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And Implications for Monetary Policy
(Background Paper for the Eighth International Conference)

Tetsuya INOUE

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# Impact of Information Technology And Implications for Monetary Policy (Background Paper for the Eighth International Conference)

Tetsuya INOUE*

Abstract

First half of this paper shows the mechanisms through which the innovations in Information Technology (IT) have impacts on our economy. Switching costs from existing technologies and network externalities may play important roles in the propagation of IT on microeconomic level. In addition to the aggregation effects of such externalities, costs of reallocating capital and re-training labor will hamper the macroeconomic performance. Mismeasurements in economic statistics may prevent us from making optimal decisions based on relative price changes. Second half of this paper discusses the issues for improving efficiency in conducting monetary policy by focusing on price mechanism. We should be careful whether to accommodate the "Supply Shocks" or not, considering the possibility of nominal rigidities or fluctuation in general price level. It is also shown that mismeasurements in price index may damage the credibility of a central bank, since it will be quite difficult for us to observe the achievement of monetary policy commitment.

Key words: Information Technology, IT paradox, Mismeasurement in Economic Statistics, Network Externalities, Adjustment Cost, Relative Price, Policy Commitment

JEL classification: D20, E50, J30, L10, N10, O30, O40

* Research Division 1, Institute for Monetary and Economic Studies, Bank of Japan (E-mail: tetsuya.inoue@boj.or.jp)

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# I. Introduction

Our modern economy is currently confronting an irreversible trend toward increasingly conceptual and intangible forms of economic resources. We can find its examples of this trend everywhere in our economy; modern factories are introducing CAD and CAM, most offices are using computers for managing inventories and human resources, and more and more households are becoming connected to the Internet and to mobile phones. Since such changes are spread throughout our economy, we might say that we are in the third Industrial Revolution, which follows the first Industrial Revolution, when machine production by a steam engine began, and the second Industrial Revolution, when electric power and chemical engineering appeared.

Major force that is propelling this movement is, of course, the rapid innovation in Information Technology (IT). It has been a stylized fact in the fields of economic growth theory and economic history that the innovation is the engine of economic growth. Like the steam engine and electric power, the innovations in IT are expected to change all the areas of economic activity, including investment, consumption, employment, and production, and to bring about a great improvement of economic performance. In this process, a firm that introduces new technologies in IT will be benefited from improvements in efficiency such as decreasing its cost of production, and rapid and more accurate decision making. Since more and more firms pursuing these benefits will introduce new technologies and use improved goods and services as inputs, the improvement in economic efficiency will spread to the whole economy. We also find that the effects of network externalities and increasing returns to scale have played major roles here. These changes, as a whole, will improve macroeconomic performance by promoting new industries, gaining efficiency in the allocation of productive resources, and the increased accumulation of human capital.

There has been a persistent doubt, however, among academic economists and policy makers that we have not obtained the fruits of this trend of innovations in IT. This line of arguments first appeared in the discussion concerning “productivity slowdown”, and it has long been drawing attention from academic economists. These analyses can be categorized into the following two hypotheses. The first hypothesis seeks its the cause of this productivity slowdown in the existence of measurement errors in economic statistics of representing prices and quantities. In other words, we may suspect that the current system of economic statistics does not either cover new goods and services, and/or else it does not correctly measure quality changes in existing goods and services. On the other hand, the second hypothesis seeks its the cause of the slowdown in the adjustment costs of introducing new technology. As for this hypothesis, the meaning of the term "adjustment costs" is very broad; it not only contains the cost of installment of physical equipment, but also the costs for of complementary innovations, training of labor, scrapping the old equipment, and moving capital from declining industries. It should be emphasized that these hypotheses are not mutually contradicting,

We will show, with the helps of theoretical models and empirical results provided by academic economists, the trajectories and mechanisms through which the innovations in IT have impacts on our economy. On the microeconomic level, switching costs from existing technologies and network externalities may play some important roles in delaying the propagation of new technologies. In addition to the aggregation effects of such externalities, the costs of moving capital to growing industries and of re-training labor will hamper the macroeconomic performance as a whole. Mismeasurements in economic statistics may prevent firms and households from making optimal decisions, since those firms and households will not be able to observe the changes of relative prices accurately.

Since the innovations in IT may be changing our economic performance in many aspects, it is surely an important task for us to discuss the optimal monetary policy in such a changing economy. Although we do not have enough theoretical discussions or empirical studies so far, we will confine ourselves to suggesting, at least, a list of issues for future discussion on how we can improve efficiency in conducting monetary policy by focusing on the effects of the developments of the price mechanism.

The main discussion in this paper can be summarized as follows:

In the first half of this paper, we review the discussions relating to the IT paradox in detail. We discuss two major hypotheses which may explain the reasons for the IT paradox; 1) measurement errors in economic statistics and 2) a broad range of adjustment costs for the introduction of new technology. In relation to the latter hypothesis, we also review the lessons from the studies of past Industrial Revolutions. We identify that we should be much more careful about the effects of mismeasurement, and not only in price indexes, since such errors may cause some serious problems when we try to observe economic relations. We also see that a time lag between the introduction of new technology and the observation of its fruits can be explained by the effects of such adjustment costs at both microeconomic and macroeconomic levels. The costs are incurred, for example, by installing capital equipment, network externalities, re-training labor, and moving capital between industries. As for the implications for investment or consumption of information itself, which can be regarded as another major aspect of current innovation in IT, we only have limited insights so far. Since it is very important to know the effects of current innovation on the formation of expectations or on asymmetries of information, especially in financial markets, we expect further investigation in this area.

In the second half of this paper, we try to present the issues on which concern the relationship between the effects of innovations in IT and the optimal way of conducting monetary policy by focusing on the price mechanism. If the measurement errors in price indexes are made serious through the various effects of innovations in IT, such as intangible quality changes, it they may incur to some extent damages on maintaining the credibility of monetary policy. Because, for example, central banks may not be able to conduct a targeting policy for either the inflation rate or the GDP growth rate, since it will be quite difficult to observe the achievement of such a policy. Thus, we again identify the importance of further investigation of measurement errors of economic statistics. Under the standard framework of the Phillips Curve or NAIRU, the effects of innovations in IT can be regarded as “Supply Shocks”. Since such shocks bring about a low unemployment rate without raising the inflation rate, we need not to accommodate them by using monetary policy. However, when we take into consideration of the costs of inefficiency by the possibilities that there exist fluctuations in the general price level, or nominal rigidities in our economy, we should be more careful about this conclusion of non-accommodation.

# II. IT paradox and its Hypotheses

## A. Productivity slowdown and IT paradox

In the United States after the World War II, the growth of GDP actually accelerated, in spite of bearish forecasts for the post-war economy. In this long-lasting boom, total factor productivity (TFP) and labor productivity also showed dramatic increases. As Abramovitz and David (1996) and Freeman and Soete (1997) shows, we had not experienced such an acceleration in productivity growth since the first Industrial Revolution. Moreover, the situation was similar in most of the developed economies in Europe and Asia. However, this trend of rising productivity disappeared after entering the early 1970's. The most dramatic change was identified in the United States where the growth rate of productivity fell below 1% per year compared with the previous rate of 3% level (Figure 1). This phenomenon was first analyzed systematically by Nordhaus (1972); he argues that the most important reason is the shift of the United States economy toward service industries with low productivity (see section B-1 in this chapter below). Even in the 1980's, the paradox was alive and well, although we had a small improvement in growth rate of productivity.

At this stagnant situation, Baily and Gordon (1988) brought a new line of analyses and empirical findings. They reconsidered the paradox by analyzing the effects of an already rapid increase in IT investment, and thus presented the "IT Paradox". The term "IT paradox" refers to the situation where a rapid increase in IT investment does not cause the acceleration of productivity growth. As Griliches (1994) and Van Ark and Pilat (1993) showed afterwards, the IT paradox has also been shown to be true in some of the other developed economies (Figure 1). Even in the 1990's, when we are seeing the continuous growing of IT investment, the paradox is current in the sense that the growth rate of productivity has not reached the level of the 1960's[1]. In the years of the IT paradox, we have a lot of research papers tackling with the issues in this area.

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[1] Some empirical studies including Morrison and Berndt (1991) and Morrison (1997) show that increasing returns to scale can be observed at a the firm level. If these findings are true, the most important problems may lie at the aggregate level.

Thus, we will review the discussion of the above two hypotheses in turn[2].

## B. Measurement Errors in Economic Statistics

The first hypothesis deals with the problems caused by measurement errors in economic statistics. We may suspect that the current system of economic statistics can not accurately measure the value of IT-related goods and services, and thus misestimates the value of production and value added of the firms which use such goods and services as intermediate inputs. As a result, we may also have inaccurate measurement of GDP as well. I will discuss in detail this hypothesis in two parts; i) problems in the area of economic activities where the measurement of economic statistics is inaccurate, and ii) problems in the area of economic activities which economic statistics does not cover at all.

### B-1. Measurement Error of Price

The most important problem of measurement error in economic statistics is, of course, mismeasurement of price. Since we see the improvements in the quality of existing goods and services, thanks to IT, firms and consumers frequently switch their demands to such improved good and services. We may suspect that such changes of quality are not reflected accurately in calculating a price index, which may bring about the mismeasurement of GDP and value added.

