Impact of Information Technology and Implications for Monetary Policy

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The first half of this paper shows the mechanisms through which 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 a microeconomic level. In addition to the aggregation effects of such externalities, the costs of reallocating capital and retraining labor will hamper macroeconomic performance. Mismeasurements in economic statistics may prevent us from making optimal decisions based on relative price changes. The second half of this paper discusses the issues for improving efficiency in conducting monetary policy by focusing on the price mechanism. We should be careful whether to accommodate the "supply shocks" or not, considering the possibility of nominal rigidities or fluctuation in the general price level. It is also shown that mismeasurements in the price index may damage the credibility of a central bank, since it will be quite difficult 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

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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 examples of this trend everywhere in our economy: modern factories are introducing computer-aided design/computer-aided manufacturing (CAD/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 widely throughout our economy, we might say that we are experiencing the Third Industrial Revolution, which follows the first revolution, when machine production by a steam engine began, and the second, when electric power and chemical engineering appeared.

The major force that is propelling this movement is, of course, the rapid innovation in Information Technology (IT). It has long been understood in the fields of economic growth theory and economic history that innovation is the engine of economic growth. Like the steam engine and electric power, innovations in IT are expected to transform all the areas of economic activity, including investment, consumption, employment, and production, and to bring about a great improvement in economic performance. In this process, a firm that introduces new technologies in IT will benefit from improvements in efficiency such as a decrease in 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, gains in the efficiency of allocation of productive resources, and increased accumulation of human capital.

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

We will show, with the help of theoretical models and empirical results provided by academic economists, the trajectories and mechanisms through which the innovations in IT have had an impact on our economy. At the microeconomic level, switching costs from existing technologies and network externalities may play important roles in delaying the propagation of new technologies. In addition to the aggregation effects of such externalities, the cost of moving capital to growing industries and of retraining labor will hamper 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 innovations in IT may be changing our economic performance in many ways, it is surely an important task for us to discuss the optimal monetary policy in such a changing economy. Although a sufficient number of theoretical discussions or empirical studies do not yet exist, we will confine ourselves to suggesting a list of issues for future discussion on how we can improve the efficiency of monetary policy by focusing on the effects of the development of the price mechanism.

Our main discussion 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 that may explain the reasons for the IT paradox: (1) measurement errors in economic statistics; and (2) a broad range of adjustment costs required by the introduction of new technology. In relation to the latter hypothesis, we also review the lessons from studies of past industrial revolutions. We should be much more careful about the effects of mismeasurement, and not only in price indexes, since such errors may cause 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 benefits can be explained by the effects of such adjustment costs on both microeconomic and macroeconomic levels. The costs are incurred, for example, by the installation of capital equipment, network externalities, retraining of labor, and movement of capital between industries. As for the implications for investment or the 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 that 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, they may to some extent damage the credibility of monetary policy. 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 accommodate them by using monetary policy. However, when we take into consideration the costs of inefficiency through the possibility 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. The IT Paradox and Its Hypotheses

A. Productivity Slowdown and the IT Paradox

In the United States after World War II, GDP growth accelerated, despite bearish forecasts for the postwar economy. During 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) show, 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 the early 1970s. The most dramatic change was identified in the United States, where the growth rate of productivity fell below 1 percent per year (Table 1). This phenomenon was first analyzed systematically by Nordhaus (1972); he argues that the main reason is the shift of the United States economy toward service industries with low productivity (see Section II.B.1 below). Even in the 1980s, the paradox was alive and well, although we did experience a small improvement in the growth rate of productivity.

Table 1 Total Factor Productivity in Selected OECD Countries

Average annual growth rate, percent

Year/Country	United States	Japan	Canada	Switzerland	West Germany	France	Great Britain
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

Source: Summary from Diewert and Fox (1997).

In this stagnant situation, Baily and Gordon (1988) brought a new line of analysis 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 refers to the situation in which a rapid increase in IT investment does not cause the acceleration of productivity growth. As Griliches (1994) and Van Ark and Pilat (1993) later showed, the IT paradox has also been shown to exist in some of the other developed economies (Table 1). Even in the 1990s, when we are seeing the continuous growth of IT investment, the paradox is current in the sense that the growth rate of productivity has not reached the level of the 1960s.[1] The IT paradox has generated a number of research papers on issues in this area. Accordingly, 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 cannot accurately measure the value of IT-related goods and services, and thus mismeasures the value of production and value added of the firms that use such goods and services as intermediate inputs. As a result, we may also have inaccurate measurement of GDP. I will discuss this hypothesis in detail in two parts: (1) problems in the area of economic activities where the measurement of economic statistics is inaccurate; and (2) problems in the area of economic activities that economic statistics do not cover at all.

