Hajime Oniki
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Measuring Impacts of New Information Technology on The Growth of the Japanese Economy: 1974-85

by Tadashi KURIYAMA and Hajime ONIKI

Introduction

The development of new information technology in Japan started in the early 1970s. It was led by the invention of IC and LSI in U.S. Manufacturing of IC and LSI in Japan began by the middle of the1970s; they were subsequently used for building NC-machines and robots. In the 1980s, new information technology spread to offices and homes in the form of personal computers, word processors, facsimiles, and new communication equipment, not to mention mainframe computers. There is no doubt that such changes increased the efficiency of the functioning of the Japanese society in general, and the aggregate productivity of the nation in particular, thereby contributing to the growth of the Japanese economy.

The objective of this work is to measure this contribution numerically. In other words, it intends to estimate the level of the national income at the present time which would have been realized if there had been no development in information technology during the period in question.

We first develop an 'accounting method' to decompose the value of produced goods and the capital stock into two components: the part attributable to the development of new information technology and the remaining part. An input-output analysis is used for this decomposition. We apply this accounting method to data of the Japanese economy for the period 1974-85 to obtain a time series of the value of produced goods and the capital stock, each decomposed into the two components. Second, by applying the factor-productivity analysis to the time series, we find that ten to twenty percent of the annual growth of the Japanese economy during this period was explained by the development of new information technology and that, without such technology, per capita national income of Japan in 1985 would have been lower than its actual level by approximately twelve percent.

This paper explains the method used and the results obtained for measuring the contribution of new information technology to the growth of the Japanese economy. We emphasize intuitive explanation rather than technical details[1]. The following is an outline of this paper. In Section 2, we discuss in detail various ways in which new information technology affects the aggregate production of the society and accelerates economic growth. Section 3 gives an informal

[1] For detailed explanation, see our article in a volume to be edited by Dr. Georgette Wang of National Chengchi University, Mucha, Taipei, Taiwan 11623.

oniki@alum.mit.edu
www.osaka-gu.ac.jp/php/oniki/

explanation of the method used in this work. Section 4 presents briefly the model used and Section 5 explains the source of the data. Section 6 presents our findings.

New Information Technology and Economic growth

What is meant by the contribution of new information technology to economic growth? This section is devoted to answering this question.

We begin by surveying the route through which the effects of new information technology are transmitted among sectors of the society. See Figure 1 for outline. First, we see that new information technology is adopted in information industries in which informational goods and services are produced and new information is generated and distributed. Information industries include the LSI industry, the computer industry, the software industry, the telecommunications industry, the database industry, and others. Second, output from information industries is sold to other industries, households, and other institutions including socio-economic systems, of which the operational efficiency is increased by new information technology.

Let us next classify in more detail the impacts of new information technology on economic growth. First, as is seem from Figure 1, new information technology brings about the growth of information industries. National income is the sum of the value added generated in all industries of the society. The growth of the information industries in Japan was so rapid that the relative weight of the value added produced in the information industries increased significantly during the 1970s and 80s; the growth of national income owes much to the development of new information technology in this sense.

Thus, we may define 'the contribution of new information technology to the growth of GNP' to be the increase in the rate of growth of value added generated in the information industries. This definition, however, is not satisfactory for the reason that it neglects completely the benefits provided by new information technology.

To explain the point, suppose that, contrary to the reality, there was no information industry in Japan and all of the informational products and services were imported from abroad. In this case, the national income in Japan would be composed of the value added of which no portion was generated by the informational industries; the contribution of new information technology would be zero, according to the definition given above. Yet, the economy would have benefited greatly from imported informational goods and services. In fact, such is the reality today in the Japanese industry; a dominant part of the database services used in Japan is 'imported' from U.S.