Following Nordhaus (1972), we have a literature of analyses regarding mismeasurement of price. For example, Gordon (1990) suggested that a price index of a durable goods consumption had an upward bias of 3%. Shiratsuka (1995) on automobile price in Japan, and Berndt and Griliches (1993) on PCs, Dulburger (1993) on semiconductors, and Brown and Greenstein (1995) on mainframe-computers all showed that the prices of

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[2] Brynjorfson (1993) and Sichel (1997) categorize the hypotheses for IT paradox as the following: 1)mismanagement (there exists some overinvestment in IT), 2)redistribution (investment in IT will bring about social costs and private profits), 3)learning (we are in a learning process for IT), 4 )a small share of computer stock in total capital stock (share of computer in capital stock is still very small), 5)mismeasurement (we can not observe the effects due to mismeasurements in statistics). It should be noted that 1), 2), and 3) are related to the adjustment costs of introducing new technologies, and 4) and 5) can be categorized as the hypothesis of measurement errors in economic statistics.

consumer durables and capital goods were subject to serious mismeasurement. In addition, Gordon and Griliches (1997) and Kozicki (1997) pointed out that imperfect competition and product life-cycles of goods make the situations even worse.

It is in the territory of services where the problem of mismeasurement is most serious. We may be aware that most of the impact of IT on economic activities is realized through quality improvements and the introduction of new services in corporate-service industries. However, as for the case of services, it may be quite difficult to make adjustments for quality changes, because they are intangible. In addition, we may not be able to find a "representative" price, because the way such services are transacted is so flexible that there may be a large range of different prices depending on a variety of transactions. We may regard such variety of services as mutually heterogeneous with each other. The seriousness of this problem is confirmed by many empirical studies; for instance, Baily and Gordon (1988) analyzed four of the industries with in which serious mismeasurement occurred (Finance and Insurance, Construction, Retail, and Transportation), three of which belong to the category service industry. Or you may remember the empirical studies of adjustment for quality changes in consumer services such as housing, telephones, transportation, medical care, and entertainment quoted by Boskin (1996). Slifman and Corrado (1996) also suggest that outsourcing corporate-services to small firms in the 1990's may be aggravating the problems of coverage of our economic statistics. Thus, taking into consideration of both such mismeasurements in service industries and the simultaneously increasing share of service production, we may have a hypothesis to explain the IT paradox. In fact, this hypothesis is suggested for the case of the United States by empirical studies conducted by Darby (1992), Griliches (1994), Kozicki (1997), Nordhaus (1997), and Nakamura (1997)[3]. The increasing share of services is also found in productive resources. For example, Stewert (1997) shows that about 70 percent of inputs in automobile manufacturing is "intangible". Wynne and Sigella (1996) estimates that upward bias by substitution effect in price indexes of intermediate inputs is 0.3%. Therefore, measurement error of price has also worsens the estimation of the value of intermediate inputs, which results in

[3] Goldfinger (1996) quotes R.Gordon's finding that the share of economic values in the United States with accurate measurement has fallen from 50% in 1947 to 30% in 1990.

mismeasurement of value added[4].

**B-2. Coverage to new goods and services**

We also suspect that our current system of economic statistics does not cover the new goods and services developed with IT. Slifman and Corrado (1996) also suggest that the newly growing corporate services industry is seriously undercovered by economic statistics. We should note that Meltzer (1997) estimates that the value of computer software reaches 150% of that of hardware, but at the same time, it has not been hardy measured accurately. This situation is also true in most of the developed countries; as for Japan, Mizoguchi (1996) shows that the estimated value of IT service production from 1974 to 1993 ranges from 120% to 170% of the value recorded by official statistics.

In relation with this problem of coverage, we may suspect that some kinds of economic activities should have been categorized improperly. A typical example is computer software. If computer software is used for several years in a firm for designing its products or for accounting, it clearly possesses the characteristics of a capital good, just like a machining center or a truck. But, in the System of National Accounts (SNA) by which most of the countries calculate GDP, computer software has been regarded as an intermediate inputs for production despite above characteristics. Such improper treatment of software has distorted the value of GDP in the years when such software produces service inputs for its user. That is, in the year when in which a firm buys an item of software, the value of GDP is underestimated, since the value of the software is calculated as an intermediate input despite the fact that it should be regarded as investment. On the contrary, in the years when the software is used for production activities, the value of GDP is overestimated, because the value of the depreciation of the software is missed under the current SNA. In addition, it should be noted that such improper treatment leads us to mismeasure the value of capital stock, which will result in mismeasurement of total factor productivity (TFP).

[4] We should note that mismeasurement of value added in service industries brings about a serious problem for estimating GDP. The reason is that, in service industries, the share of value added to gross product is much larger than in manufacturing, since most of the inputs to service industries consist of labor.

### B-3. Countermeasures for Mismeasurement

Although we have a literature analyzing the problems of mismeasurement of economic statistics, we have few effective and practical proposals for solving such problems other than the geometrical average, which is known to be an effective measure for controlling the substitution effects in calculation of price index, and is actually used in many countries.

For example, the hedonic approach has been suggested as a measure for quality adjustments in price. A lot of analyses, including Boskin (1996), regard this approach as almost the only effective measure with a theoretical background. We, however, know that both in the United States and in Japan, this approach is applied to only a few of the products in price indexes[5]. As for the reasons, we will have to solve theoretical problems such as how to avoid being arbitrary in selecting characteristics, or how to understand the relationship between the index theory and the Lancaster's theory. In addition, almost every government statistical agency claims that a relatively large cost is necessary in collecting data for regression on “characteristics”. On the other hand, it has been shown that we can control the substitution effects by introducing the geometrical mean into our calculation of a price index. Boskin (1996) shows, however, that the magnitude of such substitution effects in consumption is not so large as those of quality changes. Wynne and Sigella (1996) also suggest that its impact may also be small on intermediate inputs as well. Thus, we may conclude that we do not yet have a decisively effective countermeasure to correct the measurement error of a price index so far.

For more broader coverage to new goods and services, as Boskin (1996) points out, there may be no shortcut other than the immediate incorporation of new goods and services into economic statistics. This kind of countermeasure might be difficult, considering the additional cost of statistics production and the additional burden on reporters. As for the problem of categorization, we may advance by adopting the new System of National Account (93SNA), since computer software can be properly categorized as productive capital in this new system. We should note, however, that

[5] Although the hedonic approach was introduced to estimate the price index of computer in both the United States and Japan, its coverage has not since been changed since then.

we must have an accurate measure of software production and transactions in order for such new system to work adequately. Here, we will face the same problem as above: such characteristics as the existence of small firms and the large variety of transactions will make our estimation hard. Thus, in this area of problems as well, we do not yet have very effective countermeasures so far.

## C. Adjustment Cost - Lessons from the Industrial Revolutions

As we saw in the Introduction, the second hypothesis seeks its cause in the adjustment costs of for introducing new technologies. According to this hypothesis, the cost refers not only to the adjustment cost of installing physical equipment, but also to the cost of complementary investment, such as developing computer programs for flexible manufacturing systems and re-training labor. It also includes the cost of reallocation of productive resources from declining industry to the growing new industry of IT. Since economic historians emphasize the effects of such adjustment costs in the past Industrial Revolutions, we will start discussing this hypothesis by reviewing such analyses by economic historians.

### C-1. Time Lags of Introduction of New Technology

Many economic historians, including N. Crafts, P. David, and C. Freeman, provided a lot of implications from their studies of the past Industrial Revolutions. Among such implications, the point they most emphasize is that it took many years from the innovations of key technologies for each Industrial Revolution, before we observed its the economic impact of those innovations. David (1994) and Freeman and Soete (1997) show that only 5% of factories and 3% of households in the United States introduced electric power in 1889, 8 years after the first power station in New York had been build. And it took another 20 years before 50% of factories introduced electricity. If we parallel our current situation to this historic fact, we may have to wait for a while to enjoy the fruits from IT innovation, although it is not so clear when the current Revolution has started (Figure 2). It can be indeed argued that the time lag will be much shorter, since the speed of innovations in IT is much faster than those in the past

Revolutions[6]. Therefore, we review in detail the discussion of the implications obtained from studies of the past Industrial Revolutions.

### C-2. Some Important Characteristics of Introduction of New Technologies

### C-2-1. Introduction and Propagation of New Technology by Market Mechanism

First of all, I would like to insist that most of the new technologies have been introduced and propagated by the forces of market mechanism. National laboratories and universities indeed played an important role in the development of basic technologies or in the creation of demands related to military power or to the exploration of universe, especially in chemistry in the second Revolution, or in supercomputers and communications this time round. But, at the stage of innovation when such new technologies are being refined for commercial use, the major forces to promote innovations in IT have come from profit-maximizing enterprises with the helps of demands from utility-maximizing consumers. If we focus on the role of market mechanisms, some important characteristics can be pointed out, as below.

