Classification of three types of capital and their contribution to production

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CLASSIFICATION OF THREE TYPES OF CAPITAL
AND THEIR CONTRIBUTION TO PRODUCTION

A THESIS
SUBMITTED TO THE FACULTY OF
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BY
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ABSTRACT

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CLASSIFICATION OF THREE TYPES OF CAPITAL
AND THEIR CONTRIBUTION TO PRODUCTION

Advisor: Dr. Charlie Carter
Thesis dated May, 1992

This thesis offers a theoretical analysis of the need to redefine capital. More specifically it argues that the concept of capital, as generally defined, needs to be broadened. Empirical support is evaluated by reviewing evidence from other studies.

This study suggests that the ambiguous concept of capital can be minimized by subdividing it into three homogeneous categories. The three categories are as follows: Capital One -- labor and equipment; Capital Two -- worker's training and technology; Capital Three -- science research and education. It is argued in this thesis that
only Capital Two is crucial to production and significantly contributes to economic growth. In this thesis these three categories are classified according to their effect on production, timing of return, and degree of risk. A simple model describing their relationship is offered.

The evolution of production, the development of capital theory, and the limited empirical estimates support the thesis advanced in this paper. The standard procedure of constrained maximization demonstrates that output growth per capita depends on the optimal allocation of both worker training input and technology input.
ACKNOWLEDGMENTS

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CHAPTER I
INTRODUCTION

Similar to the concept of value, economists are interested in a very old, but still very confusing, concept of capital.

In order to avoid misunderstanding capital, this study focuses only on a developing and working definition of real capital, disregarding financial capital. In this thesis the stock of expenditure on production is considered capital. The characteristic that distinguishes capital from other factors is accumulation.

Problem Statement

According to conventional wisdom, expenditures on new plants, equipment and materials are considered investment. Classical economists subdivided capital by considering equipment as "fixed capital" and labor and materials as "variable capital." In contrast, Marxists considered labor as "variable capital," and equipment and material as "constant capital." Human capital theorists expand the concept of capital and treat those expenditures on labor that enhance its productive potential as investment. Most economists now acknowledge that expenditures which enhance
productive potential represent capital whether such expenditures enhance the productive capacity of physical equipment or enhance the productive capacity of labor. However, it is not widely recognized that many kinds of expenditures can be considered investment, since they form new kinds of capital which can enhance productive potential, for example labor training, on the job training, or technological advancements stemming from efforts in scientific research.

Recent historical events support the thesis that extension of labor and physical capital cannot explain substantial increases in production. Consider the following examples: (1) World War II nearly damaged the productive capacity of Germany and Japan. However, in less than three decades their economies recovered and their productivity surpassed many countries not devastated by war. (2) Several Asian countries enjoyed the highest growth rate in the world during the post-war period; yet none of these countries were well endowed with natural resources. On the contrary, many less-developed countries endowed with abundant natural resources, as well as large labor forces, suffered low or even negative economic growth. (3) In developed countries, in recent years, the growth of national income has greatly exceeded increases in natural resources. These resources include available land, the man hours worked, and the stock of reproducible capital.
Actual capital is changing over time, therefore, the concept of capital needs to be redefined. As a means of production, many kinds of accumulation which contribute to output and growth, have yet to be treated as capital. Describing and analyzing them is an important task. In addition, conventional theories have not explained how countries possessing quality labor and rapid accumulation of technology have much faster economic growth. A new theoretical explanation is needed. The study of capital should be viewed from a new perspective where accumulation of technology and human ability are considered capital. Capital can be classified into three categories which work in three sectors of the economy. Presently, the second category, or Capital Two, which includes training and technology, is most important to production and economic growth. The allocation of training and technology determines output.

Objective

This study describes the evolution of capital and clarifies the concept of capital. The specific objectives of this thesis are the following:

1. To demonstrate how the concept of capital has been expanding.

2. To justify the classification of capital into
three categories which work in three sectors, of which Capital Two, training and technology, is emphasized.

3. To show that growth of income per capita depends on optimal distribution of capital between training and technology.

Organization

Previous theories are reviewed in Chapter II to show how the concept of capital has been expanding and investigates historical developments in production which induced the expansion of actual capital. Chapter III classifies capital according to its effect on production and economic growth; and presents a simple model that explains the relationships of the three concepts of capital and describes their contribution to economic growth. Chapter IV explains the expenditure distribution among the three types of capital through the return of their investment. In Chapter V conclusions are drawn and several implications are made for further theory and policy development.

Appendix 1 shows the mathematical derivation of this argument. Appendix 2 provides some empirical estimates to demonstrate the appropriateness of the hypothesis advanced in this thesis.
CHAPTER II
REVIEW OF PREVIOUS CAPITAL THEORY

A Process of Capital Concept Expanding

Capital is an evolving concept. Bohm Bawerk considered capital as a tool of production "which serves as a means of acquiring." Capital goods have greater productive value in a "round-about" method of production. Marx defines capital as a value that will bring surplus value. J. B. Clark uses the "real homogeneous capital" notion to support his marginal productivity theorem. Neoclassical economists inherited these classic concepts, but modified them somewhat to render them empirically useful.

Those expenditures that are productive and those that add to the stock of reproducible capital represent a long standing controversy in economics. Mercantilists considered gold and silver as the sources of wealth. They considered trade as a means to the acquisition of treasure. Thus, the

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stock of merchandise and money used in trade was considered capital.  

The physiocrats first considered wealth as goods and defined goods as that produced through the assistance of nature. They argued that only agriculture, which can bring net products, is productive. The role of natural resources such as land, mine and water was considered capital.

Adam Smith defined capital as the excess of financial reserve stock over the subsistence requirement. People try to use these excess reserves to earn additional income. Smith distinguished aggregate stock into two parts. One part, which is expected to yield revenues, is capital. The other part is expenditure. Smith extended the productive sector to industry. Equipment, building and materials are treated as capital. Following Smith, western economists divided the factors of production into three kinds: labor, land, and capital. Smith’s classification has remained in use for almost two hundred years, though some economists have introduced services as part of productive activities.

Economists appeared and developed following the process of industrialization, leading to an emphasis on physical

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5 Ibid., Chapter 2.

capital in early economic works. The most important factors of production are classified into two kinds: labor and capital. Marx labeled both of them as capital. Entrepreneurs view them as a source of profit. Neoclassical economists from John Stuart Mill to Marshall, and many modern economists, analyze the behavior of firms and the aggregate economy through these two factors.

In economic growth theory, the Harrod-Domar model uses physical capital to explain the growth path. The Solow model connects capital and consumption growth rate with technological change. It was Solow who first included accumulation of technology into the production function and argues that changes in technology should be considered an important factor of economic growth.

Human capital as an argument in the production function appeared very late. It was T. W. Schultz who presented economists with a new perspective. The concept of capital was then extended to human ability. This inclusive concept enabled one to consider any activity which increases the quality and productivity of the labor force as capital. Enhancements in the attributes of humans created assets in the form of knowledge and skills which increase the

---


productive potential of manpower in much the same way that investment in new machinery raises the productive capacity of the stock of physical capital.  

Lucas' growth model, like that of Schultz's, includes human capital. The optimal balance growth path of capital depends directly on the rate of increase in human capital, the external effect of education, and inversely on population growth.

In a modern society, capital should have a broader meaning. Most economists acknowledge the productivity of information and knowledge. Scientific research, therefore, is productive as well. This thesis accepts the notion that any stock of investment, used as a factor of production, can be treated as capital. However, labor is a human action, a machine is physical material. Their accumulation can be distinguished as human capital and physical capital.

Generally, consumption brings people satisfaction and enjoyment directly, while investments require abstinence or postponement. Schultz classifies expenditures in a way which makes investment different from consumption. Expenditures that satisfy consumer preference and in no way

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enhance their productive capabilities represent pure consumption. Expenditures that enhance capabilities and do not satisfy any preference represent pure investment. Confusion arises when "most relevant activities clearly are in the third class, partly consumption and partly investment."

Many expenditures, in the short run, take on the characteristics of consumption, but in the long run they are investments and are, therefore, capital. Such expenditures, which enhance the productive capabilities more than satisfy the preference, should be treated as capital forming.

Human capital is the accumulation of human ability. From the simplest manual laborers to the most complex researchers, all forms of labor require investment to enhance their productive capacity. Nutrition, health care, training and education can enhance human potential. They represent an investment in human capital; the cost of which, as well as the returns, are jointly shared by family, company, and government. Their returns may be additional income, increased profits, and greater social welfare.

Physical capital is the accumulation of capacity embodied in the stock of equipment. From the simplest tools to the most complex computers, continuing investment in equipment is needed to enhance their productivity. Physical capital

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capital makes production easier and faster.

The relationship between capital, as measured by the stock of goods, and stock of human ability, is evolving. The meaning of capital is becoming more inclusive. When population, land, and natural resources are abundant, labor and land are the primary factors of production. But when these factors become scarce, diminishing returns set in. The unique method of checking diminishing returns is technology.\textsuperscript{13} The tendency is towards zero population growth in advanced countries owing to limited natural resources. Production necessarily becomes less dependent on labor and natural resource input. Education improves the quality of labor, while technology improves the capacity of physical capital.

This brief review of the source of capital theories indicates that concepts of capital differ vastly. As a means of production, early economists emphasized differences regarding the definition of capital. Mercantilists emphasized the stock of merchandise and money while physiocrats emphasized the stock of natural resources. Early classicals emphasized the notion of physical capital while neoclassicals emphasized the accumulation of equipment. The Harrod-Domar Model shows that economic growth depends on physical capital, while Solow emphasized

technology. Lucas incorporates human capital into his growth model. Modern economists place greater emphasis on human capital. They emphasize training and education, but also information and its diffusion. The concept of capital has broadened. This paper describes the classification of three types of capital and their contribution to production.

A Process of Actual Capital Expanding

Physical capital has always occupied a crucial position in production. Historians generally measure civilization by the complexity of its tools. Utilization of capital reflects degree of productivity. In today’s society technology is the most important type of capital.

Looking back on economic history we see that physical capital and human capital have been evolving. Tools appeared in primitive society. They made production more efficient than working by hand. As Marx theory of Capital demonstrates, labor was the central factor of production in slave society.4 When humans entered feudal society, land became more important. In capitalist society machines dominate production. In modern society technology occupies the dominant position. This process of evolution is shown in Figure 1.

Fig. 1. Process of capital expanding in different stages of history.

<table>
<thead>
<tr>
<th>Historical Stage</th>
<th>Dominant Factor of Production</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First Layer</strong></td>
<td></td>
</tr>
<tr>
<td>Primitive Society</td>
<td>Simple Tools</td>
</tr>
<tr>
<td>Slave Society</td>
<td>Labor</td>
</tr>
<tr>
<td>Feudal Society</td>
<td>Land</td>
</tr>
<tr>
<td><strong>Second Layer</strong></td>
<td></td>
</tr>
<tr>
<td>Industrialized Society</td>
<td>Machine</td>
</tr>
<tr>
<td>Modern Society</td>
<td>Technology</td>
</tr>
<tr>
<td>Future Society</td>
<td>Knowledge/Information</td>
</tr>
</tbody>
</table>

Figure 1 shows the evolution of production and the expansion of actual capital, from the simplest tool to the most complicated technology. The leading factor of production in a primitive society was the tool; in a slave society it was labor; in a feudal society it was land; and in the industrialized society it is the machine. In both layers, the path of progress moves from physical capital to human capital. Physical capital plays a central role in both the primitive society of the first layer, and the industrialized society of the second layer; but where the physical capital in the former was simple tools, in the latter it was complicated machines. While technology and labor are both human capital, they differ in quality; the
former is an accumulation of mental abilities, the latter is an accumulation of physical labor. In the machine era of the second layer, physical capital is most important; but in the era of information and knowledge, human capital takes on greater significance.
CHAPTER III
CAPITAL CLASSIFICATION AND A PROPOSED MODEL:
A THEORETICAL ARGUMENT

A Theoretical Argument

According to the traditional view, entrepreneurs organize production with two factors, labor and capital. Labor is distinguished from capital because workers are independent of the entrepreneurs. Entrepreneurs can own capital, such as machinery, buildings and materials, but they cannot own laborers. They must "rent" labor, which is the productive capacity of workers, and compensate them with wages, just as entrepreneurs must pay rent for the equipment they lease. By leasing equipment and paying for labor, entrepreneurs, in effect, "rent" the productive capacity of capital.