It is clear from this consideration that there exist two ways in which the benefits of new information technology are materialized; (1) *Supply-side effects*, i.e., the increase in the national income due to the increase in the value added generated in the information industries; (2) *user effects*, i.e., the benefits of informational products and services enjoyed by the industries and the other

oniki@alum.mit.edu
www.osaka-gu.ac.jp/php/oniki/

sectors of the society. Further, the user effects may be divided into two categories: *measurable user effects* and *external effects*.

The measurable user effects are the benefits of new information technology which directly materialize into a reduction in the cost of goods or an improvement of the quality of goods. The external effects are the benefits of new information technology which are realized through an overall improvement in social and economic systems. Roughly speaking, the measurable effects come from the fact that new information technology contributes to improving the quality of goods and services at the point where they are produced. On the other hand, the external effects arise from the fact that they improve the performance of social and economic systems. The external effects may further be divided into two subcategories: *external economic effects* and *external noneconomic effects*.

The external economic effects come from efficiency improvement in economic systems such as productive firms, markets, and the government from new information technology. Examples of the external economic effects are introduction of electronic fund transfer and shopping by means of BBS. The external noneconomic effects reflect improvement in public service systems, political systems, and other social systems brought about by new information technology. (See Figure 2 for a summary of all of these effects.)

In the present work, we concentrate on the measurable user effects. It does not mean that the external effects are unimportant; on the contrary, they are important factors in explaining the effects of new information technology on economic growth. We limit our attention to the measurable user effects for the reason of analytical convenience[2].

To explain the measurable user effects, let us consider the case of automobile production. New information technology affects automobile production through multiple routes, as is pointed out below.

First, the motor of an automobile is controlled by LSI, a product of new information technology; the operation of the motor is more efficient with LSI than without. For example, the average mileage of a gallon of gasoline consumed would be lower without such control given by LSI.

Second, robots, controlled by LSI and other devices, are used in assembling automobiles; they are more accurate and cheaper than humans in doing mechanical and repetitive tasks, thereby contributing to the improvement of the quality of assembled cars and the reduction of assembly costs.

Third, when a new automobile is to be designed, engineers use workstations driven by

[2] The authors performed a preliminary estimation of the supply-side effects of new information technology (The work was published in Japanese).

oniki@alum.mit.edu
www.osaka-gu.ac.jp/php/oniki/

software called CAD (computer- aided design) or CAM (computer- aided manufacturing); their work is easier and more effective when they use workstations.

Forth, a new car has to be tested repeatedly before it is put into mass production. Testing is done by experimentation and by simulation; for this, equipment controlled by IC and LSI and general purpose computers are used. Without such devices, a prototype of the new car would have to be actually produced and tested on the road at an early stage of designing; the cost of doing so would be higher than that of relying on experimentation and simulation.

Fifth, new information technology contributes to the operation of the firm selling automobiles through office automation (OA) and value-added networks (VANs). Orders from customers are put into a computer at each selling point throughout the nation, and transmitted to shipment centers and eventually to factories producing automobiles. An order of a new car contains a number of specifications regarding model, type, body color, etc., together with information on the customer. Without electronic devices, such complicated orders would have to be processed by humans with written instructions and telephone calls, thereby causing costly delays and errors. Thus, the development of new information technology contributes to the operation of automobile through OA and VANs.

Sixth, computers may be used for demand forecast, marketing, and sales promotion. The automobile manufacture can make a plan for production and distribution of cars and for purchasing factor services (workers or capital services) better with computers than without. Investment may be directed to fruitful projects by means of computer analysis. In short, management and the operation of a firm is greatly improved by new information technology.

Finally, one can point out that new information technology is useful in training workers and managers. Systems called CAI (computer-aided instruction) are considered to be more useful in technical and vocational training than in basic education.

Thus, new information technology contributes to the production and the distribution of automobiles at different levels and in different ways. LSI in the motor of a car improves its performance and adds to its value. Robots used for automobile assembly reduce the cost by substituting for expensive human labor. These are typical examples of the measurable user effects. As Figure 3 shows, the measurable user effects on the production of automobiles can be traced by examining each of the cost components comprising the price of the automobile.