Commercialization of research and development (R&D) activities is one of the most important characteristics of the current Revolution. Although, R&D activities already began in the electrical equipment industry and the chemicals industry in the second Revolution, we find such activities in almost all the kinds of industries on much larger scales in the current Revolution (Figure 3). The importance of R&D activities is emphasized by Crafts (1996) and Freeman and Soete (1997), by suggesting that one of the reasons for the differences in GDP growth rates between the first and the second Revolutions lies in the fact that R&D activity was not performed systematically in the First Industrial Revolution. In order to promote costly innovations that have the characteristic of externalities such as non-excludability and non-rivalry, most of our economic societies have a system of intellectual property rights. As Klenow (1996) emphasizes, such a system has also played an important role in accelerating R&D activities. We may understand that while most of the basic research is carried out by national laboratories and universities, most of the innovations are established by

[6] On the other hand, Mokyr (1997) suggests that propagation of computers may be much harder than those of key technologies in the past Revolutions, since computers constitute the only technology in which a human interface is deeply involved.

commercial R&D.

Risk of innovation consists of commercial risk as well as technology risk. Considering that some of technology risks are controlled at the stage of basic research, commercial risk may be most important for each firm in its R&D activities. Some famous stories suggest that controlling commercial risk is sometimes a very hard task for each entrepreneur. Freeman and Soete (1997) reports that the legal section of Bell Laboratories at first declined to file the patent for the Laser, since they could not imagine the usefulness of Laser for communication. Or, according to Rosenberg (1996), at the beginning of the 1950's, an executive of IBM was very bearish in forecasting the sales of computers, since he believed that only a few computers would satisfy the needs from all over the world. Another example by Rosenberg (1996) is that, at the end of 19th century, no one tried to buy the patent for telephones which was on sale for only 100 thousand dollars. Thus, these interesting examples illustrate that the difficulty of controlling commercial risks may delay the realization of the efforts of R&D activities.

Commercial risk is much more difficult to control because of the existence of various kinds of externalities. Here, imperfect competition also performs an important role. With—or even without—a system of intellectual property rights, innovations are advanced by imperfect competition, because each innovation is born in a particular enterprise and is commercialized through the production of heterogeneous goods or services. As a result, strategic actions by respective firm may play an important role in deciding aggregate economic performance. We will show that such intentions by firms under externalities and/or imperfect competition may delay the introduction and propagation of new technology (see section B in the next chapter).

### C-2-2. A System of New Technology

Next point we would like to emphasize is that it is the whole system of new technologies, not a single innovation that has brought about a major impact on macroeconomic performance. For example, in the second Industrial Revolution, the propagation of electric power was not realized by the innovation of the dynamo itself.

As David (1990) shows, by a series of complementary innovations such as the electric light bulb and many kinds of mechanical equipment, electrical technology gradually permeated into factories of every all kinds and households. He also insists that even the structural change of a factory to allow optimal use of electric power should be included as a component of the system of technology[7]. In addition, Freeman and Soete (1997) suggest that the appearance of big and bureaucratic firms with the helps of telephones and steel-made skyscrapers was also an important component of the innovations in the previous Industrial Revolution.

Thus, complementary innovations are of the utmost importance for the propagation of key technologies throughout our economy. Since most of these complementary innovations themselves are pursued by R&D activities of private firms, the time for such necessary innovations may be one of the primary sources of the time lag before we are able to observe the fruits of new technologies. David (1990) and Kitamura (1997) emphasize that, in our current situation, it may be necessary to take into account not only the innovation of the computer itself, but also the reorganization of the company system or the changes in the consumers' life styles.

One more important implication can be drawn from this line of arguments. Even in the course of an Industrial Revolution, the existing system of capital equipment is never replaced all at once by the new ones. Each firm will decide the optimal timing for such replacements by comparing the costs of scrapping the existing equipment and the benefits expected from new technology. Thus, the existence of switching costs may delay the propagation of new technology in some cases. David (1990) emphasizes this effect of switching costs by showing that the industries introducing electricity in the early years of the previous Industrial Revolution were the newly developing industries such as petrochemicals and special steels, which suffered no switching costs at all. As

[7] David (1990) shows the importance of the structural change of a firm. Since a steam engine was very large and expensive, an ordinary firm installed only one engine and used its power for many purposes; the power generated by an engine was transmitted through shafts and belts to all over the factory. In order to ensure for efficient transmission of power, factory was in general built vertically. On the other hand, in an electrified firm, motors were installed for each respective parts of the factory. By this dispersion of power generation, factory with a flat structure was made feasible, which dramatically decreased the cost of construction of a factory.

we see below, in this period when more and more firms are gradually introducing new technology, the trajectory of macroeconomic performance may show some interesting characteristics.

### C-2-3. Changes of Relative Price

The last point that we should note is that economic historians report that economy-wide changes of relative prices occurred in the first two Industrial Revolutions. Such changes of relative prices can be regarded as the inevitable results from of the application of economy of scale in the textiles in the first Industrial Revolution, and steel, chemical, and machinery in the second Industrial Revolution. For example, Freeman and Soete (1997) shows that a dramatic fall in the relative price of steel made it economically feasible to build skyscrapers and large network of railroads, and to make automobiles (Figure 4). As for our current Innovation, Sichel (1997) shows the price of computer services has been falling at a rate of 7% annually after adjusting for quality changes, and emphasizes that this rapid change in relative price is almost comparable to those of telephones and railways in the years of their rapid propagation as shown by Gordon (1990)(Figure 5).

A change of relative price brings about substitution of demands by consumers and firms. By these effects, marginal productivity or the profit rate of a supplier firm will be changed, which may result in the reallocation of productive resources. We, however, need to spend time and cost for this reallocation of productive resources. As we have already discussed, re-training labor and scrapping existing capital equipment will burden us with such costs. Or you may recall the discussions of "irreversibility of investments" by V. Ramey and A. Abel[8]. We may regard that these time and costs are the alternative sources of the time lag already discussed.

Another implication of the changes in relative prices is that the IT paradox may be more serious than it appears. Greenwood, Hercowitz, and Kursell (1997) empirically show that the price of capital equipment has fallen at an average rate of 3% per year from

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[8] For example, Ramey and Shapiro (1997) simulate the development of the macroeconomy in the period of reallocation of capital caused by a demand shock under the assumption of irreversibility of investment.

1954 to 1990. This finding indicates that we may have been undervaluing the growth rate of capital inputs in calculating TFP, with the result that the growth rate of TFP has been overestimated.

# III. The Introduction on New Technology and Its Impact on the Economy

Since we have reviewed the implications of two mutually complementary hypotheses, we can now proceed to discuss the mechanisms and impacts of the IT innovations of IT with existing theoretical models and empirical results.

## A. The Impacts of New Technology

As a start of the discussion in this chapter, we review the effects of innovation in IT under within the standard framework of economics. A firm introducing new technology in IT seeks to improve efficiency in production, for example by decreasing its cost of production and rendering its decision making more efficient. If these results are actually realized, the relative price of its goods or services may fall, and their quality of them may be improved. In addition, new goods and services may be developed with the new technology. Firms other than those introducing new technology may also be benefited from such improvements, since they use the innovated new products as capital equipment or intermediate inputs. In addition, the effects of network externalities and increasing returns to scale can also be expected. As a result of all the effects above, the aggregate supply curve will shift to the right. At the same time, the aggregate demand curve will shift to the right, reflecting increased demands for goods and services in IT from more and more firms and households. Thus we have economic growth without accelerating inflation by extending the production activities of IT industries. In such an expansion of the economy, we will gain in efficiency of resource allocation and accumulation of human capital at the macroeconomic level.

We may need to check the effects of externalities of technologies. In the literature of New Growth Theory, Romer (1988) and Barro (1990), for example, present growth models with externalities of government expenditure[9]. In fact, Muniagurria (1995) shows growth models with three kinds of productive resources (capital, human capital, and technology), and shows the possibility of increasing returns to scale at the macroeconomic level by assuming no depreciation of technology.

If increasing returns to scale exists, we will have some special characteristics such as a discrepancy of economic growth rates, as Fukuda (1997) shows. We, however, should note that recent empirical results on macroeconomic level are mixed[10]. Some academic economists in the Real Business Cycle school, including Hall (1988) and Cabarello and Lyons (1992), suggest that we have increasing returns to scale at the macroeconomic level. On the other hand, a series of analyses of Aiyagari (1994), Burnside (1996), and Basu and Fernald (1997a), (1997b) deny such results by taking into consideration of the effects of imperfect competition, the actual utilization rate, and the accurate valuation of intermediate inputs. These results themselves may not be relevant here, since most of them use the same data set by D. Jorgenson which covers the period up until the middle of the 1980's. In spite of this obsoleteness, this line of arguments has some important implications here. First, in order to estimate macroeconomic performance, it is necessary to measure accurately the value of intermediate inputs as well as that of capital equipment. If there are measurement errors for intermediate inputs, we may fail to judge whether our economy shows increasing returns to scale or not. Second, according to the results by the opponents of the increasing returns to scale, we may have even overestimated TFP in these years. Although their analyses say little about the growth rate of TFP, this may further deepen the IT paradox[11].

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[9] A simplest way to apply their model to our discussion on the effects of new technology is to regard "G" (infrastructure built by government expenditure) as new technologies.