Labor and equipment, however, are not homogenous. They are different in quality. Improvement in the quality of either labor or machines requires investment. The accumulation of investment in labor and equipment forms a new kind of capital.

Investment in human capital is acquired through

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apprenticeships. Skilled workers have a higher productive capacity than semi-skilled or unskilled workers. When entrepreneurs train workers, expenditure on schools and training programs represent investment in human capital.

For products and machines there is always room for improvement. Entrepreneurs employ engineers to solve technological problems to improve products and machines. Since technology makes production more efficient, these expenditures on technology can be considered investment. The accumulation of investment in technology forms a new kind of capital. Ambitious entrepreneurs establish their own research institutions to generate new products and new technology.

Schultz classified expenditure into two parts to differentiate investment from consumption. Training and technology enhance the capabilities of production, so these expenditures are treated as investments. Leontief realized that there are two sectors in the modern economy, labor-intensive and capital-intensive. In the former sector, unskilled workers are only capable of using simple equipment. They, therefore, have low productivity and earn commensurately low wages. They are homogenous, mobile, and have a high incidence of unemployment. In the capital-intensive sector workers are more skilled and specialized.

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They use higher technological equipment and have higher productivity, and so receive higher wages.\(^3\)

In this thesis a three-sector concept is suggested. In the first sector, human capital and physical capital are considered labor and equipment respectively. Both are primary factors of production. Producers employ labor and lease equipment to produce goods and services. The workers invest in themselves, which enhances the productive potential of labor. The owner of equipment invests in machines which form capital. Roundaboutedness is short and the risk of loss is relatively low. These two direct means of production, labor and equipment, are classified as Capital One in this thesis.

In the second sector, as introduced in this thesis, skill and technology are produced. They augment labor and equipment as to render efficient services. Investment in training through professional and vocational education, as well as on the job experience, forms a new kind of human capital. Investment in design, improvements and inventions forms yet another kind of capital. Though this investment serves physical capital, its accumulation is also, in essence, human capital. Technology which increases the efficiency of equipment is capital. This concept of capital is not only an accumulation of physical goods, but also an

accumulation of knowledge and information. It affects production indirectly. Roundaboutedness is longer and the risk of return is higher than for Capital One. Technology and training represent the second means of production and are classified as Capital Two in this thesis. Through labor, training indirectly affects production. Similarly, technology affects production through equipment. Investment in Capital Two increases the capacity of Capital One.

In addition to Capital One and Capital Two, this thesis defines a third category of capital, Capital Three. Training increases labor’s productivity. Education increases the efficiency of training. Better educated people are more easily trained than less educated people. Education has two functions, the screening function and the learning function. The screening function sorts people according to ability. People working in positions suited to their abilities can raise social marginal products. The learning function provides people with skills and knowledge that help them learn faster. Investment in education forms yet another kind of capital. This capital is an accumulation of knowledge and skills of the teachers and instructors who educate people.

Technology increases the productivity of equipment. Science aids technological progress. Generally, time needed between effort and result is lengthy. Achievements in science also usually need long periods of time before they
can be applied to technology. Science provides theories to guide and urge the development of technology. Investment in science forms capital. This capital is an accumulation of the results of research, knowledge and theories of science. Science generates technology and technology generates machines.

Capital Three includes both science and education. Education includes every level of schooling. In modern societies laborers need a high school education; teachers and engineers need at least a college education; scientists and professors need a graduate school education. Science includes every field of research from the simplest experiments to abstract theory. Research results and theories furthers the application and development of science. The accumulation of such research results and theories form scientific capital.

Fundamentally, capital may be classified into three kinds according to their effect on production. Capital One affects production directly. Labor combines with equipment to produce goods, whether unskilled labor or professional labor, simple tools or complicated machines. Capital Two affects production indirectly, since training affects production only through the increase in skill of labor; but it affects Capital One directly because technology makes machines efficient. So, training and technology result in increased productivity of labor and equipment. Capital
Three indirectly influences production by directly affecting Capital Two and indirectly affecting Capital One. This happens when education and science increase and diffuse knowledge and information that leads to better training and technology, which in turn influence the development of labor and equipment. Figure 2 below illustrates the relationship among Capital One, Capital Two, and Capital Three.

Fig. 2. Capital classification and their relationships.

<table>
<thead>
<tr>
<th>Products</th>
<th>Capital I</th>
<th>Capital II</th>
<th>Capital III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q</td>
<td>(L) Labor&lt;</td>
<td>(Tr) Training&lt;</td>
<td>(E) Education</td>
</tr>
<tr>
<td></td>
<td>(K) Equipment&lt;</td>
<td>(Te) Technology&lt;</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Capital I includes Labor and Equipment. Production depends on their combination. Capital II includes Training and technology. They affect production through Capital I. Capital III includes Education and Science. They influence production through Capital II. Philosophy directs the development of Education and Science.

Labor and equipment produce goods and services directly. Investment in Capital One results in almost certain returns. The period of "roundaboutedness" is short, and therefore, risk is relatively low. Incentive to invest
in Capital One is strong. Labor receives wages, owners of capital (equipment) receive profits. In the sector in which Capital One is used, either consuming goods or producing goods are produced.

Though incentive to invest in Capital One might be great, growth of income does not depend on the amount of Capital One, but on the quality of Capital One. In advanced countries population growth tends to decline causing the growth of the labor force to be commensurately slow. Scarcity of natural resources and emphasis on environmental protection restricts resource utilization. The quality of Capital One, therefore, cannot depend only on the growth of the labor force or on the growth of physical capital. The quality of Capital One is increased through investment in Capital Two.

Capital Two has a longer "roundaboutedness" and bears higher risk. Not all investment in training and technology will result in increased production in the future, because not all training and technology will be suitable for production in the future. Some of these investments will be lost due to changes in the economic situation. But when the training and technology are suitable for future needs in production the productivity of labor and equipment will increase dramatically. Although Capital Two has higher risk, higher profit generated by higher productivity draws more investment into it. Large enterprises, that have the
ability to bear high risk, invest in Capital Two; while companies which could not afford high risk only invest in Capital One.

**Characteristics of Different Capital**

We define sector one as using Capital One, and sector two as using Capital Two. The two sectors have different objectives and different operation processes. This thesis argues that in sector one, Capital One is used to increase production. Another sector focuses on productivity which uses Capital Two. Factories, transportation, and trade all belong to sector one. Vocational schools and institutes of technology belong to sector two. As society progresses, the importance of sector two will increase. Economists call sector two the service sector, because it serves direct factors of production. Now, more and more investment is being transferred from Capital One to Capital Two. In modern society, sector two has become a crucial part of the economy. The level of output or the growth rate of income primarily depends on Capital Two.

The influence of education and science on production is long-term. The input of Capital Three needs more time to affect output and has higher risk than both Capital One and Capital Two. Education increases the efficiency of training and training increases the efficiency of labor; but to what degree education influences production is unknown.
Education has plenty of external effects on society that are beneficial, but it is not profitable to investors. The profit-oriented enterprise doesn’t have the motivation to invest in education. Similarly, they have no motivation to invest in scientific research. Achievements in science often need several decades before being applied to technology. For example, electricity was discovered in the eighteenth century, but was not applied to industry until the twentieth century. The probability of success in scientific research is very small. Every achievement in research is only a small step towards reaching a successful result. Profit-oriented enterprises cannot wait so long nor bear the high risk of investing in scientific research. The long-term returns and high risk of Capital Three investments are two reasons profit-oriented enterprises are unwilling to invest in Capital Three. Another important reason is that investment in Capital Three benefits the whole society. While everyone in society would prefer to get a free ride, it is not in the nature of profit-oriented enterprises to provide them.

Since investment in Capital Three benefits the whole society and at the same time is high risk, only the government can underwrite it. Sector three, in fact, is the government sector. The government raises funds with taxes and invests them through a government budget, which enters the area of public finance. Future development depends on
making optimal decisions concerning the allocation of investment in the three capitals. The non-profit sector is managed by government and private fund associations.

Until recently six kinds of capital were defined. The endogenous part of capital includes labor, training, and education and the exogenous part includes equipment, technology, and science. The characteristics of all the capitals are shown in Figure 3.

Fig. 3. Summary of characteristics of the different capitals.

<table>
<thead>
<tr>
<th>Type of Capital</th>
<th>Capital I</th>
<th>Capital II</th>
<th>Capital III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Sector</td>
<td>Sector I</td>
<td>Sector II</td>
<td>Sector III</td>
</tr>
<tr>
<td>Effect on Production</td>
<td>Direct</td>
<td>Indirect</td>
<td>Influence</td>
</tr>
<tr>
<td>Objective</td>
<td>Production</td>
<td>Capacity</td>
<td>Knowledge</td>
</tr>
<tr>
<td>Time of Return</td>
<td>Short</td>
<td>Long</td>
<td>Very Long</td>
</tr>
<tr>
<td>Risk</td>
<td>Low</td>
<td>High</td>
<td>Very High</td>
</tr>
<tr>
<td>Profit</td>
<td>High</td>
<td>Very High</td>
<td>None</td>
</tr>
<tr>
<td>Funding</td>
<td>Selling of Stock</td>
<td>Enterprise Budget</td>
<td>Government Budget</td>
</tr>
</tbody>
</table>

Explanation for this Theoretical Argument

Products are the result of all input. Input is the
utilization of all kinds of capital. The production function can be expressed as \( q = \varphi (K_1, K_2, \ldots, K_n) \).

Traditional theory emphasizes investments in Capital One, which are all direct inputs. Capital One only plays a role in the final stages of production. Traditional theory only pays attention to the amount of Capital One, disregarding its quality.\(^4\) Quality, however, is very important. For example, skilled and intelligent labor is very different from simple manual labor, and mechanized and automated equipment is very different from simple tools. High quality labor and high quality equipment have high productivity. To increase quality, training and technology should be introduced.

The source of increasing income per capita is increased productivity. Economists define productivity as \( Q \). The production function, \( Q = f(L, K) \), is divided by \( L \) on both sides which are assumed to be homogenous:

\[
\frac{Q}{L} = \varphi \left( \frac{L}{L} , \frac{K}{L} \right) \quad \text{or} \quad \frac{Q}{L} = \varphi \left( \frac{K}{L} \right)
\]

Productivity \( Q \) is a function of capital per labor \( K \).

According to Solow's assumption:

\[
\frac{dk}{dt} = sQ
\]

The amount of capital per labor depends on the saving rate. The saving rate is the optimal choice between today's consumption and tomorrow's consumption. Friedman's hypothesis of permanent income tells us that the saving rate is constant in the long run. So, capital stock cannot increase in the traditional production function in the long run. A new model, describing economic progress, is needed.

Assume that the objective of an economy is to maximize the growth rate of income per capita. If the proportion of labor to population is constant, then the growth rate of income per capita is identical to the growth rate of productivity. Labor increases have no effect on \( Q \), where \( P \) is population. Assume the capital per worker increase is in proportion with the technology input. If the degree of homogeneity is one in the production step, the degree of homogeneity is greater than one in the improvement step:

\[
\frac{d(Q/P)}{dt} = f\left( \frac{dTr}{dt}, \frac{dT_e}{dt} \right)
\]

Where \( Q/P \) is income per capita, \( Tr \) is investment in training, and \( T_e \) is investment in technology.

Since labor increases are in proportion with population

---

increases, the capital per labor increase is in proportion with the increase in technology investment. So, the growth rate of income per capita depends on the growth rate of training and technology. This is to say economic progress mainly depends on Capital Two and its optimal allocation. The market works for Capital Two. Entrepreneurs understand that skilled and experienced workers are more profitable than unskilled and inexperienced workers. Equipment, including high technology, is also more profitable. They are willing to pay high wages and high prices for skilled and experienced workers and good equipment. Therefore, motivation to invest in Capital Two exists in the private sector.

Investment in Capital One is for today's production. Investment in Capital Two is for tomorrow's production. There is an optimal choice between Capital One and Capital Two. Capital Two is more profitable, but also more risky. If $P$ represents expected products, $C_1$ is investment in Capital One, and $C_2$ is investment in Capital Two. Hence, expected products can be expressed as the function of Capital One and Capital Two:

$$P = f(C_1, C_2)$$

The expenditure of investment in Capital One and Capital Two.

---

*A constrained maximization can express it more clearly. Its mathematical derivation is shown in Appendix 1.*
Capital Two is constrained by the enterprise's budget, which is $E$.

$$E = \sigma C_1 + \delta C_2$$

$\sigma$ is the price of Capital One. $\delta$ is the price of Capital Two.

Using the Lagrange function, we find the maximum condition for production is:

$$\frac{f_i}{f_2} = \frac{\sigma}{\delta}$$

Figure 4 shows the relationship between investment in Capital One and Capital Two. The isoquant curve, $I$, represents the expected products. An investment has the same expected return with a different combination of today's production, investment in Capital One, and tomorrow's production, investment in Capital Two. $L$ is the budget line. Its slope depends on the price of Capital One and Capital Two. The tangent point is the optimal share of Capital One and Capital Two. As technology and training progresses, the expected return will increase in respect to Capital Two and the price of Capital Two will decrease, so the budget line moves to the Capital Two side, which leads investors to prefer investing more in Capital Two.
If productivity and saving rates are constant, income per capita cannot increase: $S = s \cdot Y$. Savings equals saving rate times income. Assume $I = S$, savings equals investment. Under the condition of constant productivity, we define

$$I = \Theta K + \mu K$$

Investment is equal to the diminishing rate of return times capital, $\Theta K$ which complements the drop of marginal products, plus the depreciation rate times capital, $\mu K$ which replaces capital depreciation. There is no net capital accumulation $\frac{\Theta K}{\Theta t} = 0$ or $K = 0$. If Labor-input is constant without increase in productivity, income per capita will not increase. Technology can cause investment to receive net capital accumulation:

$$I > \Theta K + \mu K \text{ and } I - (\Theta K + \mu K) = \Delta K$$

28
Capital increase leads to income increase; income increase leads to a savings increase.

Capital Three is not profit-oriented. The government, therefore, bears the responsibility for Capital Three investment. Government expenditure may be divided into two kinds just as individual expenditure. The two kinds are public consumption, such as infrastructure and welfare plans; and public investment, such as education and science. These two kinds form Capital Three. Government has the option to choose between public good and public investment. Determining the government budget is either an economic problem or a political one. Economically, government should try to maximize the benefits to society. A rational government will allocate more funds to Capital Three for economic growth in the future.

**Empirical Specifications**

If the data on expenditures for training and technology, either in the private or government sector, could be collected, then the hypothesis that economic growth is explained by changes in vocational education and technology could be tested.

A regression model could provide empirical evidence if relevant data were available. Although Edward F. Denison’s work is consistent with the theoretical model presented in
this thesis, the following empirical model is suggested:

\[ Q_t = A \cdot E_t^\alpha \cdot T_t^\beta \cdot e \]  

(1)

\( E \) represents vocational education, \( T \) technology, and \( Q \) output. \( e \) is the residual. The percentage change of \( Q_t \) is:

\[ \frac{\Delta Q}{Q} = \frac{Q_t - Q_{t-1}}{Q_{t-1}} = \Delta \log Q_t \]

or:

\[ \frac{1}{Q} \frac{dQ}{dt} = d\ln Q \]

The change of \( E_t, T_t \) is the same as \( Q_t \). So (1) may be written as:

\[ \frac{1}{Q} \frac{dQ}{dt} = d\ln Q = d\ln A_t + \alpha d\ln E_t + \beta d\ln T_t + d\ln e_t \]

or:

\[ \ln Q_t = \ln A_t + \alpha \ln E_t + \beta \ln T_t + \ln e_t \]  

(2)

The objective is to test \( \alpha + \beta = 1 \). If \( \alpha + \beta = 1 \) is significant, it is strong evidence that Capital Two explains the growth rate of output entirely. Since time series data will be used, a test is needed to see whether there is a correlation between errors. The Durbin-Watson test regresses \( \ln e_t \) on \( \ln e_{t-1} \), to get the coefficient \( \phi \).
If \(DW \approx 2 - 2\phi\) is greater than a crucial value, OLS could be used; if \(DW\) is less than a crucial value, then this model needs a transformation using the Cockrane-Orcutt method. First regress \(\ln e_t\) on \(\ln e_{t-1}\) to arrive at coefficient \(\phi\), then let:

\[
\ln Q' = \ln Q_t - \phi \ln Q_{t-1}, \quad \ln E'^* = \ln E_t - \phi \ln E_{t-1}
\]

and:

\[
\ln T'_t = \ln T_t - \phi \ln T_{t-1}
\]

Every time series needs to be taken through this kind of transformation. A new time series data is offered. Regress \(\ln Y_t^*\) on \(\ln E'_t\) and \(\ln T'_t\) to obtain coefficients \(\alpha\) and \(\beta\).

To test \(\alpha + \beta = 1\), let \(\alpha = 1 - \beta\). Substitute this into the original regression equation:

\[
\ln Q_t = \ln A_t + (1 - \beta) \ln E_t + \beta \ln T_t + \ln e_t
\]

The restricted form becomes:

\[
\ln Q_t - \ln E_t = \ln A_t - \beta (\ln E_t - \ln T_t) + \ln e_t
\]

From the unrestricted model we have \(SSE_u\). From the restricted form we obtain \(SSE_r\). The \(F\) test may be used:

\[
F = \frac{(SSE_u - SSE_r)}{SSE_r/n - 2 - 1}.
\]
If the value for $F$ is greater than the critical value, we can accept the hypothesis: $\alpha + \beta = 1$. This means that Capital Two, education and technological growth, entirely explains the growth of output per person.
When making investment decisions, capital returns are the central issue. Investments in different capital have different types of return due to the factors of time and risk.

The length of time between investment and return greatly influences the size of return. People prefer immediate satisfaction. Only a high rate of return encourages people to invest in long-term projects. The longer the time span, the larger the return.\(^1\) Risk is another important factor influencing the size of return. People tend to have an aversion to risk. They prefer safe projects even when higher risks lead to higher profits. High costs need high returns to cover them.\(^2\)

Capital One is used directly for production input in labor and equipment which proceeds to the output of products in a short time and at a low risk. Workers' wages are covered by the value of the products they produce during the

---

\(^1\) Bohm Bawerk includes a detailed discussion about time preference in his work, *Positive Theory of Capital*.

last period:

\[ P_t Q_t = \frac{1}{\alpha} W_{t-1} \]

\( Q_t \) is the total amount of products. \( P_t \) is the average price of products. \( P_t Q_t \) is the value of total products. \( W_{t-1} \) is the wage of the last period. \( \alpha \) is the coefficient of labor's contribution. The wage payment of the last period can be covered by this period's return.

The cost of equipment needs many years to be covered. Since the future is uncertain, risk increases capital-intensive enterprise's need for more funds for forming physical capital. Return, however, should be higher:

\[
\sum_{t=1}^{n} \frac{R_t}{(1 + r)^t} = \beta K
\]

K is the value of physical capital. \( \beta \) is the coefficient for the capital's contribution. R is the return of every period, while \( r \) is the interest rate, and \( n \) is the number of periods. This is the life of the machine.

Capital Two is used for raising the quality of Capital One. Its return has to be shown in the value increase of Capital One. A trained worker can earn more than an untrained worker. \( W_{tr} \) is the income of trained workers. \( W_u \) represents the income of untrained workers. So, \( W_{tr} - W_u \) is the benefit of training. \( T_n + W_u \) is the opportunity cost of
study. $T_u$ is tuition and $W_o$ is income foregone:

$$\sum_{t=1}^{n} (T_u + W_o)(1 + r)^{t} = \sum_{t=1}^{n} (W_{tr} - W_o)p/(1 + r)^{t}$$

The right side is the return of training every year in the future. Assume the average training needs three years. Then the left side is the total cost of three years of training. The cost may be paid by the individual or the enterprise. For the enterprise, $W_{tr} - W_o$ becomes $P_{tr} - P_o$. $P_{tr}$ is products of trained workers. $P_o$ is products of untrained workers. The return is the increased value of products. If the left side is greater than the right side, no one will participate in training. If the left side is less than the right side, many will participate in training. This equation includes the discount rate $r$, because cost and benefit should be compared in present value. $^3$ $p$ is the probability of success of training.

Similarly, returns of technological investment are shown in the increased value of equipment. Advanced equipment includes a lot of technology. High technology generates high productivity. It makes:

$$P_{te} - P_o = [ \sum_{t=0}^{n} W_{te}(1 + r)^{n} + \sum_{t=n+1}^{n+g} P_{te}(1 + r)^{n} ] p$$

$P_t$ is the present value of equipment including new technology. $P_0$ is the present value of original equipment. $W_t$ are the wages of the engineers working on the technology. $P_s$ is the patent of the new technology which represents the income for the patent holder. $p$ is the probability of success of the new technology. The left side is the benefit of new technology. The right side is the cost of new technology.

$p$, the probability, is placed in Capital Two, because Capital Two has high risk.

It is very difficult to estimate return of investment in Capital Three, because it is a long-term investment. Its risk level is unknown and its return time is so long that its effect cannot be seen within one generation. Individuals and enterprises do not have the ability and relevant information to invest in it. However, Capital Three is very important for the future economy. Hence, investment in it has to be the responsibility of government. The size and level of investment in this sector is determined by governments’ ability to invest.

If Capital Three input in production is important to society, why are the private sectors reluctant to invest in it? Since the private sector’s objective is to maximize profit; investing in Capital Three is unlikely (Figure 5).
Fig. 5. Actual return of capital for a firm.

When the risk and time exceed one point, the return drops close to zero.

However, governments' objective is to maximize the welfare of society. Therefore, the government must bear the task of investing in Capital III, where the potential return for society is higher (Figure 6).

Fig. 6. Potential return of capital for society.

In the long run, Capital III can greatly benefit society; so the potential return is higher than for other capital.
The curve in Figure 5 and Figure 6 are continuous because the three capitals overlap and cannot be clearly separated. The curves in both are concave because among the three types of capital diminishing returns exist. Under certain budget constraints we can find a maximum return for capital. For actual return, Capital Two is higher over certain long periods. For potential return, Capital Three is the highest where there are no time constraints.

If we consider discount rates for present value, all of capital's marginal value of marginal products is equal. Capital Three's marginal products, however, are impossible to calculate. The strategy of development in any country faces the big problem of how to estimate the present value of return on Capital Three investment. This becomes a political question which is an issue involving the government budget.

In modern society, Capital Two occupies the largest share of the economy. In the industrialization period, Capital One had the largest share of the economy. The return from them generally matched their contribution to the economy. Whether Capital Three will ever gain the largest share of the economy is not known. There are some indications, however, that this transformation will take place. The information industry, for example, has developed quickly in recent years. This industry is aimed at the diffusion of knowledge, which is the result of education and
science.
CHAPTER V
CONCLUSION AND IMPLICATION

The history of economics progress shows that the progress of the means of production has been an evolutionary process. In every stage of history, one factor, such as land, labor, machine, etc., has played a leading role in the economic growth of a society. Accumulation of investment in these factors forms capital. Capital is expanding as society evolves. Many more types of capital appear and exist in modern society.

The development of capital theories imply that economists are expanding their concept of capital. Since the human capital concept is accepted by economists, the definition of capital has essentially changed. Any stock, as a means of helping production, may be treated as capital. Capital may be classified as three types which work in three sectors. Capital One, including labor and equipment or all direct inputs, affects production directly. The time needed to cover costs is short and risk is relatively low. Capital Two, including training and technology, affects production indirectly. The time needed to cover costs is long, and the risk is high. Capital Two affects productivity of Capital
One and work in sector two. Capital One and Capital Two are profit-oriented. Their returns depend on their contribution to production or productivity. Capital Three, including education and science, influences production. The length of time its investment needs for return is so long and risk so high that Capital Three is not profit-oriented. Since Capital Three benefits the whole society, it must be subsidized by the public sector. The government handles this sector through redistribution.

Economic growth is one of the objectives of the economy. Only the growth rate of income per capita is significant to the improvement of human life. Capital One contributes to the amount of products produced. Capital Two contributes to the increase in productivity. A model was suggested. The growth of income per capita is a function of training and technological growth. This can be tested by the empirical model.

Different kinds of capital have different patterns of return. The cost-benefit approach can help to secure the size of return. The return of Capital One and Capital Two can be measured by their contribution to production. Capital Three falls within the public domain. It helps the long-term development of the economy for which the government bears responsibility.
Implications

This theory has some implications for economic development, the business cycle, and the budget deficit. Economic development theories generally emphasize physical capital accumulation. In practice, however, this strategy has proven incorrect in recent decades. Problems in less developed countries may be diagnosed as lacking in Capital Two. The government of these countries should adopt a bias policy to encourage more funding flow into Capital Two, since Capital Two is a source of productivity. Some experiences in successful developing countries show that the quality of labor and the application of new technology are the basic sources of fast growth.

Modern business cycle theories diverge from Keynes' tradition. They emphasize supply side shock. This shock comes from technology. Solow's "residual" is a technology shock. Much technology applied to production at the same time will bring prosperity. Little or no technology used in production will bring a recession. Similarly, a great amount of high quality labor joining production will cause prosperity and vice versa. It is appropriate to our point of view, that Capital Two is the economic engine of growth. Sudden changes in Capital Two cause the business cycle.

Budget deficit could be a big problem, if funding was used on "public consumption." It would be a debt burden for the next generation. If the deficit came from "public
investment," however, the next generation would enjoy high economic growth, because Capital Three will help Capital Two in the future. So, good deficit should be distinguished from bad deficit. Education and research appropriation could be an investment in the long run. This kind of deficit is not a problem.

These views are useful for economic theory. It is hoped that this discussion can help clarify the concept of capital. Capital theory is developing, so capital needs to be classified clearly.
APPENDIX 1

MATHEMATICAL DERIVATION FOR THE MODEL

The model described in Chapter III could be expressed in a mathematical form.

Some assumptions are necessary for this. First, the objective of an economy is to maximize the growth of output per person. Second, the labor growth rate has a constant proportion to population growth, while growth of natural resources can only complement the depreciation of physical capital. So, increases in labor and physical capital cannot help the objective. Third, for simplicity, time lag is ignored. Allow every period’s investment to impact its own output. A magnitude approach is as follows:

The objective function is

\[ Q = f(Z_1, Z_2, \ldots, Z_n) \] (1)

\( Z \) represents the variety of inputs and their different combinations. They have a direct effect on output.

\[ Z_i = z_i(E_i, T_i, \epsilon) \] (2)

The productivity of all inputs and their combination depend on Capital Two. \( E \) represents vocational education, \( T \)
represents technology. The rest of the impact is treated as a residual $\epsilon$.

The budget constraint includes two parts. One is private net profit assigned for labor training and technological exploration; another is governmental appropriation. Assuming a unit of education has a certain price, $P_1$, and a unit of technology has a certain price, $P_2$, every private producer $i$ invests in training $E_i$ units and in technology $T_i$ units. The total private investment could be:

$$B = \sum_{i=1}^{n} (P_1E_i + P_2T_i)$$  \hspace{1cm} (3)

The government appropriates an amount for vocational education, which can afford $E$ unit:

$$e = P_1E$$  \hspace{1cm} (4)

t amount for technology exploration, which can afford $T$ unit:

$$t = P_2T$$  \hspace{1cm} (5)

Total expenditure on Capital Two for government is:

$$A = e + t = P_1E + P_2T$$

The full investment in Capital Two is:

$$S = B + A = \sum_{i=1}^{n} (P_1E_i + P_2T_i) + (P_1E + P_2T)$$
\[
= \sum_{i=1}^{n+1} [(P_1(E_i + E) + P_2(T_i + T)]
\]

\[
= \sum_{i=2} (P_i E_i + P_2 E_i) \quad (6)
\]

Maximizing the production function (1) is subject to the productivity function (2) and full investment in Capital Two (6).

The Lagrangian may be expressed as:

\[
L = f(Z_1, Z_2, \ldots, Z_r) + \Omega[S - (P_1 E_i + P_2 T_i)] \quad (7)
\]

The first order condition with respect to direct inputs, the Capital One, is zero:

\[
\frac{\partial L}{\partial Z_i} = f_1(Z_1, Z_2, \ldots, Z_r) - \Omega(P_1 \frac{\partial E_i}{\partial Z_i} + P_2 \frac{\partial T_i}{\partial Z_i}) = 0 \quad (8)
\]

Since the productivity function is:

\[Z_i = z(E_i, T_i, \epsilon)\]

Capital Two's cost function can be expressed as its inverse:

\[E_i = z^{-1}(Z_i) \quad \text{and} \quad T_i = z^{-1}(Z_i)\]

So, \(\frac{\partial E_i}{\partial Z_i}\); \(\frac{\partial T_i}{\partial Z_i}\) are marginal coefficients.
\[ P_1 \cdot \frac{\partial E_i}{\partial z_1}; P_2 \cdot \frac{\partial T_i}{\partial z_1} \] are marginal cost of training and marginal cost of technology:

\[
\frac{f_1(z_1, z_2, \ldots z_r)}{f_2(z_1, z_2, \ldots z_r)} = \frac{\frac{\partial E_i}{\partial z_1} + \frac{\partial T_i}{\partial z_1}}{(P_1 \frac{\partial E_i}{\partial z_1} + P_2 \frac{\partial T_i}{\partial z_1})} = 0
\]

\[ f_i, f_j \] are marginal products of Capital One.

\[ P_1 \frac{\partial E_i}{\partial z_1} + P_2 \frac{\partial T_i}{\partial z_1} \] is the marginal cost of Capital Two.

This implies that:

\[
\frac{MP_1}{MP_j} = \frac{\frac{\partial E_i}{\partial z_1} + \frac{\partial T_i}{\partial z_1}}{\frac{\partial E_i}{\partial z_j} + \frac{\partial T_i}{\partial z_j}} = \frac{MC_i}{MC_j}
\]

This means that the ratio of marginal products of any direct inputs, Capital One, must equal the ratio of marginal cost of Capital Two, which are vocational education and technology. Marginal costs are shadow values of \( Z \).

Therefore, the question of maximum output becomes what is the optimal distribution of funds among education and technology. Capital One’s marginal products depend on Capital Two’s marginal cost.

When the unit price of education increases, investment
will shift to technology. Similarly, if marginal products of technology increase, investment will shift to technology and vice versa.

The percentage approach is the same as the magnitude approach. The use of percentage is more reasonable, because Capital One's impact on the growth rate is ignored.
APPENDIX 2

PREVIOUS EMPIRICAL EVIDENCE

Chapter III presented the classification of capital and their contribution to production. This appendix presents empirical evidence to support the theoretical argument.

Denison, in his work, *Trends in American Economic Growth 1929 - 1982*, made detailed estimates of contributions from all sources of growth. He found that the change in contributions to the growth rate show that labor’s contribution is declining while education’s contribution is increasing; capital inventories are declining while structure and equipment is increasing. This means that the growth rate is increasingly dependent on Capital Two.

Denison attributes the economic slowdown partly to the decline in total work hours. He shows that since 1929 work hours have declined from 48.5 hours per week to 34.5 hours per week (see table 1). Although the labor force actually increased between 1929 and 1982, the increase was offset by the decrease in work hours. This implies that labor input is not an important factor to economic growth since the labor input per person has been decreasing while the economy has grown. This means that labor, an element of Capital
One, cannot explain the growth of output per person.

The growth of capital input per person is increasing. This doesn't mean that the physical capital, which is another element of Capital One, is increasing. Table 2
shows that while inventories declined, structure and equipment increased, which implies that capital input changes include much technological innovation. If the changes in technological innovation could be separated from growth of capital, it would make only a little difference over time in physical capital. This means that physical capital, another element of Capital One, would also not have a significant effect on economic growth.
**TABLE 2**

GROWTH RATES OF CAPITAL INPUT IN THE NONRESIDENTIAL BUSINESS SECTOR

<table>
<thead>
<tr>
<th>Period</th>
<th>Capital input per person employed</th>
<th>Capital input per person potentially employed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nonresidential Structures and Equipment</td>
<td>Nonresidential Structures and Equipment</td>
</tr>
<tr>
<td></td>
<td>Inventories (1)</td>
<td>Equipment (2)</td>
</tr>
<tr>
<td>Longer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1929-82</td>
<td>1.34</td>
<td>1.25</td>
</tr>
<tr>
<td>1929-48</td>
<td>0.28</td>
<td>-1.04</td>
</tr>
<tr>
<td>1948-73</td>
<td>2.44</td>
<td>2.63</td>
</tr>
<tr>
<td>1973-82</td>
<td>0.52</td>
<td>2.34</td>
</tr>
<tr>
<td>Shorter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1929-41</td>
<td>0.02</td>
<td>-1.50</td>
</tr>
<tr>
<td>1941-48</td>
<td>0.74</td>
<td>-0.24</td>
</tr>
<tr>
<td>1948-53</td>
<td>3.23</td>
<td>2.81</td>
</tr>
<tr>
<td>1953-64</td>
<td>2.16</td>
<td>2.80</td>
</tr>
<tr>
<td>1964-73</td>
<td>2.35</td>
<td>2.32</td>
</tr>
<tr>
<td>1973-79</td>
<td>0.50</td>
<td>1.43</td>
</tr>
<tr>
<td>1979-82</td>
<td>0.55</td>
<td>4.20</td>
</tr>
</tbody>
</table>

Labor and physical capital are influenced by education and technology. Both are Capital Two. Table 3 shows that among the elements that influence Capital One, only education and structure equipment are increasing. Structures and equipment increases imply technological development. Compared to Capital One, Capital Two is increasingly affecting economic growth.

**TABLE 3**

**SOURCES OF GROWTH OF ACTUAL NATIONAL INCOME PER PERSON EMPLOYED CONTRIBUTION TO GROWTH RATES IN PERCENTAGE POINTS**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Education</td>
<td>0.40</td>
<td>0.38</td>
<td>0.40</td>
<td>0.47</td>
</tr>
<tr>
<td>Nonresidential Structures</td>
<td>0.09</td>
<td>-0.10</td>
<td>0.19</td>
<td>0.18</td>
</tr>
<tr>
<td>and Equipment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>-0.05</td>
<td>-0.03</td>
<td>-0.04</td>
<td>-0.04</td>
</tr>
</tbody>
</table>


Table 4 summarizes the contributions of all kinds of input to the growth rate. This evaluation coincides with the theory advanced in this thesis. Education and advances
in knowledge are seen to provide the largest contribution; both belong to Capital Two and Capital Three, but not Capital One. When other factors are examined, capital growth can be referred to technological changes. The economic scale may be the result of technological improvement. Resource allocation might be a transfer from Capital One to Capital Two. This empirical evidence is appropriate to our analysis; Capital Two plays an important role in economic growth.
TABLE 4

CONTRIBUTION TO 1929 - 1982 GROWTH RATES

<table>
<thead>
<tr>
<th>Actual National Income</th>
<th>Total</th>
<th>Per Person</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Whole Economy</td>
<td>Residential Business</td>
</tr>
<tr>
<td>Growth Rate (%)</td>
<td>2.9</td>
<td>2.8</td>
</tr>
<tr>
<td>Percent of Growth Rate:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Sources</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Labor Input</td>
<td>32</td>
<td>20</td>
</tr>
<tr>
<td>Education</td>
<td>14</td>
<td>19</td>
</tr>
<tr>
<td>Capital</td>
<td>19</td>
<td>14</td>
</tr>
<tr>
<td>Advances in Knowledge</td>
<td>28</td>
<td>39</td>
</tr>
<tr>
<td>Resource Allocation</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>Economies of Scale</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>Environment</td>
<td>-1</td>
<td>-2</td>
</tr>
<tr>
<td>Land</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other</td>
<td>-8</td>
<td>-13</td>
</tr>
</tbody>
</table>

Source: Denison, Trends in American Economic Growth, p. 30
Presently, the government of the United States is realizing that the growth rate depends on the increase in Capital Two. The President's report of 1988 says that the nation's productive capacity depends on the level of technology, the supply and quality of capital, and the number and skill of workers. It emphasizes investment in human capital and technological progress. Other major industrialized nations spent large amounts of money on R & D. Table 5 shows that fast growth countries such as West Germany and Japan spent a relatively high percentage of their GNP on R & D. The United States, however, spent a lower percentage of the GNP on non-defense R & D expenditures.\(^1\)

\begin{table}
\centering
\caption{R & D Expenditures for Five Major Industrialized Countries in 1987}
\begin{tabular}{lcccc}
\hline
 & France & West Germany & Japan & United Kingdom & United States \\
\hline
R & D expenditures (billions of dollars) & 16.4 & 22.8 & 41.7 & 15.7 & 127.7 \\
As a percent of GNP & 2.4 & 2.8 & 2.8 & 2.4 & 2.8 \\
Estimated non-defense LR & D expenditures (billions of dollars) & 13.1 & 21.6 & 41.4 & 11.7 & 88.6 \\
As a percent of GNP & 1.8 & 2.6 & 2.8 & 1.8 & 2.0 \\
\hline
\end{tabular}
\end{table}

Source: National Science Foundation

\(^1\)President's Report (1988).
BIBLIOGRAPHY