On the other hand, new information technology used to facilitate the functioning of automobile markets provides benefits to both producers and users of automobiles. This is a case of the external economic effects; the benefit of improved markets cannot be traced in the form of cost reduction or quality improvement of automobiles.

The objective of this paper is to aggregate the measurable user effects of new information technology into a small number of data so that we may get an idea about the magnitude of the effects.

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This objective is pursued by utilizing economic theories called input-output relations and 'real' economic variables.

Outline of the Method

In order to isolate the contribution of new information technology, we divide the whole economy into two sectors: the new information sector and the other sector, to be called the H-sector and the Z-sector, respectively. Further, the value of goods and services and the value of capital stock are also divided into two components, to be called H- and Z-components, respectively. Thus, there will be two types of capital stock, the H-capital and the Z-capital; likewise, we consider two types of labor, the H-labor and the Z-labor. The H-component of labor is the part of the productive factor which has the skill of working with the H-capital, and the Z-component is the part which does not have such skill.

It is noted that, in reality, the H-component and Z-component of capital stock or labor may not be distinguished physically. For example, an automobile has LSIs (an H-capital) attached to its motor. A motor is composed of iron and other materials, of which the production relies directly or indirectly on new information technology. Furthermore, the effects of new information technology are not always visible; frequently, it is hidden in the cost and the quality of a car in the sense that the cost is lower and the quality higher with the help of new information technology than otherwise.

From this observation, we are led to the following strategy to measure the contribution of new information technology. Whether visible or invisible, tangible or intangible, we express the effects of new information technology by looking at the composition of the value of a commodity. We do this for the reason that the cost, i.e., the money element, is the only attribute transferable from one commodity to another; the cost factor is the only 'carrier' of the effects of new information technology.

For this reason, the present paper concentrates on tracing the effects of new information technology by computing the cost of a commodity. We divide the *nominal* value of a commodity into two parts, H- and Z-components, and treat each of them distinctly. The nominal value spent on the H-component of a commodity is increased because of new information technology. We know the case of electronic calculators, which ten years ago cost some hundred thousand yen per piece, whereas today they cost one thousand yen of less. On the other hand, money spent on the Z-components is not so significantly affected as money spent on the H-components is.

Figure 4 exhibits an example of tracing the H-components of the price of an automobile by examining backward through production processes. First, the cost of an automobile contains the cost of using assembly robots, which in turn is determined by the price of robots. The cost of an automobile contains other H-components, but we do not show them explicitly here except the cost of using robots.

oniki@alum.mit.edu
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In the cost of robots, as in the cost of automobile, various H-components are included, one of which may be the cost of software used with the robots. We can focus on the cost of the software, of which one component is the cost of using a workstation of the software. In this way, we can divide the cost of an automobile into H-components and Z-components by tracing backward the chain of input-output relations. This chain is endless; however, by using a model called “the price-value-added model of input-output analysis, “we can add up all of the effects arising from every step of this chain and divide the price of an automobile into the H-component and the Z-components.

The H-component and the Z-component of a commodity are distinguished by quality indicators and price deflators. In fact, in the present work, we use a single price-quality index for the H- (or Z-) component, rather than a price index and a quality index constructed separately, which expresses the amount of money needed to purchase a unit of commodity measured in terms of efficiency.

In this work, we encountered a great deal of difficulty in collecting statistical data which reflect the quality improvement. Data on price changes may be available in some cases, whereas data describing quality improvements are almost always unavailable. In the present work, we were not able to find a way out other than by using certain simplifying procedures in obtaining suitable data. In the future, however, when data with quality specifications are available, we may be able to use a more accurate estimation procedure than the one presented in this work.

The Model

This section explains the model used[3].