[10] At the microeconomic level as well, empirical results are mixed. Some studies including Morrison (1997) suggest the existence of increasing return to scale at a firm level. On the other hand, most of the arguments of the Real Business Cycle school are based on the assumption of decreasing returns to scale at a the firm level.

[11] We should note that whether we should use gross product or value added for calculating TFP remains a difficult question to answer. For example, if we consider this question in relation to measurement errors of in economic statistics, both alternatives have problems of quality adjustments; as for gross product, we may have the problem for of aggregation; as for value added, we may have the problem for of capital and labor inputs.

The situation is much the same for externalities. At the microeconomic level, we have some evidence of the effects of externalities from IT, for example see Greenstein, Lizardo, and Spiller (1997). But at the macroeconomic level, we have few empirical results in spite of the rich accumulation of theoretical models. One of the reasons may be difficulty in identifying the ways of propagation of new technology itself. Some academic economists have begun to tackle this hard problem by analyzing huge amounts of information on patent registration and citation in the United States. By their results, we have some interesting insights in this area. Eaton and Kortum (1996) show that the effects of the international transfer of technology by patent citation are enhanced by the level of human capital accumulation in the host country. Jaffe and Trajtenberg (1996) also suggest that patents registered by corporate firms are more frequently cited than those registered by national laboratories and universities. However, as Griliches (1994) warns, before we can discuss the mechanism of propagation of technology by using these results, we should be clear about the relation between contents of a patent and their its fruits, and the stability of this relationship. As for the studies using patent information, we may be in at the stage of accumulating empirical results to form some stylized facts[12].

## B. The adjustment Costs of Introduction of New Technology

Although new technology may improve our economic performance through various mechanisms, it may not be easy for us to see such results in so short a time. As lessons from the past Industrial Revolutions suggest, various kinds of adjustment costs may play roles in delaying the propagation of new technology. In this section, we discuss the effects of such adjustment costs by using existing theoretical models and empirical results.

### B-1. Adjustment Costs on at the Microeconomic Level

In a market economy, for each firm, it is uncertain about the aggregate results of

[12] Cabarello and Jaffe (1993) also report that the number of patent registrations per the cost of R&D activities has been decreasing in the United States. Although it this is a very interesting finding indeed, we should check the relationship between the contents of a patent and their its fruits before we can conclude that the productivity of R&D activity has been decreasing.

introducing new technology, because the result itself will be the collection of decision making by each firm. In addition, the standard of technologies may be changed more frequently because of the increasing productivity of R&D activities, as it is clear from the recent developments of the operation system of PC. In this situation, the switching cost is a very important factor for each firm to take into account when deciding the optimal timing of converting technologies. Bresnahan and Greenstein (1996) illustrate the contents of switching costs for converting computer systems in a firm; not only the cost of replacement of hardware, but also the costs for of developing new software, re-training staff in the information system department, and changing the ways of using computers at the end-user level.

When a switching cost exists, we have the lock-in effect of so called defacto-standard, as Farrel and Saloner (1986), or Klemperer (1987a), (1987b) show. Moreover, Farrel and Shapiro (1988) insist that such effects may be strengthened when suppliers are able to control the value of switching costs. However, we should not be in a hurry to judge that the switching cost will always prevent the introduction of new technology. For example, Stein (1997) discusses the effects of switching costs in the framework of "Creative Destruction". "Creative Destruction" was the idea first shown by J.Schumpeter; it refers to the phenomenon in which the endogenous introduction of new goods and services or new ways of production incessantly destroys the old ones. He assumes that the switching cost for buyers is increasing in time by learning-by-doing, and that innovations outside the market benefit potential suppliers. Under such assumptions, the longer the incumbent supplier dominates this market, the more probably it will continue to dominate it; on the other hand, once a new entry has occurred, the more frequently such a conversion will occur again[13][14].

By focusing on the idea that systems of technologies have played a major role in the previous Industrial Revolutions, we can present some new implications as well. In the

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[13] Aghion and Howitt (1992) insist, however, the possibility that the acceleration of innovation may harm the incentives for R&D. The reason is that a potential entrant may expect that he will not be able to dominate the market for a long period due to the acceleration of innovation itself.

[14] Concerning the cleansing effect which has been also discussed in the literature of creative destruction, some empirical studies deny its existence. See, for example Cabarello and Hammour (1994).

current Industrial Revolution, we have the system of computers and communication networks. Milgrom and Roberts (1990) illustrate that, by connecting computers via communication networks, a firm can improve its efficiency in production with the integration of CAD and FMS, or in its white-collar office with computerized control of its inventories and funds. Since we can observe a dramatic increase in investment in communication in recent years (Figure 6), these effects will bring about a big impact on business activities as a whole.

As is clear from the above discussion, network externality plays a major role in the current Industrial Revolution. Network externalities, as first discussed by M.Katz ,C.Shapiro, and S.Berg, is the externalities by which each buyer or user will be benefited from the increase in their number. This line of arguments is, of course, applicable to the analysis of actions of firms, by focusing on their demand of for goods and services in the form of capital equipment and intermediate inputs. Then, the effect of externalities may then be regarded as the increase in marginal productivity of such inputs. We can definitely say that the effects of network externalities are positive for economic performance, if the full compatibility is satisfied with all the users of the system. In the example of given by Milgrom and Roberts (1990), a firm will benefit, if more retailers or banks are connected to such a network.

However, if we start from more realistic situation where there is no unification of such networks, we may have some difficulties in reaching optimality. For example, as Katz and Shapiro (1985) and Matutes and Regibeau (1988) show, if there are costs for each firm to adjust its product to make it compatible, a firm may not choose to supply compatible products, since the benefit of increased demand may leak to other firms just because of network externality itself. In such a situation, a firm will deliberately supply a product which is incompatible with the standard product. In addition, in a period of rapid innovation, it may be quite hard for a firm to make a correct forecast of what kind of specification will be the standard in the future. Thus, network externality may delay the propagation of new technology in some cases.

**B-2. Adjustment Costs on at the Macroeconomic Level**

We now turn to the effects of adjustment costs at the macroeconomic level. First, we will discuss the aggregate effect of adjustment costs at the microeconomic level. In the current Industrial Revolution, the production or customization of computer software, and the education of staff in information systems departments may be major sources of microeconomic level adjustment costs, as Bresnahan and Greenstein (1996) insist. From the macroeconomic point of view, these kinds of costs can be regarded as costs of developing complementary inputs for new technology. Based on this idea, Helpman and Trajtenberg (1994) and (1996) show the general equilibrium model with R&D activities and imperfect competition in the markets of intermediate inputs. Their model shows very interesting characteristics in the trajectory between equilibria; we have to wait before accelerating in the growth of production, since, at the first stage of innovation (they name it “time to sow”), a larger proportion of productive resources must be devoted to R&D activities. In fact, the model suggests that there is a possibility of economic downturn during this trajectory. On the other hand, the fruits of this innovation will be realized and the growth rate will be accelerated in the second stage. For our discussion of price mechanism in the following chapter, we should note that the relative price of labor and capital and also the relative wages of skilled and unskilled labor play important roles in the reallocation of such productive resources.

Another source of adjustment cost at the macroeconomic level is the cost of reallocation of productive resources. A firm that introduces new technology improves efficiency in production. As a result, compensation to productive resources employed by the firm will be improved by increasing marginal productivity. In a neoclassical general equilibrium model, capital and labor will move from other firms seeking for these excess returns, and in the end, we are at another equilibrium with no excess returns. However, in reality, a cost has to be paid to reallocate productive resources since they were originally specified to comply with a certain method of production. In the literature of “Irreversibility of Investment”, Abel and Eberly (1995), (1996) illustrates the effects of the cost of reallocation of capital equipment. Their main result is that even if there is an excess return of investment in some industry, it may persist for some time, since it may be optimal for some investors to do nothing because of the existence of such costs. Aghion and Howitt (1992) and Cabarello and Hammour (1994) also show that the costs of reallocation may enhance the effects of “Creative Destruction” which we saw above.

Human capital is of course another important source of productive resources. We will review the impacts of IT on the compensation to human capital, before we proceed to consider the effects of the costs of reallocation. A representative analysis is done in Kruegar (1993). He insists that the wage premium of computer users is about 10% of the average wage. However, a series of analyses by Goldin and Katz (1996), Entorf and Guellec (1997) and DiNardo and Pischke (1997) point out that there might be an error in the regression specification; Kruegar's result only shows that most of computer users are high ranking officers in their firms[15]. On the other hand, Kremer and Maskin (1996) and Agenor and Aizenman (1997) empirically find that the wage premium of skilled labor in more articulate models[16][17]. We also have a positive correlation between IT investment and average level of skill in labor, which is shown by Wolff (1996), Doms (1997), and Motohashi (1996) in most of developed countries. Therefore, we may conclude that IT investment is one of the sources of the wage premium of skilled labor via the increasing demand for skilled labor, as Lichtemberg (1993) suggests.