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), there is a literature of analyses regarding mismeasurement of price. For example, Gordon (1990) suggested that a price index of durable goods consumption had an upward bias of 3 percent. Shiratsuka (1995) on automobile prices in Japan, and Berndt and Griliches (1993) on personal computers (PCs), Dulberger (1993) on semiconductors, and Brown and Greenstein (1995) on mainframe computers all showed that the prices of 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 make the situation even worse.

It is in services that 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, in 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.

1. Some empirical studies, including Morrison and Berndt (1991) and Morrison (1997), show that increasing returns to scale can be observed at the firm level. If these findings are true, the main problems may lie at the aggregate level.
2. Brynjorfsson (1993) and Sichel (1997) categorize the hypotheses for the 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 (the share of computers in capital stock is still very small); and (5) mismeasurement (we cannot 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.

We may regard this variety of services as mutually heterogeneous. The seriousness of this problem is confirmed by many empirical studies; for instance, Baily and Gordon (1988) analyzed four industries in which serious mismeasurement occurred (finance and insurance, construction, retail, and transportation), three of which belong to the category of service industries. We may also recall 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 of corporate services to small firms in the 1990s may be aggravating the problems of coverage in our economic statistics. Thus, a hypothesis that takes into consideration both such mismeasurements in service industries and the simultaneously increasing share of service production may 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 are "intangible." Wynne and Sigalla (1996) estimate that upward bias by substitution effect in price indexes of intermediate inputs is 0.3 percentage point. Therefore, price measurement error also worsens the estimation of the value of intermediate inputs, which results in mismeasurement of value added.[4]

2. Coverage of 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 under-covered by economic statistics. We should note that Meltzer (1997) estimates that the value of computer software reaches 150 percent of that of hardware, but at the same time it has not been measured accurately. This situation is true in most developed countries; as for Japan, Mizoguchi (1996) shows that the estimated value of IT service production from 1974 to 1993 ranged from 120 percent to 170 percent of the value recorded by official statistics.

In relation to this problem of coverage, we may suspect that some kinds of economic activity have been categorized incorrectly. 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 countries calculate GDP, computer software has been regarded as an intermediate production input despite its above characteristics. This inappropriate treatment of software has distorted the value of GDP in the years when such software produces service inputs for its user. In other words, in the year in which a firm buys an item of software, the value of GDP is underestimated, since the value of

3. Goldfinger (1997) quotes Gordon's finding that the share of economic values in the United States with accurate measurement fell from 50 percent in 1947 to 30 percent in 1990.
4. We should note that mismeasurement of value added in service industries causes 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.

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 inappropriate treatment leads us to mismeasure the value of capital stock, which will result in mismeasurement of TFP.

3. Countermeasures for mismeasurement

Although the literature analyzes 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 calculating a 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. Many 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 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 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 Sigalla (1996) also suggest that their impact may be small on intermediate inputs. Thus, we may conclude that we do not yet have a decisively effective countermeasure to correct the measurement error of a price index. For broader coverage of 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 Accounts (1993 SNA), since computer software can be properly categorized as productive capital in this new system. We should note, however, that we must have an accurate measure of software production and transactions in order for the new system to work adequately. Here we face the same problem as above: such characteristics as the existence of small firms and the large variety of transactions will make our estimation difficult. Thus, in this area of problems as well, we do not yet have very effective countermeasures.

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 introducing new technologies. According to this hypothesis, the cost

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

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 retraining labor. It also includes the cost of reallocation of productive resources from declining industries to the new, growing industry of IT. Since economic historians emphasize the effects of such adjustment costs in past industrial revolutions, we will begin a discussion of this hypothesis by reviewing such analyses by economic historians.

1. Time lags of introduction of new technology

Many economic historians, including Crafts, David, and Freeman, have provided many implications from their studies of past industrial revolutions. Among such implications, the point they most emphasize is that it took many years after the innovations of key technologies for each industrial revolution before we observed the economic impact of those innovations. David (1994) and Freeman and Soete (1997) show that only 5 percent of factories and 3 percent of households in the United States introduced electric power in 1889, eight years after the first power station in New York had been built. And it took another 20 years before 50 percent of factories introduced electricity. If we parallel our current situation to this historic fact, we may have to wait some time to enjoy the benefits of IT innovation, although it is not so clear when the current revolution started (Table 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 past industrial revolutions.

Table 2 Major Developments and Share of Electricity

1870 1875 1880 1885 1890 1895 1900 1905 1910 1915 1920 1925 1930

■ **Share of power for mechanical drive provided by steam, water, and electricity**

Steam 52%	Steam 64%	Steam 78%	Steam 81%	Steam 65%	Electricity 53%	Electricity 78%
Water 48%	Water 36%	Water 21%	Water 13%	Electricity 25%	Steam 39%	Steam 16%
		Electricity < 1%	Electricity 5%	Water 7%	Water 3%	Water 1%

■ **Key technical and entrepreneurial developments**

- 1870 DC electric generator (hand-driven)
- 1873 Motor driven by a generator
- 1878 Electricity generated using steam engine
- 1879 Practical incandescent light
- 1882 Electricity marketed as a commodity
- 1883 Motors used in manufacturing
- 1886 Westinghouse markets AC polyphase induction motor; General Electric Company formed by merger
- 1893 Samuel Insull becomes president of Chicago Edison Company
- 1895 AC generator at Niagara Falls
- 1900 Central Station (New York City) steam turbine and AC generator
- 1907 State-regulated territorial monopolies
- 1917 Primary motors predominate; capacity and generation of utilities exceed those of industrial establishments

Source: Summary from Devine (1983).

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

2. Some important characteristics of the introduction of new technologies

a) Introduction and propagation of new technology according to the market mechanism

First of all, I wish to emphasize that most of the new technologies have been introduced and propagated by the forces of the 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 the universe, especially in chemistry during the second revolution, or in supercomputers and communications this time around. But at the stage of innovation where such new technologies are being refined for commercial use, the major forces promoting innovations in IT have come from profit-maximizing enterprises with the help of demands from utility-maximizing consumers. If we focus on the role of the market mechanism, some important characteristics can be pointed out, as below.

Commercialization of research and development activities is one of the most important characteristics of the current revolution. Although R&D activities had already begun in the electrical equipment industry and the chemical industry during the Second Industrial Revolution, we find such activities in almost all kinds of industries on a much larger scale during the current revolution (Table 3). The importance of R&D activities is emphasized by Crafts (1996) and Freeman and Soete (1997), who suggest 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 during the former. 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. Thus, while most basic research is carried out by national laboratories and universities, most innovations are established by commercial R&D.

Table 3 Major Innovations in Semiconductors

Innovations	Firm	Year
Single crystal growing	Western Electric	1950
Integrated circuit (IC)	Signetics	1962
Light-emitting diodes	Texas Instruments	1964
Beam lead	Western Electric	1964
Charge-coupled device (CCD)	Fairchild	1969
Static random-access memory (SRAM)	Intel	1969
Dynamic random-access memory (DRAM)	Intel	1971
Microprocessor	Intel	1972

Source: Summary from Dosi (1981).

Innovation risk consists of commercial risk and technology risk. Considering that some 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) report that the legal section of Bell Laboratories at first declined to file a patent for the laser, since it could not imagine the usefulness of lasers for communication. According to Rosenberg (1996), at the beginning of the 1950s an executive at IBM was very bearish in forecasting sales of computers, since he believed that only a few computers would satisfy worldwide needs. Another example given by Rosenberg is that, at the end of 19th century, no one tried to buy the patent for telephones, which was available for only US$100,000. 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 at a particular enterprise and is commercialized through the production of heterogeneous goods or services. As a result, strategic actions by individual firms 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 III.B).

b) A system of new technology

The next point we wish to emphasize is that it is the entire system of new technologies, not a single innovation, that has had 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 alone. As David (1994) shows, by a series of complementary innovations such as the electric light bulb and many kinds of mechanical equipment, electrical technology gradually permeated factories of all kinds as well as 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 large and bureaucratic firms with the help of telephones and steel-frame skyscrapers was 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 and society. Since most of these complementary innovations are pursued by the R&D activities of

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 all over the factory. In order to ensure efficient transmission of power, factories were in general built vertically. On the other hand, in an electrified firm, motors were installed for each part of the factory. By this dispersion of power generation, factories with flat structures were made feasible, which dramatically decreased the cost of construction of a factory.

private firms, the time required for such necessary innovations may be one of the primary sources of the time lag before we are able to observe the benefits 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 consumers' lifestyles.

One more important implication can be drawn from this line of argument. Even in the course of an industrial revolution, the existing system of capital equipment is never replaced all at once by the new one. Each firm will decide the optimal timing for such replacements by comparing the cost 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 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) Changes of relative prices

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 of the application of economies of scale in textiles during the First Industrial Revolution, and steel, chemicals, and machinery during the Second Industrial Revolution. For example, Freeman and Soete (1997) show that a dramatic fall in the relative price of steel made it economically feasible to build skyscrapers and large railroad networks, and to make automobiles (Table 4). As for our current innovation, Sichel (1997) shows that the price of computer services has been falling at a rate of 7 percent annually after

Table 4 Relative Prices of Steel Rails in the United States

Price of steel rails in the United States

Year	Steel rails, U$ 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

Source: Freeman and Soete (1997).

adjusting for quality changes, and emphasizes that this rapid change in relative price is almost comparable to those of telephones and railroads in the years of their rapid propagation, as shown by Gordon (1990) (Table 5).

Table 5 Prices of Computer Services, Telephones, and Transportation

Real price changes for computing services, electricity, rail transit, and airline transit, various periods

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: Sichel (1997).

A change of relative price brings about substitution of demand by consumers and firms. These effects alter the marginal productivity or profit rate of a supplier, which may result in the reallocation of productive resources. