourage its firms in the priority capital-intensive industries to export. In this case, the exports will not be profitable, even though the firms may have a high ratio of exports to foreign markets and may achieve fast technology improvements.[13] The firms' survival relies on the protection of domestic markets, preferential loans from banks, and other policy support. The country will have poor external accounts, accumulate foreign debt, and be easily affected by external shocks.[14] It may be better for an LDC to adopt a CAD strategy that encourages exports rather than a CAD strategy that encourages import substitution. However, the overall economic performance of a country that adopts the export-promotion strategy will be poorer than the country that adopts the CAF strategy.[15] Therefore, it is not true that a more external trade orientation is a better policy for promoting an LDC's growth.

(iv) Financial Deepening

Since the pioneering works by Shaw (1969) and Mckinnon (1973), many researchers have argued that there exists causality between financial deepening and economic growth in an economy. The indicator that is often used to measure the financial deepening is either the M2/GDP or the value of credits by financial intermediaries to the private sector divided by the GDP. The relationship has been supported empirically by Levine (1997, 2000) and Rajan and Zingales (1998).

However, the degree of financial deepening in an LDC to a large extent is endogenous to the government's development strategy. Under the CAD strategy, the carriers of the government's development strategy are the large-sized firms. To support the financial needs of nonviable large-sized firms, the government often nationalizes the firms and uses direct fiscal appropriation, skipping financial intermediation, to support these firms, as in the former socialist planned economies, India and other LDCs. Even if the government relies on private firms as the carrier for the CAD strategy, the financial needs of the large-sized firms will be large and can only be met by a heavily regulated oligopolistic banking system. In either case, the

[13] I met a senior manager of Hyundai Automobile Company in the United States in the early 1990s. He told me that Hyundai was still losing money after 10 years of successful exportation of cars to the US market.

[14] Korea is a good example of this strategy.

[15] Taiwan and Korea are good examples for comparison. Taiwan has followed the CAF strategy consistently, whereas Korea has often attempted to switch from the CAF strategy to the CAD strategy. The GDP growth rate, income distribution, macro stability, and other development indicators in Taiwan are better than those of Korea.

financial system in the country will be underdeveloped. However, the most competitive and dynamic firms in LDCs are the labor-intensive small- and medium-sized firms. They are discriminated against and often denied access to financial services. The financial system is thus very inefficient. Moreover, the firms in the priority sectors that receive preferential access to bank loans are not viable. They may not be able to repay loans. The banks often accumulate a large amount of bad debt from the large-sized firms in the priority sectors, causing eruptions of financial crises. A precondition for financial deepening in an LDC is therefore the change of the government's development orientation from a CAD strategy to a CAF strategy.

(v) Macroeconomic Stability

A bulk of empirical studies shows that the volatility of the macroeconomy could hamper long-run growth (Barro 1997 etc.). If the government in an LDC adopts the CAD strategy, the firms in the priority industries are not viable and rely on preferential loans, trade barriers, and other policy support for survival. Because the existing comparative advantage is not utilized, the economy as a whole will not be competitive, a dynamic change in the economy's comparative advantage cannot be sustained, and the economic performance of the economy will be poor. The economy will have a weak financial sector and poor external accounts. The macroeconomic stability will become unsustainable when fiscal deficits, debt burdens, and financial fragility accumulate. A country that follows the CAF strategy will have better external accounts, healthier financial and fiscal systems. The country will be better equipped to resist external shocks and will have a much better record of macroeconomic stability.[16]

(vi) Income Distribution

The relationship between income distribution and economic development is one of the oldest subjects in development economics. Kuznets (1955) proposed an inverted-U hypothesis, suggesting that inequality tends to widen during the initial stages of economic development, with a reversal of this tendency in the later stages. There is mixed evidence for this hypothesis. A number of cross-sectional studies by Paukert (1973), Cline (1975), Chenery and Syrquin (1975), and Ahluwalia (1976) support this

[16] In the recent East Asian financial crisis, Taiwan, Hong Kong, Singapore, and Malaysia were affected slightly whereas Korea, Indonesia, and Thailand were hard hit. One reason for the different performances among these two groups of economies is the difference in their development strategies. The first group followed the CAF strategy closely whereas the latter group adopted the CAD strategy (Lin 2000).

hypothesis. However, the study of 43 episodes in 19 countries by Fields (1991) finds that there is no tendency for poorer countries to yield increased rather than decreased inequality or for richer countries to yield decreased rather than increased income inequality. A case study on Taiwan by Fei, Ranis, and Kuo (1979), however, shows that the Taiwanese economy achieved growth with equity. I propose that the adoption of the CAF strategy in an LDC will alleviate income inequality whereas the adoption of the CAD strategy will aggravate the income inequality. The most important asset that the poor have in an LDC is their own labor. The CAF strategy will result in a sustained economic growth through the development of more labor-intensive industries, creating more job opportunities for the poor, increasing the wage rates, and allowing the poor to have a share in the benefits of growth. On the contrary, the CAD strategy, by facilitating the development of more capital-intensive industries, will reduce job opportunities for the poor and suppress the wage rates of the working poor. Growth will not be sustainable either. When the economy breaks down, the poor will suffer the worst hardship, as evidenced by the recent East Asian financial crisis (Stiglitz 1998).

IV.4: The Choices of Development Strategy

When development economics started to take shape in the mid 20th century, the dominant view among development economists was to advise the governments in LDCs to ignore their own comparative advantages and to adopt an inward-looking variant of the CAD strategy, such as the heavy-industry-oriented strategy or the import-substitution strategy. Proponents of the CAD strategy have often confused the causality of dynamic change of comparative advantage. They have urged LDCs to disregard the constraint of relative capital scarcity in its factor endowments and to directly establish the same capital-intensive industries as the DCs. They have thought that the economic development could be accelerated if LDCs bypass the stage of developing labor-intensive and/or resource-intensive industries.

I argue that the alignment of industry/technology with an economy’s comparative advantage is the key in facilitating the international diffusion of the technology, to speed up the rate of economic growth and to realize convergence with DCs. The dynamic change of an economy's comparative advantage depends on the dynamic change of the economy's endowment structure, which depends on the rapidity of capital accumulation in the economy, and which in turn depends on how well economic agents in the economy exploit existing comparative advantages in their choices of industry/

technology. An LDC that takes the comparative advantage of its own factor endowments as the guiding principle of its choice of industry/technology will minimize the imitation cost, experience faster shifts in its endowment structure, and sustain a continuous upgrading of its industrial structures. The development experience of the East Asian “Four Little Dragons” is a good illustration of the merits of the CAF strategy.

Like many other developing economies, Taiwan, Korea, Hong Kong and Singapore were very poor after World War II. In the early 1950s, their levels of industrialization were low, their capital and foreign exchange were extremely scarce, and their per capita incomes were very low. Like any other developing economy, they also faced the problem of choosing an appropriate path for developing their economies. Taiwan, Korea, and Singapore adopted an import-substitution CAD strategy to begin with but soon gave up the attempt to develop heavy industries in the initial stage. Instead, based on their factor endowments, they energetically developed labor-intensive industries, promoted exports, and expanded their outward-oriented economies to utilize to the full extent their economies' comparative advantages.

In developed countries, such as the European countries, the United States, and Japan, labor-intensive industries were gradually being replaced by technology- and capital-intensive ones because of the increasing abundance of capital and the rising wage rates in their economies. Hong Kong, Taiwan, Korea, and Singapore had abundant, inexpensive labor. Therefore, when the developed countries' comparative advantages changed to more capital- and technology-intensive industries, the "Four Little Dragons" were able to capitalize on the dynamic opportunities. Through trade linkages and the openness of their economies, labor-intensive industries in developed countries were relocated to these Asian economies. Because of the intensive use of their comparative advantages, the "Four Little Dragons" were very competitive and were thus able to achieve rapid capital accumulation. Along with the accumulation of capital and the change in comparative advantages, they gradually upgraded to more capital-intensive and technology-intensive industries. Therefore, the "Four Little Dragons" were able to sustain more than thirty years of rapid growth, first becoming newly industrialized economies and then reaching or nearly reaching the level of developed economies. The extraordinary achievement has attracted worldwide attention.

Most developing economies adopted the CAD strategy in the 1950s and maintained that strategy for quite a long time. Why has Hong Kong never tried the

CAD strategy and why did Taiwan, Korea and Singapore switch to the CAF strategy shortly after trying the CAD strategy? Are these Little Dragons just lucky or is their choice of CAF strategy attributable to the wisdom of their political leaders? Ranis and Mahmood (1992) propose that the success is due to their poor natural resources. In addition, I propose that it is also attributable to their small populations. The CAD strategy is very inefficient and costly. How long this strategy can be maintained in an LDC depends on how many resources the government can mobilize to support it. The larger the per capita natural resources or the larger the population size in an economy, *ceteris paribus*, the more resources that government can mobilize to maintain the inefficient CAD strategy. For an economy with poor natural resources and a small population size, the adoption of the CAD strategy will cause economic crisis very soon. By that time, the government will have no other choice but to be forced to carry out reforms and a change in strategy (Edwards 1995). In effect, influenced by the prevailing economic thoughts in the 1950s and motivated by the dreams of nation-building, many political leaders and intellectuals in Taiwan and South Korea never gave up on their desires to accelerate the development of the capital-intensive heavy industries. However, their per capita natural resources were extremely poor and their populations were very small. The implementation of the CAD strategy in the early 1950s in Taiwan led to an immediate huge fiscal deficit and high inflation, and soon the government was forced to give up the strategy (Tsiang 1984). When Korea adopted the heavy machinery and heavy chemical industry push in the 1970s, a similar result also happened, and the push was postponed (xxx). Singapore and Hong Kong are both too small in population and too poor in natural resources to implement the CAD strategy.

V. Strategy Choice and Convergence: Empirical Testing

The various aspects of the CAF strategy and the CAD strategy, compared in Section VI.3, can be empirically tested. Mingxing Liu and several of my other PhD students at Peking University are attempting to use cross-country panel data and China's cross-province panel data to examine the implications of such comparisons. In this section, I will focus my discussion on the choice of development strategy and its effect on convergence.

V.1: The Empirical Measurement of Strategy Choice

The CAF strategy requires that the capital intensity of an economy's manufacturing sector to be endogenous to the economy's factor endowments. That is, the optimal capital intensity of an economy's manufacturing sector K_i/L_i can be described as a function of the economy's capital endowment K and labor endowment L as follows.

$$\left(\frac{K_i}{L_i}\right)^* = F\left(\frac{K}{L}\right) \qquad (1)$$

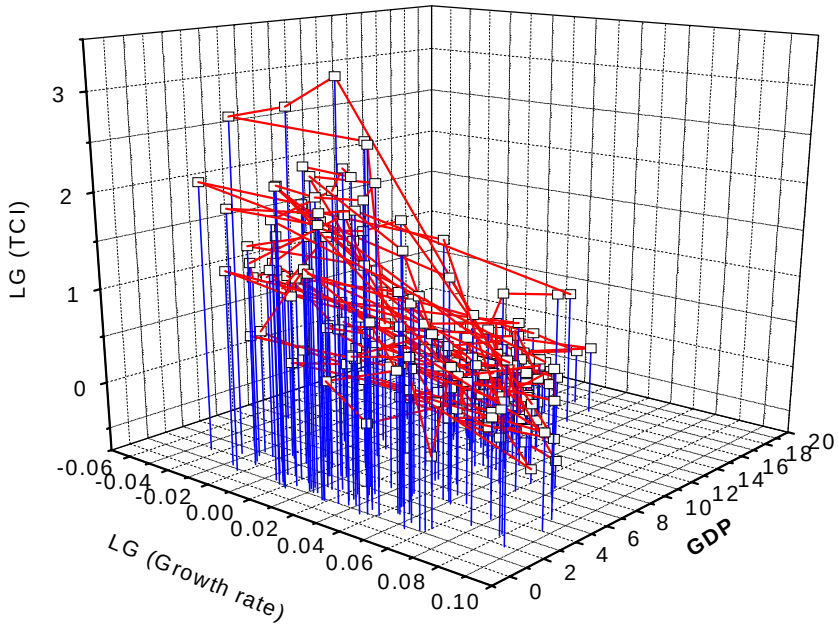
To measure an economy's deviation from the CAF strategy, I will first construct a simple statistical indicator, TCI, the actual technology choice index of manufacturing sector, which is defined as the actual capital/labor ratio of an economy's manufacturing industry divided by the capital/labor ratio of the whole economy. That is,

$$TCI = \frac{(K_i/L_i)}{(K/L)} \qquad (2)$$

Figure 4 plots the relationships between TCI, per capita GDP, and the GDP growth rate based on the data of 42 countries in the period from 1970 to 1992.[17] As revealed in Figure 4, there exists a negative relationship between TCI and growth rate, when the income level is controlled.

Figure 4: TCI, Per capita GDP, and GDP Growth Rate

[17] The data of per capita GDP, the GDP growth rate, and TCI for 42 countries in the period from 1970 to 1992 are reported in Appendix I. The method for calculating the TCI and the data resources are reported in Appendix II.



According to our theory, the government's adoption of the CAD or CAF strategy will influence the choice of TCI in an economy.

I will then define the optimal technology choice index of manufacturing sector, TCI*. From the first-order Taylor expansion of Equation (1), we obtain

$$\left(\frac{K_i}{L_i}\right)^* = \omega\left(\frac{K}{L}\right) \qquad (3)$$

where ω is a constant. The optimal technology choice index TCI* is defined as follows:

$$TCI^* = \frac{\left(K_i/L_i\right)^*}{\left(K/L\right)} = \omega \qquad (4)$$

That is, TCI* is the optimal TCI at a given factor endowment of an economy. [18]

[18] In addition to factor endowments, TCI* is expected to be a function of the stage of development of

We can measure the government's development strategy indirectly as follows:[19]

$$DS = TCI / TCI^* = TCI / \omega \qquad (5)$$

If the government adopts a CAF strategy, we expect that $DS = 1$. If the government adopts a CAD strategy to promote its capital-intensive industries, we expect $DS > 1$, whereas if the government adopts a CAD strategy to protect its traditional sector for a purpose, such as employment, we expect $DS < 1$. The larger the deviation in DS is from one, the stronger the CAD strategy. Although TCI* is not observable, the above idea constitutes the major thrust of the econometric model to be analyzed in our empirical study.

Obviously, the above indicator, based on the capital intensity in the manufacturing industry, cannot capture the whole picture of a development strategy and its impacts on economic growth. For example, a government may support a few industries only, not all the manufacturing industries; or it may support only some large firms in an industry instead of every firm in the particular industry. In addition, the measurement of factor endowments is incomplete. In particular, skilled labor and unskilled labor are not separated, and the differences in natural resources across economies are ignored. Those are the subjects for future research.

V. 2: Empirical Specifications

The approach that will be used to test the effect of strategy choice is conditional β convergence, as discussed by Durlauf and Quah (1999). I will first estimate a growth equation derived as a log-linear approximation of the transition path of per capita GDP around its steady state. Unlike the general neoclassical model, this approach explicitly takes into account the possibility of multiple equilibriums in economic growth.[20].

Consider the following equation:

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an economy and the relative abundance of natural resource in an economy.

[19] This measure was first proposed in Lin and Yao (2001).

[20] It is worthwhile to note that an alternative approach with a focus on the non-convexities in the production function and poverty traps has found multiple regimes in cross-country dynamics with a so-called polarization effect, in which the convergence rate varies according to time and the initial state (Durlauf 1993; Galor and Zeira 1993). These findings suggest that the initial conditions matter in the convergence. However, it is too simple to explain the success of the East Asian NIEs only through the threshold effect because their initial conditions were not much different from those of other unsuccessful Asian economies, such as Philippines, Thailand, and Indonesia.

$$\frac{\log y_{j(T+t)} - \log y_{jt}}{T} = C + \left(e^{\lambda_{jt}T} - 1\right)\log y_{jt} + B\mathrm{X} + \varepsilon_{jt} \qquad (6)$$

where y_{jt} is the Per capita GDP of the jth country in year t; **X** is a set of explanatory variables; and the constant C can be decomposed into country-specific and time-specific effects, that is, $C = \mu_j + \kappa_t$. λ_{jt}, the rate of convergence, is not a constant.[21] We attribute the dynamic adjustments of λ_{jt} to the choice of development strategy and specify it as follows:

$$e^{\lambda_{jt}T} - 1 \hat{=} \beta_1 + \beta_2 \left(Log(DS)\right)^2 = \beta_1 + \beta_2 \left(\log(TCI_{jt}) - \log(\omega)\right)^2 \qquad (7)$$

where $\beta_1 < 0$ and $\beta_2 > 0$. For the purpose of simplicity, we assume the optimal technology choice index TCI* to be a positive constant, ω,in a given period from t to t+T. We take β_1 as the natural condition under a CAF strategy. Thus, any deviation from TCI*, induced by the CAD strategy, will reduce the convergence rate, because the rate of capital accumulation and the rate of technological progress will be depressed and the imitation cost will go up.

Substituting (7) into (6), we obtain the following specification

$$\frac{\log y_{j(T+t)} - \log y_{jt}}{T} = C + \gamma \log y_{jt} + \beta_2 \log y_{jt} \log^2 TCI_{jt} + \beta_3 \log y_{jt} \log TCI_{jt} + \mathrm{BX} + \varepsilon_{jt} \qquad (8)$$

where

$C = \mu_j + \kappa_t$; $\gamma = \beta_1 + \beta_2 \log(\omega)$; $\beta_3 = -2\beta_2 \log(\omega)$.

Obviously, if the government adopts a CAF strategy, then (8) will reduce to the general specification in the neoclassical model and, if not, the convergence may not happen across economies. To be specific, if the government adopts a CAD strategy, γ may be positive or negative. That is to say, the impact of the initial level of the per capita income on the growth rate will be uncertain under the CAD strategy. For testing the effect of strategy choice on convergence, we will pay special attention to the regression results of β_2 and β_3. Based on our hypothesis, it is expected that $\beta_2 > 0$ and $\beta_3 < 0$.

[21] In the general setting, $\lambda = -\left(1 - \alpha_h - \alpha_p\right)\left(\delta + \nu + \xi\right)$, where α_h and α_p are the production elasticities of human capital and physical capital with $\alpha_p + \alpha_h < 1$; δ is the depreciation rate; ν is the growth rate of labor; and ξ is the rate of technology progress (Durlauf and Quah 1999). Since all parameters are exogenously given, λ must be constant in the convergence path.

V. 3: Data

The data cover the period from 1970 to 1992 for 42 countries. The per capita GDP will be included in the regressions in two different ways: the first is by a yearly observation and the second is by an average at every five-year interval except for the period from 1990 to 1992.[22] In addition to using the total sample, we also use a sub-sample of 29 countries, whose per capita GDP was lower than 8000 dollars in 1970 because of the possible different role played by governments in DCs and LDCs.

The dependent variable is the growth rate of real per capita GDP constructed as the differences of the log values of per capita GDP, averaged over at a five-year interval or at only one year.

The explanatory variables include several independent variables in addition to TCI:

GDP: The real per capita GDP at the beginning of the period, which is used as a proxy for the initial condition. For the five-year average dataset, the **GDP** includes observations for 1970, 1975, 1980, 1985 and 1990. The estimated coefficient is expected to have a negative sign.

GDP-1: The real per capita GDP lagged by one year. This variable is used as the initial condition in the yearly dataset. The GDP figures are taken from the Penn World Tables Mark 5.6, constructed by Summers and Heston (1991). They are calculated in 1985 prices (dollars) and also adjusted by the purchasing power parities. The estimated coefficient is expected to have a negative sign.

Investment: The ratio of total investment to GDP including private investment and public investment, provided by Easterly and Yu (2000). The estimated coefficient is expected to have a positive sign.

Openness: The ratio of total value of exports and imports to GDP, provided by Easterly and Yu (2000). The estimated coefficient is expected to have a positive sign.

[22] Generally speaking, the average over a given time horizon eliminates business cycle effects. However, the arbitrary choice in the length of time may lead to a misspecification in the regression. In fact, there is a lack of reasonable rules to allow us to analyze the degree of misspecification at higher frequencies or at lower frequencies.

Inflation: The inflation rate, provided by Easterly and Yu (2000). The estimated coefficient is expected to have a negative sign.

Education-p: The ratio of the population with education attainment of primary schooling to the total population in 1970, 1975, 1980, 1985 and 1990, taken from Barro and Lee (2000). The estimated coefficient is expected to have a positive sign.

Education-s: The ratio of the population with education attainment of secondary schooling to the total population in 1970, 1975, 1980, 1985 and 1990, taken from Barro and Lee (2000). The estimated coefficient is expected to have a positive sign.

Pol: The indicator for political constraint, constructed by Henisz (2001). The higher this indicator, the lower the risk of political changes and the more decentralized the political power. The estimated coefficient is expected to have a positive sign.

Dummy Variables for legal origin: According to LaPorta, et al.(1999), the origin of a country's legal structure can be categorized into four systems: British, French, German, and Scandinavian. We use the following abbreviations for this variable: **BL**, **FL**, **GL**, **SL**. **BL** is used as the reference variable in the regression.

As for the regression on the five-year average data, **TCI**, **Investment, Openness, Inflation** and **Pol** are all constructed with the average values of the same five-year intervals, whereas **Education-p** and **Education-s** are the observations at the beginning of the period. All the above explanatory variables in the regression are the natural logarithms of their values. In the cases of the yearly datasets, the one-year lagged values of **TCI** symbolized by **TCI –1** are used as the explanatory variable. For **Investment, Openness** and **Inflation,** the observations in the current year are used. The variables for human capital have to be dropped from the regression because the dataset only has observations at five-year intervals.

V. 4: Results

The empirical estimations are reported in Tables 2 and 3. Table 2 presents the results from the yearly dataset, whereas the results in Table 3 are from the five-year average dataset. Models I and II in Table 2 and Models III and IV in Table 3 are the

estimations from the two-way fixed-effect model, in which the country-specific effect and the time-specific effect are controlled. The LSDV method is used to fit the data to the models. The results of the Hausman test, shown at the bottom of Tables 2 and 3, reject the null hypotheses of random-effect models in favor of the alternative two-way, fixed-effect models. Models V and VI in Table 3 are the results from the one-way fixed-time effect model, including proxies for political constraints and legal origins. Models I, III, and V use the whole samples, whereas Models II, IV, and VI use the sub-samples of countries with per capita GDP below US$ 8000 in 1970.

From the results in Tables 2 and 3, we see that β_2 and β_3 have the expected signs in all Models, and the estimates are statistically significant, except for β_2 in Models 1 and 5, in which data from DCs are also included in the samples. The results indicate that the choice of development strategy in a LDC has the expected significant impact on the country's path of income convergence to DCs.

Tables 2 and 3 also show that the estimates of investment, openness and inflation are statistically significant and all have the expected signs as suggested in the literature. However, the estimates for human capital contradict the general expectation. As for the institution environment, a country's legal origin seems to have a stronger effect on economic growth than the political constraint. The results suggest that the French and German legal origins are more favorable to an LDC's economic growth than the British and Scandinavia origins.

As discussed in section IV.3, the inflation rate, openness, and investment of an economy are likely to be endogenous to the economy's choice to development strategy. Table 4 reports the re-estimates of Models I-VI by the reduced form equations, which include only the exogenous variables. The sign and statistical significance of the estimated coefficients of β_2 and β_3 are basically the same as those estimates in Tables 2 and 3.

Table 2: Regression Results from the Yearly Dataset

	Model I (Obs.=886)	**Model II** (Obs.=600)

LogGDP-1	-0.89641E-01*** (0.11185E-01)	−0.85434E-01*** (0.13219E-01)
LogGDP-1*Log^{2}TCI-1	0.68203E-03 (0.46574E-03)	0.11959E-02* (0.63896E-03)
LogGDP-1*LogTCI-1	-0.18677E-02* (0.10647E-02)	−0.32853E-02** (0.16049E-02)
Inflation	-0.46708E-01*** (0.58368E-02)	−0.45731E-01*** (0.67713E-02)
Openness	0.33055E-01*** (0.90370E-02)	0.29379E-01*** (0.11008E-01)
Investment	0.67009E-01*** (0.76987E-02)	0.64519E-01*** (0.96987E-02)
Adjusted-R^2	0.33793	0.32896
Hausman Test	67.72	41.32

1. Standard errors are reported in the parentheses.
2. *, **, and *** indicate, respectively, significance at the 10% , 5%, and 1% level.

Table 3: Regression Results from the Five-year average Dataset

	Model III (Obs.=201)	**Model IV** (Obs.=136)	**Model V** (Obs.=201)	**Model VI** (Obs.=136)
LogGDP	−0. 42640E−01*** (0. 10306E−01)	−0. 44530E−01*** (0. 10907E−01)	−0. 82460E−02** (0. 37902E−02)	−0. 90825E−02** (0. 44538E−02)
LogGDP* Log^2TCI	0. 86405E−03* (0. 45245E−03)	0. 89225E−03* (0. 52083E−03)	0. 30802E−03 (0. 23693E−03)	0. 58707E−03* (0. 33046E−03)
LogGDP* LogTCI	−0. 23821E−02** (0. 99086E−03)	−0. 25642E−02** (0. 12511E−02)	−0. 16764E−02** (0. 67425E−03)	−0. 25754E−02** (0. 10068E−02)
Inflation	−0. 10459E−01* (0. 57277E−02)	−0. 11851E−01** (0. 59153E−02)	−0. 11167E−01** (0. 49085E−02)	−0. 12434E−01** (0. 54388E−02)
Openness	0. 28237E−01*** (0. 10022E−01)	0. 25110E−01** (0. 10793E−01)	0. 81303E−02** (0. 34001E−02)	0. 75129E−02 (0. 47006E−02)
Investment	0. 42788E−01*** (0. 10165E−01)	0. 39041E−01*** (0. 11548E−01)	0. 35084E−01*** (0. 76988E−02)	0. 31956E−01*** (0. 10028E−01)
Education-p	−0. 10806E−01* (0. 55044E−02)	−0. 25344E−01*** (0. 82304E−02)	−0. 68793E−02* (0. 34875E−02)	−0. 10148E−01** (0. 47608E−02)
Education-s	−0. 10742E−01* (0. 63716E−02)	−0. 91805E−02 (0. 78165E−02)	−0. 46554E−02 (0. 42407E−02)	−0. 12531E−02 (0. 51602E−02)
Pol			0. 42712E−02 (0. 11214E−01)	0. 37748E−03 (0. 12444E−01)
FL			0. 76658E−02* (0. 42881E−02)	0. 11658E−01** (0. 54501E−02)
GL			0. 24761E−01*** (0. 52964E−02)	0. 29076E−01*** (0. 71247E−02)
SL			0. 25582E−02 (0. 52345E−02)	0. 48341E−02 (0. 12242E−01)
Adjusted-R^2	0. 59512	0.65520	0. 38537	0.42009
Hausman Test	25.75	23.9		

1. Standard errors are reported in the parentheses.
2. *, **, and *** indicate, respectively, significance at the 10%, 5%, and 1% level.

Table 4: Regression Results without Endogenous Variables

	Regression Results from the Yearly Dataset (Two-way Fixed Effects)		Regression Results from the Five-year Average Dataset (One-way Fixed Effects)			
	Model I (Obs.=924)	Model II (Obs.=638)	Model III (Obs.=210)	Model IV (Obs.=145)	Model V (Obs.=210)	Model VI (Obs.=145)
LogGDP	−0. 53626E−01*** (0. 12016E−01)	−0. 50957E−01*** (0. 14083E−01)	−0. 30991E−01*** (0. 10909E−01)	−0. 27513E−01** (0. 11880E−01)	−0. 10535E−01*** (0. 36427E−02)	−0. 91645E−02** (0. 43947E−02)
LogGDP* Log^2TCI	0. 45785E−03 (0. 51674E−03)	0. 12292E−02* (0. 69159E−03)	0. 54305E−03 (0. 51031E−03)	0. 89087E−03 (0. 61539E−03)	0. 23366E−03 (0. 24620E−03)	0. 75879E−03** (0. 33883E−03)
LogGDP* LogTCI	−0. 28977E−02** (0. 11495E−02)	−0. 49225E−02*** (0. 16819E−02)	−0. 35918E−02*** (0. 10456E−02)	−0. 44629E−02*** (0. 13793E−02)	−0. 21810E−02*** (0. 69630E−03)	−0. 36917E−02*** (0. 98772E−03)
Pol					−0. 85715E−02 (0. 11335E−01)	−0. 13195E−01 (0. 12265E−01)
FL					0. 67920E−02* (0. 38512E−02)	0. 73152E−02 (0. 49198E−02)
GL					0. 29694E−01*** (0. 52554E−02)	0. 34020E−01*** (0. 69406E−02)
SL					0. 34483E−02 (0. 54092E−02)	−0. 67522E−02 (0. 12748E−01)
Adjusted-R^2	0. 16982	0. 16731	0. 42853	0. 46800	0. 26526	0. 30766

1. Standard errors are reported in the parentheses.
2. *, **, and *** indicate, respectively, significance at the 10% , 5%, and 1% level.

VI. Concluding Remarks

In this lecture, I have argued that most LDCs fail to benefit from the industry/technology gap and to converge to the income level of the DCs because most of them follow a wrong development strategy. The temptation to close the industry/technology gap as soon as possible is strong for LDCs. However, at a low level of factors endowment structure, LDCs' economies do not have the comparative advantages necessary for capital-intensive industries/technologies and their firms will not be viable in an open, free and competitive market if they enter/adopt the capital-intensive industries/technologies. To give priority to the development of non-comparative advantage industries/technologies, the governments in LDCs often adopt a CAD strategy and give the nonviable firms policy support through a series of distortions in interest rates, foreign exchange rates, and other prices, and use administrative measures to allocate resources with distorted prices directly to the firms in the priority industries. With the above policy measures, an LDC may be able to establish firms that adopt high technologies in advanced industries for which it does not have the comparative advantage. However, the development of financial market will be repressed, foreign trade will be retarded, rent-seeking activities will be wide spread, the macro economy will be unstable, income distribution will be unequal, the economy will be very uncompetitive, and the country will fail to converge with the DCs in terms of income.

I argue here that the optimal industry/technology structure of an economy is endogenously determined by the economy's factor endowment structure and that the CAF strategy is a better strategy for an LDC's development. This is because the CAF strategy will induce the firms in an LDC to enter industries for which the country has a comparative advantage and facilitate the firms in borrowing technology from the more advanced countries at low cost. The economy will be competitive. The country will have a rapid upgrading of its factor endowment structure and consequently, its industry/technology structure. As such, the CAF strategy will help an LDC to converge with DCs. The empirical findings from the cross-country analyses are consistent with the above hypothesis. To implement the CAF strategy, a government needs to maintain an open, free, and competitive markets. The government can also adopt an industrial policy to facilitate firms' upgrading of industry/technology. However, the functions of an industrial policy are limited to information sharing, investment coordination, and compensation for externalities.

The government of an LDC plays an especially important role, for good or bad, in the country's economic development. As Lewis (1955, p. 376) has noted, "No country has made economic progress without positive stimulus from intelligent governments, … On the other

hand, there are so many examples of the mischief done to economic life by governments…" Here I would like to propose, for the government in an LDC to be an intelligent one, its most important task is to get the development strategy right!

Appendix I: The Average Per capita GDP, Per capita GDP Growth Rate, and TCI

		1970-74	1975-79	1980-84	1985-89	1990-92
Australia	GDP P.C.	11138.2	11859.8	12679.8	14170.2	14386.3
	% GDP P.C.	0.018	0.014	0.016	0.022	-0.009
	TCI	0.592	0.515	0.484	0.575	0.690
Austria	GDP P.C.	8258.0	9609.8	10601.0	11616.6	12833.3
	% GDP P.C.	0.045	0.026	0.013	0.025	0.017
	TCI	0.915	0.854	0.830	0.891	0.952
Belgium	GDP P.C.	9043.6	10227.4	11026.4	11919.2	13375.0
	% GDP P.C.	0.046	0.016	0.010	0.026	0.017
	TCI	0.774	0.763	0.752	0.998	1.318
Canada	GDP P.C.	11185.4	13229.0	14297.4	16600.4	16634.3
	% GDP P.C.	0.041	0.029	0.012	0.032	-0.023
	TCI	1.015	1.038	0.962	0.989	0.864
Chile	GDP P.C.	3702.8	3249.8	3609.0	3834.2	4566.3
	% GDP P.C.	0.000	0.008	-0.018	0.051	0.038
	TCI	2.144	2.198	3.256	1.891	0.662
Colombia	GDP P.C.	2332.4	2683.8	2944.2	3139.6	3325.7
	% GDP P.C.	0.041	0.027	0.005	0.022	0.009
	TCI	2.507	2.020	2.232	2.289	2.394
Costa Rica	GDP P.C.	3108.4	3589.4	3301.4	3317.6	3504.3
	% GDP P.C.	0.040	0.028	-0.035	0.014	0.011
	TCI	1.989	1.663	1.603	1.687	1.698
Cyprus	GDP P.C.	4179.2	4257.6	5660.0	7032.8	8712.3
	% GDP P.C.	0.008	0.055	0.042	0.046	0.051
	TCI	1.732	1.631	1.035	0.807	0.736
Denmark	GDP P.C.	10183.0	10965.0	11653.6	13425.2	14005.0
	% GDP P.C.	0.017	0.019	0.016	0.019	0.010
	TCI	0.705	0.801	0.904	0.965	0.854
Egypt	GDP P.C.	1186.0	1412.0	1763.0	1914.4	1898.0
	% GDP P.C.	0.011	0.052	0.045	0.000	-0.007
	TCI	4.319	3.971	4.183	3.767	3.307
El Salvador	GDP P.C.	1889.8	2194.0	1831.2	1826.0	1851.0
	% GDP P.C.	0.014	0.023	-0.044	0.004	0.010
	TCI	6.058	6.004	8.169	7.948	6.772
Finland	GDP P.C.	8799.4	9638.8	11241.0	12929.2	12907.3
	% GDP P.C.	0.052	0.013	0.027	0.038	-0.057
	TCI	0.890	0.894	0.836	0.914	1.051
France	GDP P.C.	9880.2	11019.8	11888.4	12871.6	13897.3
	% GDP P.C.	0.036	0.021	0.006	0.025	0.007
	TCI	0.930	0.820	0.790	0.889	0.990

Appendix I (continued): The Average Per capita GDP, Per capita GDP Growth Rate, and TCI

		1970-74	1975-79	1980-84	1985-89	1990-92
Germany	GDP P.C.	9888.4	11019.8	11930.0	13136.8	14598.7
	% GDP P.C.	0.026	0.030	0.007	0.024	0.020
	TCI	0.658	0.706	0.708	0.769	0.849
Greece	GDP P.C.	4754.8	5564.8	5943.4	6388.8	6773.2
	% GDP P.C.	0.048	0.034	0.004	0.023	0.002
	TCI	1.602	1.550	1.569	1.650	1.879
Guatemala	GDP P.C.	2135.2	2461.4	2371.2	2098.6	2175.0
	% GDP P.C.	0.030	0.026	-0.033	-0.004	0.017
	TCI	15.095	15.217	15.974	19.242	26.836
Iceland	GDP P.C.	7856.0	9750.2	11774.8	13172.4	13095.7
	% GDP P.C.	0.069	0.045	0.019	0.024	-0.022
	TCI	0.629	0.566	0.573	0.670	0.846
India	GDP P.C.	789.4	840.6	944.0	1140.8	1265.7
	% GDP P.C.	0.002	0.018	0.037	0.041	0.012
	TCI	9.747	9.315	9.746	11.456	10.934
Indonesia	GDP P.C.	787.6	1056.0	1485.6	1719.2	2040.0
	% GDP P.C.	0.054	0.058	0.060	0.025	0.047
	TCI	6.680	4.469	3.115	2.022	2.247
Ireland	GDP P.C.	5368.4	6268.4	6974.0	7695.4	9435.3
	% GDP P.C.	0.034	0.035	0.009	0.036	0.041
	TCI	1.079	1.188	1.256	1.399	1.304
Israel	GDP P.C.	6828.4	7371.6	8122.0	8787.6	9555.0
	% GDP P.C.	0.052	0.004	0.016	0.018	0.031
	TCI	0.767	0.826	0.905	1.061	1.124
Italy	GDP P.C.	7969.2	9044.4	10345.6	11508.6	12603.7
	% GDP P.C.	0.038	0.025	0.014	0.030	0.013
	TCI	1.254	1.315	1.426	1.499	1.475
Japan	GDP P.C.	7934.0	9030.2	10633.6	12611.8	14790.7
	% GDP P.C.	0.044	0.032	0.028	0.040	0.032
	TCI	1.626	1.855	2.458	2.339	2.029
Kenya	GDP P.C.	765.0	862.6	862.0	869.6	909.0
	% GDP P.C.	0.035	0.019	-0.022	0.019	0.000
	TCI	8.874	8.083	7.107	7.210	9.593
Korea	GDP P.C.	1928.4	2813.0	3483.4	5123.8	7157.9
	% GDP P.C.	0.086	0.079	0.037	0.084	0.071
	TCI	2.777	1.718	1.738	1.552	1.733
The Netherlands	GDP P.C.	9757.4	10850.2	11100.6	11974.4	13168.7
	% GDP P.C.	0.034	0.017	0.000	0.022	0.018
	TCI	0.875	0.974	1.145	1.324	1.349

Appendix I (continued): The Average Per capita GDP, Per capita GDP Growth Rate, and TCI

		1970-74	1975-79	1980-84	1985-89	1990-92
New Zealand	GDP P.C.	10168.2	10316.0	10904.6	11619.6	11310.0
	% GDP P.C.	0.039	-0.014	0.020	0.005	-0.012
	TCI	0.669	0.602	0.767	1.039	1.115
Norway	GDP P.C.	8726.4	10770.6	12537.4	14588.6	15155.7
	% GDP P.C.	0.035	0.043	0.028	0.017	0.020
	TCI	0.697	0.668	0.700	0.729	0.851
Pakistan	GDP P.C.	948.0	980.4	1143.0	1323.8	1406.7
	% GDP P.C.	-0.003	0.024	0.027	0.029	0.008
	TCI	6.886	10.085	12.439	11.516	11.739
Peru	GDP P.C.	2876.4	2981.4	2809.6	2681.8	2150.0
	% GDP P.C.	0.037	-0.023	-0.017	-0.027	-0.024
	TCI	2.729	3.247	3.600	3.212	3.878
The Philippines	GDP P.C.	1483.2	1734.6	1838.2	1618.2	1717.0
	% GDP P.C.	0.025	0.031	-0.022	0.008	-0.009
	TCI	7.929	5.022	4.724	5.983	4.243
Portugal	GDP P.C.	4028.8	4590.6	5034.6	5721.0	7673.6
	% GDP P.C.	0.087	0.009	0.005	0.056	0.060
	TCI	1.247	1.213	1.211	1.105	0.546
South Africa	GDP P.C.	3381.2	3421.8	3524.8	3323.2	3167.3
	% GDP P.C.	0.038	-0.016	0.009	-0.009	-0.028
	TCI	1.416	1.335	1.530	1.590	1.766
Sri Lanka	GDP P.C.	1246.4	1411.8	1778.0	2039.6	2165.7
	% GDP P.C.	0.009	0.036	0.044	0.011	0.028
	TCI	4.449	3.040	1.965	1.416	1.020
Sweden	GDP P.C.	11110.4	11951.6	12636.2	14078.6	14370.3
	% GDP P.C.	0.023	0.009	0.015	0.021	-0.016
	TCI	0.773	0.842	0.889	0.950	1.095
Syria	GDP P.C.	2701.8	3996.0	4377.4	3952.8	4057.7
	% GDP P.C.	0.068	0.050	-0.009	-0.013	0.047
	TCI	3.640	4.421	5.762	6.540	6.228
Taiwan, China	GDP P.C.	2624.6	3625.0	4778.0	6567.6	8576.1
	% GDP P.C.	0.079	0.069	0.044	0.075	0.054
	TCI	1.619	1.312	1.015	0.911	0.989
Turkey	GDP P.C.	2432.4	2992.8	2906.2	3329.4	3738.0
	% GDP P.C.	0.041	0.021	0.004	0.024	0.037
	TCI	7.813	6.312	5.942	4.306	3.414
United Kingdom	GDP P.C.	9035.6	9840.2	10383.6	12291.2	12919.7
	% GDP P.C.	0.025	0.021	0.009	0.039	-0.013
	TCI	0.707	0.694	0.840	0.885	0.897
United States	GDP P.C.	13680.0	14772.4	15447.8	17281.8	17864.3
	% GDP P.C.	0.016	0.021	0.008	0.021	-0.003
	TCI	0.675	0.744	0.871	0.870	0.907
Venezuela	GDP P.C.	7525.6	7944.4	6874.2	6354.6	6586.0
	% GDP P.C.	-0.005	0.017	-0.048	-0.015	0.060

	TCI	2.445	1.707	1.992	2.201	2.645
Zimbabwe	GDP P.C.	1199.2	1210.0	1278.0	1171.4	1197.3
	% GDP P.C.	0.059	-0.027	0.003	-0.006	-0.003
	TCI	3.473	3.662	3.299	4.118	5.814

Note: 1) For each country, the figures in the first row is the per capita GDP, measured in 1985 US dollars; the second line reports the growth rate of per capita GDP; The third line reports the TCI. 2) The growth rate of per capita GDP is calculated as follows:

$$\frac{\log(GDP_{i,T}) - \log(GDP_{i,t})}{T - t}$$

where i indicates the countries, t indicates the period, (T-t) is the length of the observation interval.

APPENDIX II : The Calculation of TCI

Our calculations on the index of technology choice (TCI) can be divided into three steps:

Step I. Filling the missing values. One of the main problems in constructing the TCI index is to obtain the time series of fixed capital investments in the whole economy and in the manufacturing industry. Crego, et al. (2000) provided preliminary data sets for these time series and the related deflators in domestic prices. To fill in the missing values, two methods are used. First, we convert two kinds of the fixed investment and nominal GDP into the constant own-currency values in 1990 using the investment deflator by Crego and CPI by Heston and Summers (1991), and assume that the time trend of changes in fixed investment rate is as follows:

$$\log\left(\frac{I_t}{GDP_t}\right)=\alpha+\lambda t+\varepsilon_t$$

where I_t and GDP_t are the real values in domestic price. The fitted results will fill in the missing values of the fixed investment series. The second method is to use the ARMA model for the fixed investment series directly. The results from the above two methods are highly similar, and we use the results from the first method in the following calculation.

Step II: Calculating the physical capital stocks in the whole economy and in the manufacturing industry from 1970 to 1992. As in Crego, et al. (2000), let s_j be the productivity ratio of the asset after *j* years of use and L to be the lifetime of the asset. Then, we have

$$K_t = s_0 I_t + s_1 I_{t-1} + ... + s_L I_{t-L}$$
$$K_t = s_0 I_t + s_1 I_{t-1} + ... + s_T I_{t-T} + K_{t-T-1}, \; if \; T < L$$

where

$0<s_j<1$, if $0 < j < L$; $s_0 = 1$; $s_j = 0$， if $j \geq L$.

More generally, the productivity of the asset will depreciate with time and, thus, s_j can be formulated by

$$s_j = (L - j)/(L - \beta j), \; 0 \leq j < L$$
$$s_j = 0, \; j \geq L$$

where β is a parameter bounded from above such that $s_j > 0$. When $0 \le j < L$, this specification also means

$ds_j/dj = L(\beta - 1)/(L - \beta j)^2 < 0$,

$d^2 s_j / dj^2 = 2L\beta(\beta - 1)/(L - \beta j)^3 > 0$, if $\beta < 0$

> 0, if $0 < \beta < 1$

$= 0$, if $\beta = 1$,

which indicates that the productivity ratio will fall over the lifetime, and the falling rate depends on the value of β. By assuming that $\beta = 0.7$ and $L = 10$, we can obtain the capital stocks from the above method.

Step III: Calculating TCI. The formula for calculating TCI is as follows:

$$TCI_j = \frac{K_{mj} / L_{mj}}{K_j / L_j}$$

where K_{mj} / L_{mj} is the capital/labor ratio for the manufacturing industry of j country, and K_j / L_j is the capital/labor ratio for the whole country j. The figures of L_{mj} are taken from the database on the manufacturing industry provided by UNIDO (2000). The figures for L_j are obtained from Summers and Heston(1991).

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