If such a premium exists, skilled labor moves to firms and industries where it will be better compensated. We may discuss the effects of the costs of reallocation by applying the above-mentioned "irreversibility of investment" models we see above. In a labor market, however, people react "endogenously" to such a change in relative wages. They decide how much to invest in training for a required skill by comparing its costs and benefits. Such effects of human capital investments can be analyzed by using the two-sector growth models by of H. Uzawa or R. Lucas. Alternatively, using the more simple models by of Grossman and Helpman (1991, ch3) or Cabarello and Hammour (1994) with a Leontief production function, we can show that if the cost of moving capital or skills re-training increases, the effect of IT investments decreases,

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[15] For example, DiNardo and Pischke (1997) report that they found the wage premium of telephone users as 9-14% of the average wage under the same framework as Kruegar (1993).

[16] Agnor and Aizenmann (1997) point out that, other than skill-biased innovation, the reasons for such a discrepancy in relative wages are the existence of an efficient wage for skilled labor, and downward pressure on the wage of unskilled labor due to increased competition in unskilled -labor-intensive industries.

[17] It should be noted that the "skills" are rather well defined in the United States in the data by the Department of Labor or the Census Bureau.

since the supply of skilled labor decreases.

## C. Information as an Input for to Production

Information itself plays two different major roles in IT innovation. The first role is what was shown above; information as technology alone or as embodied in some kinds of capital equipment or intermediate inputs. The second role is as the object of investment or consumption. For example, a firm buys the market research data for more efficient marketing. People also consume such the kinds of information presented by Internet or Satellite Communication. In the last part of this chapter, we will briefly discuss the implications of the second role.

Almost any all kinds of information have in common the characteristics of externalities such as non-excludability and non-rivalry. Standard microeconomics suggests that there may be excess demand in such a market because suppliers are not optimally compensated because of the existence of externalities. Innovations in IT may make the situations better, since it may make it feasible for suppliers to exclude free-riders or to collect its fee at lower costs. In addition, there may be even an excess supply of information, since the costs of delivery and storage of information have rapidly been decreased. We may also suspect that increasing returns to scale operate in the information delivery industries such as market research.

In addition to these stereo-typed arguments, we would like to discuss whether the innovations of IT affect the asymmetry of information[18], or the formation of expectations of future events, because this question has very important implication for financial markets where market participants consume the second type of information when deciding their transactions. With the introduction of IT, it is much easier and cheaper to collect information on the developments of markets, for example the data of historical price. It is unclear, on the other hand, whether the innovations in IT make them it easier to access or produce information on concerning the credit risks of other

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[18] It should be noted that the asymmetry of information is a relevant concept only in the situation where one has correct information but the other does not. It may be also important for us to consider the situation in which all the agents do not have correct information.

participants. Even when they have the same contents of information, we have little idea whether they form the same expectations or not. Considering the importance of this area of discussion, we hope to have that there will be future developments in both theoretical and empirical studies.

## IV. Impacts The impact of IT on the Price Mechanism and Implications for Monetary Policy

In this last chapter, we will discuss the implications of innovation in IT for monetary policy. As we saw above, innovations in IT may have many and various effects on our economy; therefore we should check whether such effects will change the optimal way of conducting monetary policy. Because we do not yet have so far a literature on such a specific line of arguments, our analysis here will be a patch-working of various theoretical models. We, however, hope that this will be a starting point for future discussions by those who have interests in this area.

Our strategy here is focusing on the price mechanism. As we discussed in preceding chapters, innovations in IT will affect prices in various ways. Because of differences in marginal productivities in between firms, and the effects of quality changes and substitution, the relative prices of productive resources, goods and services are changed, which are related to TFP growth. These changes of relative prices should be regarded as desirable, since they play the role of guideposts to enable firms and households to make optimal decisions. Under the standard framework of the Phillips Curve or NAIRU, effects of the innovations in IT can be regarded as "Supply Shock" which will bring about a fall in the general price level or inflation rate and a rise in GDP growth.

These developments of the price mechanism have several very important implications for conducting monetary policy. As we have seen in the second chapter, mismeasurement of the price index related to innovations in IT is detected almost everywhere. One of the most serious effects on monetary policy is the possibility of damaging credibility in central banks. As for "Supply Shocks", standard discussion will guide us to the conclusion that we need not make any accommodation at all. It might be necessary for us, however, to re-examine the optimal way of conducting of monetary policy, if the changes in relative prices have a simultaneous influence on the general price level. This is because, if there exists uncertainty in regarding the general price level, we may also lose efficiency, since we can not accurately observe the changes in relative prices. Or, if there exists nominal rigidities in some part of our economy, even a perfectly foreseen fluctuations in the general price level will make our economy deviate from optimality. We will discuss these issues in the following sessions in order.

## A. Mismeasurement of Price Index and Monetary Policy

Concerning the way in which we conduct our monetary policy, confidence has been the key concept after the seminal work by Kydland and Prescott (1977). In order for efficiency of our economy, they argue that it is utmost important for central banks to enhance confidence in monetary policy, since doing so will stabilize the expectations of inflation on the part of investors and consumers. Targeting policy has been suggested as one of the practical ways to enhance such credibility. J. Taylor emphasizes that such targeting policy is definitely different from policy rules in the sense that targeting should be regarded as a system of policy or a policy commitment. More concretely, while it is sought strictly for the achievement of target of money supply targets alone under a rule of money supply, we do not in principle have any operational target or medium target under a system of targeting policy. There are two lines of opinions as to which economic indicator should be better as a target. For example, Mishkin (1997) supports inflation targeting since the price index is better in accuracy and frequency. He also suggests that it may be easier for us to reach a consensus on the target rate. On the other hand, Taylor (1985) and Hall and Mankiw (1997), for example, support nominal GDP targeting since inflation targeting may have the a “deflationary” bias. They also insist that we can automatically accommodate to “Supply Shocks” under nominal GDP targeting.

Before we can judge which target is better suited to conditions of innovations in IT, we should, of course, take into consideration of mismeasurement of the price index. If such mismeasument exists, inflation targeting policy may not be feasible, since it may be difficult for both the central bank and private agents to judge whether such target is being successfully achieved. Also, as with nominal GDP targeting, it may be difficult to set the optimal level of such a target, since we may not be able to review accurately the performance of inflation and real GDP.

For the purpose of this argument, we need to examine the characteristics of measurement errors caused by innovations in IT. For example, even if such measurement error exists, when the value of such error is stationary in a time series, it may not cause us so much trouble to us. The reason is that both central bankers and private agents can estimate the true rate of inflation by taking into consideration of the average rate of errors. We should note, however, that such stationary errors may bring us troubles when such average errors are large, since we have to set a wide target range. Alternatively, we may have a time lag before we have an accurate estimate of such errors. Both of these possibilities may damage confidence in a targeting policy. But, it is when such errors are non-stationary in a time series that we have much more serious problems. With the errors of such characteristics, it may be almost impossible for us even to estimate the inflation rate, or, needless to say, to judge whether or not the target has been achieved.

Although examining the characteristics of measurement errors of a price index is very important task for us, we have very few theoretical or empirical studies on of this issue. The reason is, of course, that we can not directly observe such errors from economic statistics. From the analysis of the effects of the hedonic approach by Shiratsuka (1995) and a lot of empirical studies on quality adjustment quoted by Boskin (1996), we may at least suppose that measurement errors by resulting from quality changes and substitution effects are volatile in a time series. Although Gordon (1992) shows that such this kind of error may disappear at the times of revision of price index, we might say that 5 or 10 years are relatively long lags for us when considering price changes caused by rapid innovation in IT. Thus, we have found another serious problem of mismeasurement of price indexes. When we take into consideration the fact that measurement errors of price indexes themselves are difficult to reduce, it may be feasible to change the method of constructing inflation indexes for the purpose of conducting efficient monetary policy.

## B. Supply Shocks and Monetary Policy

### B-1. Phillips Curve/NAIRU

It may be accepted that the most standard framework for discussing the effects of innovation on macroeconomy is the Phillips Curve or NAIRU. Under such a framework, the effects of innovation in IT can be regarded as "Supply Shocks", which bring about a higher growth rate of GDP and a lower rate of unemployment without raising the rate of inflation. We can regard this change as the curve will shift to the left in the Phillips Curve, or a fall of NAIRU in some cases.

Recent macroeconomic situation of the United States at least coincides a with the result of the above story. Stiglitz (1997), Gordon (1997), and Lorn and Rich (1997) emphasize that NAIRU in the United States has fallen greatly from a rate of about 7% level in the 1980's to the current moderate rate of 5% middle level (Figure 7)[19]. Concerning the case of Japan, many academic economists are negative even to its existence itself[20]. The reason is argued to be that the expected rate of inflation has been insensitive to changes in the actual rate of inflation, and thus the acceleration of inflation has not occurred since the oil price shock of 1973.

With regard to the reason for the fall in NAIRU in the United States, Stiglitz and Gordon point out the possibility that improvements in productivity brought about by innovations in IT acted as "Supply Shocks", in addition to thinner mark-up due to global competition in major products, and the higher elasticity of labor supply. As for labor markets, if such innovations in IT bring about excess demand for skilled labor, this may cause an upward pressure on NAIRU, as Blanchard and Katz (1997) suggest. We have, however, a counter-evidence in the empirical study by Tootel (1994), which shows that there are scarcely any segments of the labor market in which such a mis-match of skilled labor is serious.

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[19] At the same time, we should note that some academic economists including Chang (1997) deny the usefulness of NAIRU, since the macroeconomic structure behind underlying NAIRU should be always changing depending on the kinds of shocks to which affect our economy.

[20] On the other hand, there exist some empirical studies showing that NAIRU has gone up in the 1990's in Japan. For example see Nishizaki (1997)

Thus, if we discuss the effects of innovations in IT under the framework of the Phillips Curve or NAIRU, we are lead to conclude that such supply shocks should be regarded as a desirable change, and that monetary policy should not accommodate them at all. We, however, should be careful about the possibilities of incurring the costs of falling prices of some goods and services. This line of arguments might be relevant to Japan where we actually observe near-zero inflation. In the following sections, we will review the discussions concerning the relationship between relative price and general price level, and costs of falling prices. We will then re-examine the appropriateness of the "Supply Shocks" story above.

**B-2. Relative Prices and the General Price Level**

In the first half of this paper, we have seen the evidence for and the mechanisms by which the relative prices of goods and services related to innovations in IT have been decreased (see for example (Figure 5)). Although it may sound natural to consider that this fall in relative prices have bears some relationship to the general price level, it appears that academic economists have not reached a conclusion on what kinds of influences relative prices and the general price level have upon each other. Nor do we understand which direction of causality exists.

Some of the empirical studies, for example, one of the earliest ones by Vinning and Elwertowski (1976), and afterwards by Parks (1978), Domberger (1987), and Ball and Mankiw (1992), report that they found a positive correlation between them. Moreover, Taylor (1981) and Hess and Morris (1996) show that such a positive correlation was identified in many of OECD countries in which inflation rates were higher (Figure 8). As for the reasons for this positive correlation, we have a variety of hypotheses, most of which we see in the list by Fischer (1981) (Figure 9). For example, Mussa (1977) and Ball and Mankiw (1992) emphasize a combination of "menu cost" and distortion of distribution of shocks. Taylor (1981) and Plosser (1997) suggest that the endogenous action of monetary policy in the face of relative price change is the reason for changes in general price level. According to this hypothesis, even when relative price change itself has nothing to do with general price level, genaral price level is changed by monetary policy. Domberger (1987) and Debelle and Lamont (1997) are negative towards macroeconomic reasons because they observe such a positive correlation even in their cross cross-sectional settings. Because we have not reached a conclusion on the reason for such a positive correlation, we, of course, are not able to say anything on the direction of causality. We should also note that some empirical results suggest that this correlation is weaker when the rate of inflation is very low. We can observe this characteristic in Japan (Figure 10).

Even in such an ambiguous situation, we have at least one important implication for our discussion here. That is to say, we might at least imagine the possibility that downward forces are working simultaneously on the general price level, since we have some evidences of falling relative prices of goods and services in IT. Although this possibility may be a "big if", we may suppose that it deserves careful consideration, since a falling general price level has some important effects, as is shown in the following sections.

**B-3. The Cost of Falling Price-Noise to in respect of the Observation of Relative Prices**

In order to examine the costs of falling prices, it may be useful to start by reversing the arguments concerning rising prices. Shoe-leather cost will be benefits in a situation of falling prices. In addition, Aiyagari (1990) and Wolman (1997) point out that this kind of cost will be negligible in the near future, since the means of transaction will be interest-bearing. Distortionary effects from a nominally fixed tax will also benefit tax payers. Then, the rest of the arguments consists of a problem concerning the informational function of a price. In other words, when the rate of change in the general price level becomes volatile, it becomes quite difficult to observe relative price changes accurately, and thus difficult for economic agents to make optimal decisions. In such a situation, it is also difficult to allocate intertemporally investment and consumption, since it is difficult for firms and households to observe intertemporal relative prices (or the real discount rate), as Fischer (1993) shows. Although this line of argument generally refers to the a period of high inflation, the argument may be also true when inflation is low or during a period of deflation; as Hess and Morris (1996) show, if the linear relationship between volatility and the level of inflation rate is true, the ratio of the volatility to the level is constant regardless of the rate of inflation.

As for the relationship between innovations in IT and noise to observation of relative prices, we are able to present two important points. First, innovations in IT have comprise several opposing forces. It is often argued that such innovations in IT make it easier for us to collect information on prices in general. On the other hand, it is quite difficult to measure prices accurately because of the mismeasurement of prices or price indexes[21]. If imperfect competition is one of the characteristics of the market in conditions of innovation, we may doubt that whether fluctuations in mark-up ratios constitute another source of this noise[22].

Second, it is important to note that the direction of causality is opposite between the argument concerning the cost of fluctuations in the general price level and the argument concerning price changes resulting from innovations in IT. In the argument of the cost of fluctuation in general price level, we might implicitly assume the story that the accurate observation of changes of in relative prices is prevented by exogenous changes of in the general price level. On the other hand, in the argument concerning innovations in IT, by assuming that changes in the general price level occur simultaneously with changes in relative prices related to such innovations, changes in the general price level are in turn thought to prevent us from accurately observing relative price changes. Although our latter argument appears to be contradictory, it may be worth examining if we add one more assumption that each firm or household is not able to observe relative price changes other than in the case of a few products that are familiar to it.

### B-4. The Cost of Falling Prices—Nominal Rigidity

Thus, we have examined the reversed arguments concerning the costs of inflation. We have, however, another important argument which has no counterpart in the argument of inflation. That is the cost of nominal rigidity. A recent study by Blinder (1997) shows the evidences of nominal rigidities, and insists that the effects depend on factors such as coordination failures, imperfect competition, and implicit contracts. With

[21] In such a situation, suppliers may not want to change their prices frequently, because the benefits of price changes as well are ambiguous for them also.

[22] Baba (1997) shows that, when the fluctuation in mark-up is considered, the cost of inflation in Japan is increased by nearly 1% of GDP in the years from 1974 to 92.

nominal rigidities in some prices, needless to refer to Aiyagari (1990) or Bernanke and Mishkin (1996), a fall of in the general price level causes a substantial cost to our economy because of the inefficiency of allocation of resources. For example, Akerlof, Dickens and Perry (1996) show, by their simulation model assuming rigidity in nominal wages, that the unemployment rate will be increased by 2.6% when the inflation rate goes down from 3% to 0% from 3% level. Moreover, Fuhrer (1994) and Freedman and Kuttner (1996) suggest that we should be very careful about the cost of disinflation when nominal rigidities exist in some prices.

As a matter of course, it should be noted that some academic economists present the arguments against the existence of nominal rigidity. For example, in the comment for Akerlof, Dickens, and Perry (1996), R. Gordon insists that the "Lucas Critique" is valid for their result; he argues that their empirical result of nominal rigidity only shows that a fall in nominal wages has been rare in the years of relatively high inflation. G. Mankiw also suggests that workers may accept a fall in nominal wages during a period of lower inflation. As for Japan, most of the empirical studies including Sachs (1979) and Gordon (1982) suggest that nominal wages have been more flexible than in other industrialized countries. Ueda and Kimura (1997) empirically analyze the mechanism of such flexibility by decomposing the wage into its component parts; they show that total compensation is very flexible since it is adjusted by overtime compensation and bonuses[23].

Thus, the existence of nominal rigidity is still ambiguous, especially in a period of low inflation. At this moment, all we can point out is the possibility that, if general price level falls due to the decrease in the prices of services related to computers and communications, <u>and if</u> nominal rigidity exists in some areas, such as in the wages of unskilled labor, we may incur a substantial cost to our economy.

At the end of the series of sections above, we may summarize two hypotheses discussed herein. In general, if macroeconomic changes by resulting from innovations in IT can

[23] At the same time, they show hourly wage is less flexible. Based on these results, if overtime compensation and bonuses reaches zero due to a long -lasting depression, employment may be more flexible.

be regarded as "Supply Shocks" in a framework of Phillips Curve or NAIRU, it may be optimal for monetary policy not to accommodate such shocks. On the other hand, if the changes in relative prices resulting from innovations in IT exhibit a correlation with the general price level, and if there exists a volatile general price level or nominal rigidities, a fall in the general price level may incur a substantial cost to our economy because of the inefficiencies in allocation[24]. In such a situation, accommodation by monetary policy might be better in the sense of optimality[25]. Thus, it should be our future task to examine empirically and explain theoretically the existence of pressures of induced by relative price changes, and the conditions about the optimality of monetary policy under volatile inflation and/or nominal rigidity.

## V. End Notes

We have tried to present the most comprehensive list of issues for discussion at the eighth International Conference. Our final and most important goal is discussing and understanding the optimal ways of conducting monetary policy under the changing economic performance due to innovation in IT. Although the effects of the innovation can be regarded as favorable "Supply Shocks", we should also note the following possibilities which might be brought about by the innovation itself. First, the measurement error of economic statistics may incur some damages on the credibility of monetary policy, because such errors may make accurate observation of economic performance quite difficult. Second, a fall of general price level may cause a loss of efficiency, if there exists some correlation between relative price and general price level, <u>and if</u> there exists nominal rigidity.

As it is clear from the discussion in this paper, our existing theoretical models and empirical studies have interesting implications but only a limited coverage at all. In order for understanding our changing economy and maintaining its efficiency, we should tackle the tasks of further investigations one by one.

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[24] We may add another source from the "Fisher Relation". If the expected rate of inflation falls to a very low level , monetary policy may not be able to stimulate the economy. The reason is that the real interest rate can not be able to set low enough, even if the central bank sets the nominal interest rate as zero.

[25] In discussing the optimality of monetary policy, of course, we should also take into consideration of the effects of the changes in expected rate of inflation.

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(Figure 1) Total Factor Productivity in selected countries in OECD

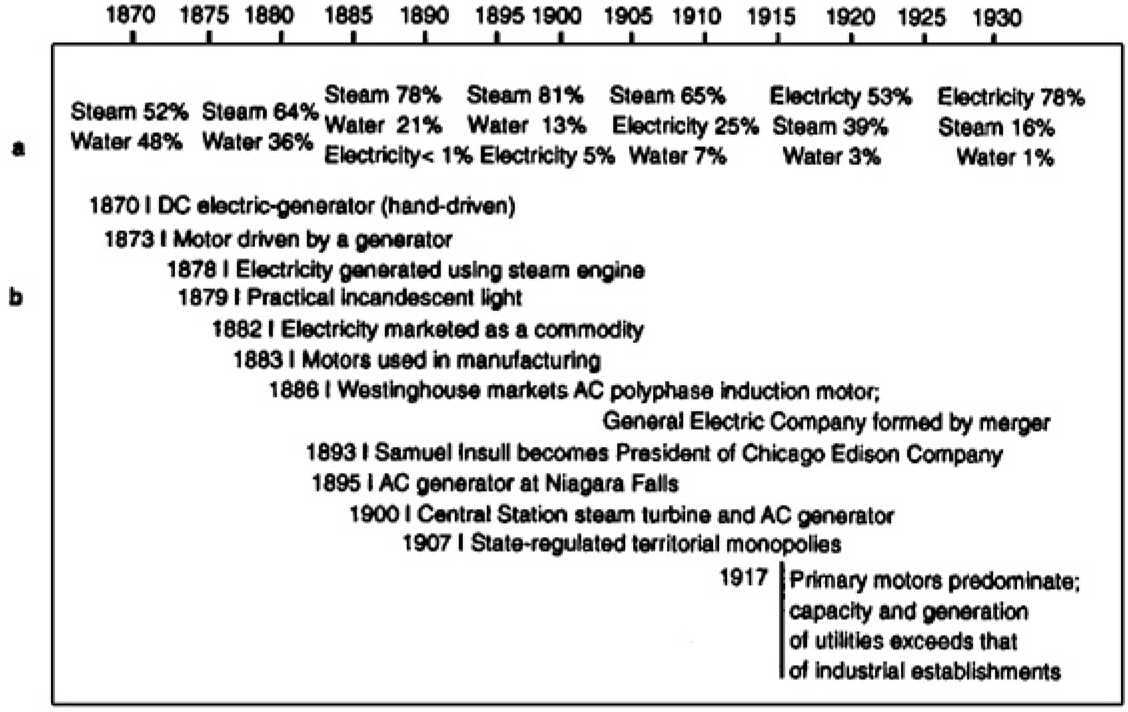
(Summary from Diewert and Fox (1997))

(Average Annual Growth Rate)

| Year/Country | USA | JPN | CAN | CHE | DEU | FRA | GBR |
|---|---|---|---|---|---|---|---|
| 1961-65 | 2.25% | 6.21% | 2.56% | 2.72% | 3.21% | 3.64% | 1.85% |
| 1966-70 | 1.01% | 6.85% | 1.85% | 2.64% | 2.67% | 3.26% | 3.00% |
| 1971-75 | 0.50% | 2.05% | 1.59% | 0.30% | 2.48% | 2.39% | 2.02% |
| 1976-80 | 0.41% | 1.11% | 0.76% | 1.32% | 1.56% | 2.19% | 0.90% |
| 1981-85 | 0.62% | 1.53% | 1.18% | 0.41% | 1.38% | 1.91% | 1.75% |
| 1986-90 | 0.52% | 2.11% | 0.15% | 1.91% | 2.10% | 1.46% | 1.06% |
| 1991-92 | 0.56% | 1.54% | -0.29% | 0.25% | 2.11% | -0.02% | 0.58% |

CAN:Canada, CHE:Switzerland, DEU:West Germany, GBR:Great Britain

(Figure 2) Major Developments and Share of Electricity (Summary from Devine(1983))




*a* Share of power for mechanical drive provided by steam, water and electricity
*b* Key technical and entrepreneurial developments

(Figure 3) Major Innovations in Semiconductor (Summary from Dosi(1981))

| <Innovations> | <Firm> | <Year> |
|---|---|---|
| Single Crystal Growing | Western Electric | 1950 |
| Integrated Circuit (IC) | Signetics | 1962 |
| Light Emitting Diodes | Texus Instruments | 1964 |
| Beam Lead | Western Electric | 1964 |
| CCD | Fairchild | 1969 |
| SRAM | Intel | 1969 |
| DRAM | Intel | 1971 |
| Microprocessor | Intel | 1972 |

(Figure 4) Relative Price of Steel Rail in the United States (Freeman and Soete(1997))

| *Year* | *Steel rails* *$ per ton* | *Consumer price index* |
|---|---|---|
| 1870 | 107 | 38 |
| 1875 | 69 | 33 |
| 1880 | 68 | 29 |
| 1885 | 29 | 27 |
| 1890 | 32 | 27 |
| 1893 | 28 | 27 |
| 1895 | 24 | 25 |
| 1898 | 18 | 25 |
| 1910 | 28 | 28 |
| 1920 | 54 | 60 |
| 1930 | 43 | 50 |

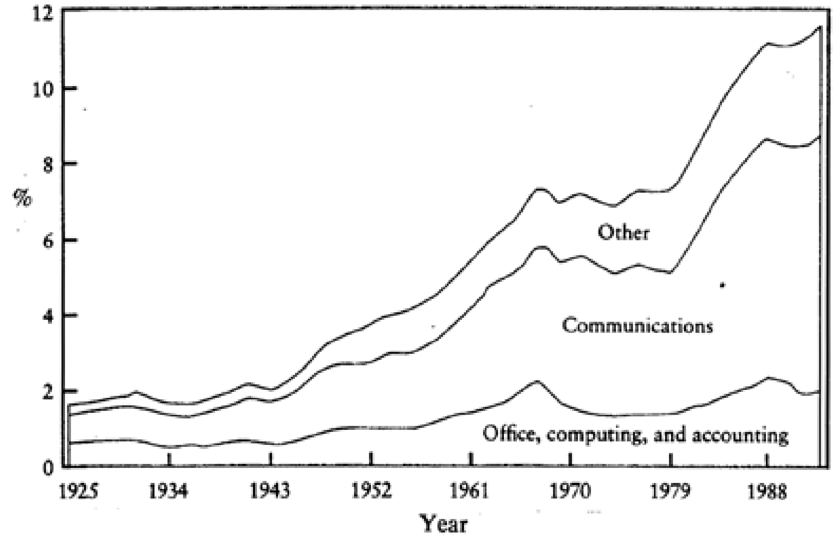
（Figure 5） Prices of Computer Service, Telephone, and Transportation （Sichel(1997)）

| *Item* | *Period of coverage* | *Observed price change (percent, annual rate)* | *GDP or GNP deflator (percent, annual rate)* | *Real price change (percent, annual rate)* |
|---|---|---|---|---|
| Computing services | 1987–1993 | −4.4 | 3.5 | −7.9 |
| Electricity | 1899–1948 | −4.5 | 2.5 | −7.0 |
| Rail transit | 1850–1890 | −2.7 | 0.0 | −2.7 |
| Airline transit | 1935–1948 | 0.2 | 5.0 | −4.8 |

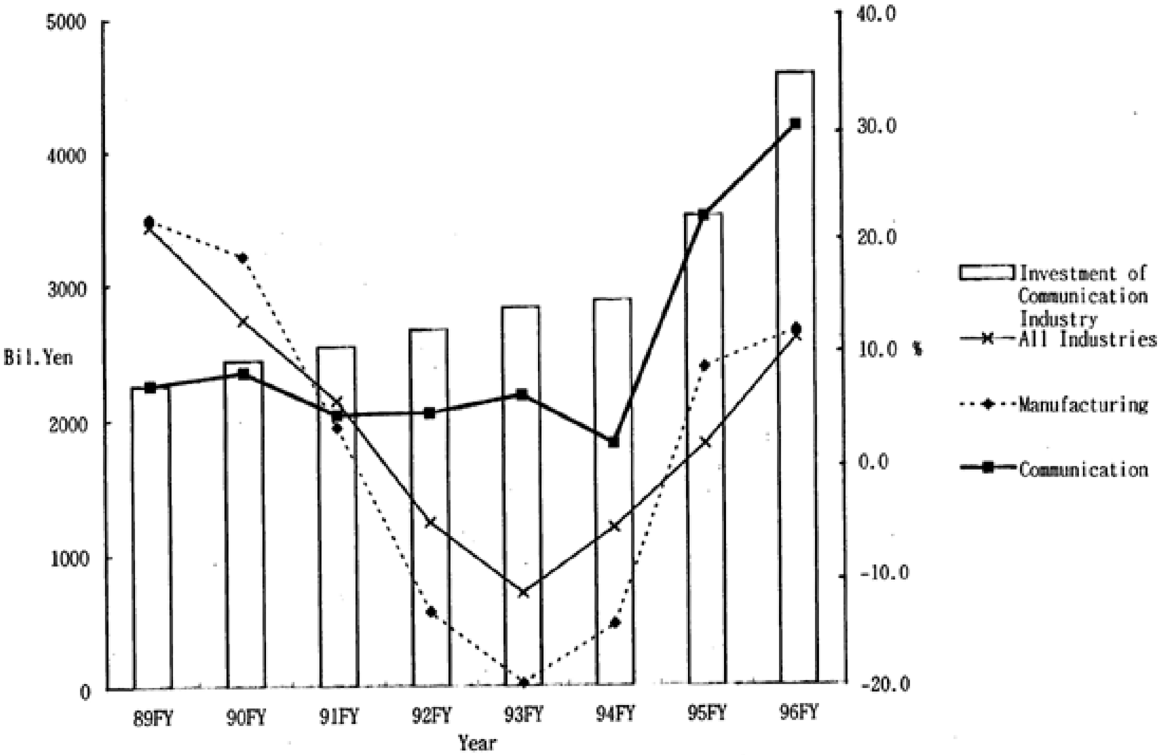
Source: Computing services prices from table 3-4. Electricity prices from Gordon (1992). Airline transit prices from Gordon (1991). Rail transit prices from Fishlow (1966, p. 585); the figures in the table aggregate Fishlow's prices for freight and passenger rates using a Tornquist index. Real price changes equal nominal price changes less change in GNP or GDP deflator. For 1850–1890, the GNP price deflator is from Gallman (1966). For 1899–1929, the GNP price deflator is from Balke and Gordon (1989), and for 1929–1993, the GDP price deflator is from U.S. Department of Commerce (1992) and *Survey of Current Business*.

(Figure 6) Investments in Communication in the United States and Japan
(Sichel (1997)、 Ministry of Post and Telecommunication)

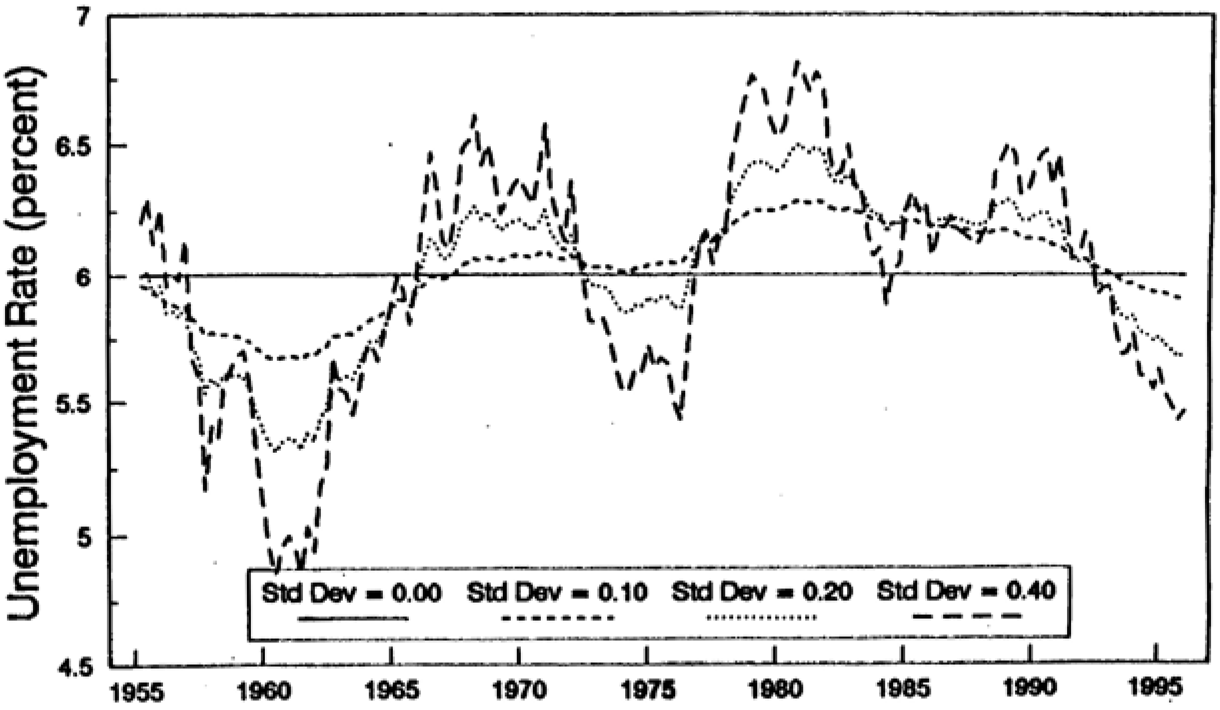
Information Processing Equipment as a Share of the Net Capital Stock (1925-93)



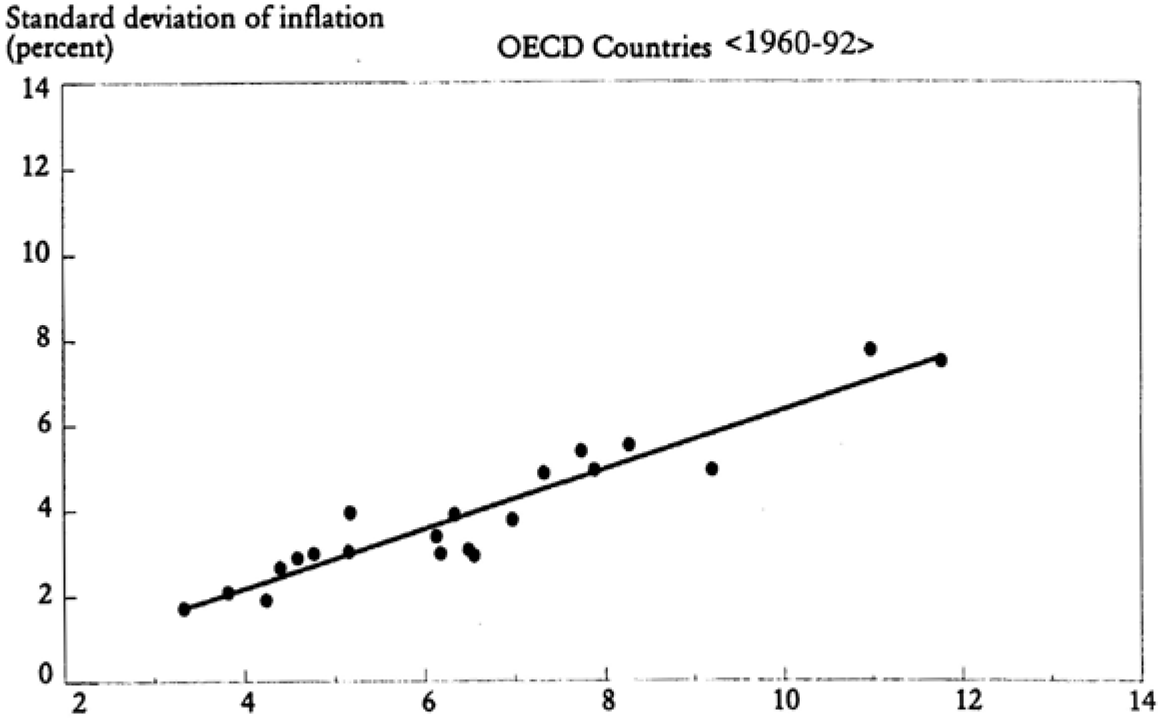

Investment of Communication Industry and Its Annual Growth Rate



(Figure 7) NAIRU for Chain-Weighted GDP Deflator (Gordon (1997))



(Figure 8) Inflation and Volatility of Relative Price / Information
(Hess and Morris (1996))



(Figure 9) Hypotheses for the relation between Relative Price Change and Inflation (Fischer(1981))

| Approach | Exogenous factors | Function of inflation associated with relative price variability | Welfare implications |
|---|---|---|---|
| 1. Market clearing with imperfect information | Policy disturbances | Unanticipated inflation or deflation | Misperceived aggregate disturbances produce resource misallocations |
| 2. Menu costs | Inflation rate | Inflation or deflation | Inflation or deflation creates resource misallocations and generates unnecessary transaction costs |
| 3. Asymmetric price response | Relative disturbances | Either inflation rate or inflation in excess of base rate | Price inflexibility leads to resource misallocations: there is too little relative price variability |
| 4. Relative shocks same as aggregate shocks | Real disturbances | Deviations of inflation from underlying rate in either direction depending on type of shock | Relative prices should vary for efficient allocation |
| 5. Allocative effects of macro policy | Changes in policy | Changes in inflation rate | Given the changes in policy, relative prices should vary for efficient allocation |
| 6. Endogenous policy | Real disturbances | Same as 3 | Policy may offset welfare loss associated with relative shocks by making appropriate price adjustments possible |

(Figure 10) Inflation and Volatility of Relative Price in Japan <1971:1Q-1997:3Q>