As is stated in the preceding section, we start with a presumption that the whole economy is divided into two productive sectors, *the new information sector* (the H-sector) and *the other sector* (the Z-sector). The output produced in the H- (or Z-) sector is called *commodity* H (or Z). We use the letters H or Z to identify the component contained in a commodity or in a factor of production, as well as to identify a sector of the economy. We consider three factors: the real capital stock, the labor force, and the research and development expenditure, expressed by the variables K, L, and R, respectively. Each of the two commodities and each of the three factors contains both H- and Z-components. The objective of the ‘accounting’ is to trace the way in which these two components are transferred from input to output in the process of investment and production.

To evaluate the H- and Z-components of output and investment, we consider the price of investment good and the price of capital services. In order to take into account quality improvement in the H- (or Z-) investment good, we define its price as the amount of money to be paid for a unit of *productive capacity* of the H- (or Z-) investment good, rather than a *physical* unit.

[3] See Bank of Japan (1974).

oniki@alum.mit.edu
www.osaka-gu.ac.jp/php/oniki/

As a consequence of the advancement of information technology, the price of the H-investment good decreased significantly during the period in question. This is a consequence of two factors: a rapid decrease in the price if information commodities and a rapid improvement in the quality of information commodities and a rapid improvement in the quality of information commodities. From the price of investment good, we obtain the price of capital services by using an equation in Jorgenson and Griliches (1967: 249-283).

To divide the output price into the two components, we first calculate the proportion of each component in the value added distributed to capital and labor. We make a special assumption regarding the research and development expenditure. We assume that the entire research and development value added in the H-sector is composed of the H-component, whereas the one in the Z-sector is composed of the Z-component. In fact, this assumption 'defines' the two sectors H and Z; the H-sector is the collection of productive activities with the research and development expenditure devoted solely to the production of the H-component, and the Z-sector is simply the collection of the rest of the economy.

We next proceed to calculate the proportion of H- and Z-components in the unit price of the commodity produced in each sector. To do this, we use the value-added price version of the Leontief input-output model. Furthermore, we define the unit of each commodity to be that quatity of the commodity which can be purchased for a unit amount of money; accordingly, the price of each commodity is equal to one. After some work, we obtain an expression indicating the proportion of the H- and the Z-components in the unit price of output from the H- and the Z-sectors.

Next step is to calculate the real investment and the real capital stock of each component in each of the two sectors. The gross nominal H- (or Z-) investment is computed from the nominal amount of investment good produced in each sector; we distribute the latter proportionally, using the investment coefficients, to the two components of each sector. The real gross investment is obtained by applying the deflator (the price of the capital service) to the H- and the Z-investment in each sector. The real capital stock at the beginning of a period is then obtained by means of the conventional capital-stock-investment-depreciation relation.

The objective of the computation explained above is to obtain a time series of the real capital stock for sectors H and Z and for components H and Z; i.e., to obtain four series of the real capital stock. To do this, we used the Leontief price model for calculating the cost of each commodity to obtain H- and Z-components, and derived the nominal investment for each of the two components distributed into each of the two sectors, H and Z. We then obtained the real capital stock from the real investment data. We may call this procedure the 'H-capital accounting.'

All of the steps in the H-capital accounting are designed in such a way that, starting from the real capital stock at the beginning of a period, we perform a number of operations to end up with the real capital stock at the beginning of the following period. Therefore, if we are given data for

oniki@alum.mit.edu
www.osaka-gu.ac.jp/php/oniki/

the exogenous variables and the initial values, we are able to compute all variables needed for the second step.

We next explain the method used for evaluating the effects of the H- and Z-components to the growth of GNP, i.e., productivity analysis. The basic concept is that of the aggregate production function, which is written as

(1) $GNP\ (t) = F\ (k\ (t),\ l\ (t),\ t)$

where t denotes a time period (a year in this work), $K\ (t)$ the aggregate capital service, and $l\ (t)$ the aggregate labor service, both considered to generate $GNP\ (t)$, the gross national product for period t. As is well known, (1) is an extension of the concept of the micro-level production function, which is written based on the observation that factory production is carried out by combining capital service (e.g., that of machines and equipment) with labor service.

The last argument t in the aggregate production function indicates the presence of technological progress; it means that aggregate production may be increased with the same quantity of capital input and labor input if there is technological improvement taking place over time. Inclusion of t in the production function is a method for expressing technological progress.

In this paper, we employ an alternative method; we will be interested in technological progress which is ‘embodied’ in capital of labor; technological progress in this sense can be expressed as, and is equivalent to, a quantitative increase in capital or labor service. This method fits in with our objective of considering the effects of new information technology by means of cost calculation. Below, we explain this briefly.

First of all, observe that, when the input of capital service of that of labor service is increased quantitatively without a quality change, then it will lead to an increase in the aggregate products, $GNP\ (t)$. There is no technological progress in this case; it is simply a quantitative expansion.

In reality, however, it is seldom the case that an increase in GNP is achieved through a purely quantitative expansion of factor inputs. Qualitative changes are involved always. It is noted that the variables $k\ (t)$ and $l\ (t)$ are both aggregate entities; $k\ (t)$ is, in fact, calculated from the money value of the services from a large number of machines and equipment, and $l\ (t)$ is calculated from the money value of a large number of labor services of different types receiving different wages. In order to be free from changes in the absolute price level, the money value is ‘deflated’ by using a price index. The price index used for deflation is obtained from the money value of a ‘basket’, which is a collection of productive factors considered as ‘representing’ the composition of capital or of labor. If technical progress takes place and the composition of a factor is changed, then the

oniki@alum.mit.edu
www.osaka-gu.ac.jp/php/oniki/

basket needs to be revised.

From this consideration, one sees that technological progress which takes place in the form of the improvement in machine capabilities may be reflected in the variable $k(t)$ through a change in the price index. Likewise, technological progress taking place with the improvement of labor quality may be expressed as an increase in the variable $l(t)$ through a change in the wage index. Observe that the total money value of the capital service and the total wage payments to labor are statistically well – defined entities, whereas the definition of price index is not firm, varying with the content of the basket.

In this work, we try to incorporate technological progress arising from the development of new information technology into the variables $k(t)$ and $l(t)$, rather than letting the time variable t represent technical progress, in the aggregate production function. This will be done by devising appropriate price indexes. The reason for doing this is that the measurable user effects of technological progress are observed with changes in the quality of capital stock and improvements in labor quality. If the data $k(t)$ and $l(t)$ are estimated properly, such quality improvements should be expressed as an increase in the level of $k(t)$ and $l(t)$. On the other hand, the (nonmeasurable) external effects of new information technology may be handled through the time variable t in the aggregate production function.

The present approach was promoted originally by D. Jorgenson and Z. Griliches (1967). They extended this approach a step further to claim that if one successfully incorporated technological progress into an improvement of capital or labor quality, then one should be able to explain 'all' of the increase in output by the change in the variables $k(t)$ and $l(t)$. The role of the time variable t in the aggregate production function would become minimal. In such an approach, the part of technological progress attributed to the time variable t is considered 'unexplained'; it is called the *residual*. The presence of a residual may suggest that there is some portion of technological progress which is not yet expressed as an improvement in the quality of capital or the labor force.

We next explain our strategy for using the aggregate production function to measure the contribution of new information technology to the growth of the Japanese economy. We follow the line having been set out by Jorgenson and Griliches and try to express technological progress in the form of improvement in the quality of capital stock and of the labor force. To do this, we divide each of capital stock and the labor force into two components, the H- and Z-components. In this work, there will be two kinds of capital stock, the H-capital stock and the Z-capital stock; likewise, we consider two types of labor, the H-labor and the Z-labor. The H-component is the part of the productive factor which is formed by new information technology. On the other hand, the Z-component of the productive factor is the remaining part. The aggregate production function (1)

oniki@alum.mit.edu
www.osaka-gu.ac.jp/php/oniki/

is then written as

(2) $GNP\ (t) = F\ (k\ (H, t), k\ (Z, t), l\ (H, t), l\ (Z, t), t)$.

According to the frame work expressed in equation (2), the growth of gross national product, GNP (t), can be attributed to an increase in one of the four factor inputs, the H-capital, the Z-capital, the H-labor, of the Z-labor (denoted in equation (2) by $k\ (H, t)$, $k\ (Z, t)$, $l\ (Z, t)$, respectively), or to the variable t. In short, our analysis is to divide the increase in GNP into the five components.

Let us next explain briefly the way we divide the growth rate of GNP. Roughly speaking, GNP is the sum of the final products of the society (i.e., the total products minus intermediate products), of which the value is distributed to the owners of capital and the labor force who contribute to the production of GNP. The part distributed to the owners of capital is called profits (property income) and the part distributed to workers is called wages (labor income). Therefore, by using the distribution data of GNP, we can calculate the contribution of a productive factor to an increase in GNP. Take the H-capital, for example. The part of GNP attributable to it is equal to the price of the H-capital times $k\ (H, t)$, the profits distributed to the owner of the H-capital. The contribution of an increase in the H-capital to the growth of GNP is equal to the product of its price and the increase in the quantity of capital stock $k\ (H, t)$.

As is known widely, it is difficult to estimate equation (2) directly from time series because of likely multicollinearity. Growth accounting is a way of avoiding this difficulty; is assumes that all of the factor markets are competitive and decomposes the growth rate of GNP, instead of estimation the production function directly.

First of all, we obtain time series of capital stock $k\ (H, t)$ and $k\ (Z, t)$ and of labor force $l\ (H, t)$ and $l\ (Z, t)$, each being divided into components H and Z but aggregated over sectors. When using these variables for growth accounting, we assume that the service provided by the capital stock or by the labor force is proportional to the stock variable itself; i.e., we assume away idle capacity with the capital stock or unemployment of the labor force. These assumptions are made for simplicity.

National income $x\ (t)$ needs to be divided into the income distributed to capital, $x\ (K, t)$, and the income distributed to labor, $x\ (L, t)$, neglecting indirect taxes, subsidies, and other miscellaneous items:

(3) $x\ (t) = x\ (K, t) + x\ (L, t)$.

The share of the income distributed to each factor, and the shares of income distributed to

oniki@alum.mit.edu
www.osaka-gu.ac.jp/php/oniki/

each component of each factor, are obtained from the data in the 'accounting.'

We then decompose, using the standard growth accounting method, the growth rate of GNP. First, we obtain the real national product, and its growth rate. Next, we calculate the growth rate of each component of each factor. The contribution of each of the four factors to the growth of the national product may then be calculated by multiplying the share with the growth rate of each of the four productive factors. Finally, residuals are computed.

Description of the Data

This section gives a brief description of the data which were used to generate time series of the H- and Z- components of the produced good, the capital stock, and the labor input, and the data for growth accounting.

(i) *Time period:*

We used annual data for the Japanese economy from 1973 to 1985. The year 1973 was taken to be the initial period ($t = 0$), so that we have a sample period of 12 years, from 1974 to 1985. The development of new information technology was accelerated after 1985; its contribution to the growth of the Japanese economy should be much higher after 1985 than during the sample period.

(ii) *Sectors:*

As is explained in the preceding section, we used a two-sectoral framework of the aggregate Japanese economy to estimate the contribution of new information technology. The first sector, the H-sector, is defined to be a collection of industries which are heavily driven by such technology. From the industries in the endogenous sector of the Japanese input-output tables, we selected computer industry, integrated circuit industry, telecommunications industry, information service industry, and other related industries, to form the H-sector. All of the remaining industries in the endogenous sector except the research and development industry are aggregated into the Z-sector.

(iii) *Input-output, value-added, and investment coefficients:*

Input-output coefficients and value-added coefficients are obtained by aggregating the input-output tables of the Japanese economy. The investment coefficients are estimated by the authors from capital stock data.

(iv) *Price indexes and the rate of depreciation:*

As is explained in the preceding section, our strategy is to divide the nominal cost of a produced food into H- and Z-components and to obtain the 'real' value of each component by deflating the nominal value using a price index. To do this, we need a price index for each of the H- and Z-components. We use the imputed deflator of the gross national product as the price index of the Z-component.

oniki@alum.mit.edu
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We estimated our own price index of the H-component from the price of computers; we did this by adjusting the nominal price of mainframe computers by means of the 'hedonic index' method; we regressed the nominal price of newly leased mainframe computers on two quality indicators, the computation speed and the memory size, as well as a time trend.

(v) *The rate of capital depreciation:*

The difference in technological progress and that in price reduction between the H- and Z-components is related to the rate of depreciation of each type of capital stock. Since no systematic data for depreciation of each component is available (data available from financial reports are useless because they are based on taxation rules, not economic or engineering facts), we assumed that, on average, the length of time for a product to depreciate to 10% of the original value is 12 years for the Z-component and 6 years for the H-component. The corresponding rate of depreciation is equal to 7% and 15% per year, respectively, for the Z- and H-components. The reason that the H-product depreciates much faster than the Z-product is that, because of rapid technological progress and competition, the H-product becomes obsolete a few years after it is purchased, even though it is still usable.

(vi) *Labor input and the wage rate:*

The most difficult problem in preparing data for our work arises when a definition of H0 and Z-components of the labor input is to be chosen. It is intuitively clear that, at each step of production (e.g., automobile assembly), a part of labor service (that for operating and maintaining assembly robots) is combined with H-type capital equipment (robots) to produce an output with H-component (automobiles assembled with robots, as distinct from automobiles assembled manually). During the process in which new information technology is adopted, the quality of the labor service is improved through education, training, and learning; the H-component of labor input is increased accordingly. It is not straightforward, however, to give a definition in which labor input may be classified into one of the H- and Z-components. Since the "production of human capital" is not included in the input-output relation of this model, the labor input cannot be divided in the same way as is the capital stock. We need to use some proxy to represent the H- and the Z-components of the labor input. In fact, there are several ways of defining H- and Z-components of labor, and the final results depend significantly on the choice made.

For this reason, we consider three alternative definitions of H- and Z-components of the labor input. The first definition assumes that the H-labor is zero; this means that all of the H-components in the economy are generated from R&D expenditures in the H-sector. The result obtained from this assumption would give a lower bound to measures of the contribution of new information technology to economic growth.

In the second definition, wages and salaries are divided into H- and Z-components according to the job content of workers; wages paid to system engineers, programmers, machine

oniki@alum.mit.edu
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operators, and keypunchers are classified as being composed of the H-component only. This presumes that computer operation requires new skill to be obtained from education and training. In this definition, we assume, in effect, that the labor input of H-type workers is indispensable for the H-capital to be productive. The cost of the H-capital and the H-labor becomes, in parallel, apart of the H-component of the price of the commodity.

The third definition, which is the one we employ in this work, is the same as the second definition except that the range of the H-type worker is taken to be much greater than in the second definition, the H-type worker is a computer specialist. In the third definition, a part of nonspecialist labor is also included in the H-component. We consider the hours of office workers devoted to handling informational devices as the H-component of labor input. We used data collected by the Japan Office Automation Association[4]. This study reports data on the hours that clerical and office workers spent in handling general purpose computers, office computers, personal computers, word processors, and on-line equipment. We may state that the effects of office automation is taken into consideration in this model

(vii) *National income data:*

Data for the national income statistics are obtained from the Japanese national income tables for the years 1973-85. To divide the nominal factor income $x(t)$ into profits and wages (i.e., into $x(K, t)$ and $x(L, t)$, we first take the sum of operating surplus and consumption of fixed capital as the income distributed to the capital (profits), and compensation to employees as the income distributed to the labor force (wages). We divide all other incomes, including the income distributed to proprietors, in proportion to profits and wages. This assumes, in effect, that the composition of capital and labor with proprietors and other sectors (e.g., self-employed workers) is the same as in the sector in which profits and wages are distinguished statistically.

Findings

In this section, we briefly present the results we obtained. Because of the limitation of space, we will not show here all the results we calculated; we have selected time series which are useful for us to understand the relative magnitudes of the two sectors, and the differences in the rate of growth of the two components, during the period 1974-85.

First of all, the price of the capital service of each component is calculated from the price of the investment good, i.e., the price of the newly produced good. The price data are shown in Table 1 and are depicted in Figure 1. It is seen that the price of the Z-component increased slowly during the period 1973-85 at the rate of 2% each year. On the other hand, the price of the H-component decreased at the rate of 32% each year, which means that the price became approximately one –thirtieth at the end of the 12-year period. In other words, an amount of 1000

[4] See Japan Office Automation Association (1987).

oniki@alum.mit.edu
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yen spent on the H-product in 1985 is, in effect, 30 times greater than the same amount of money spent on the H-product in 1973.

Next, by using the price of capital services, we divide the value-added generated by the capital stock into H- and Z-components for each year of this period, and the value-added generated by labor is divided into the two components. Table 2 shows the decomposition of the produced good in the H- and Z-sectors into the two components.

The contribution of the H-type labor from information professionals and nonprofessionals during the period they work with the H-type equipment like personal computers and word processors is shown in Table 3. The H-component sis calculated, on average, to be 8.2% of the H-good and 2.5% of the Z-good.

The real capital stock divided into H- and Z-components for each of the H- and Z-sectors is given in Table 3. Graph for the capital stock is given in Figure 2.

It is seen that the Z-component of the capital stock in 1980 yen increased approximately 70% during the period 1973-85. The H-component of the capital stock in 1973 is almost zero because we assumed that the initial value of this capital stock at the end of the year of 1972 is zero. The rate of growth of the H-capital stock for the period 1973-85 is seen in Figure 2. The H-component of the capital stock at the end of 1985 is close to 1/4 of the Z-component.

For purposes of comparison, we have also added tables representing the capital stock measured in current prices. It is seen that the H-capital stock rose significantly in constant prices relative to that in current prices. As is stated previously, this indicates the rapid progress in new information technology expressed by quantitative increase in the capital stock measured in constant prices. One can say that the model is used to convert the progress of new information technology, a qualitative phenomenon, into the increase in the H-capital stock, a quantitative indicator.

Decomposition of the growth rate of the Japanese economy for the period 1974-85 into the five components is shown in Tables 4; percentage decomposition is shown in Tables 5. Graph is also provided (Figures 3 and 4).

It is noted that, in our model, the definition of H-component of labor input is taken to be so broad that it includes the labor services provided bay workers who are not specialists in computers or communications, but who devote a part of their time to using products and services in which new information technology plays a dominant role. Thus, the time spent by an individual working in an automobile assembly factory by operating robots is counted as forming apart of the H-component of the automobile being produced. Furthermore, when a business worker uses a word processor or a personal computer to edit a draft and send it to the head office, then the part of the wages paid to this worker measured in proportion to the time spent on such equipment is included in the H-component of the output of the company. Under this assumption, the contribution of new information technology to the growth of the Japanese economy is estimated to be as high as 6.9% to 31.7% of the aggregate growth rate. In particular, a part equal to 0.64% per year in the average growth rate 3.9% per year of the Japanese economy from 1974 to 85 owes to the development of new information technology. If this contribution were replaced by the contribution of the Z-component, then the real value of the capital stock would be smaller and the level of gross national product in 1985 would be lower by approximately 12% than the actual value.

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oniki@alum.mit.edu
www.osaka-gu.ac.jp/php/oniki/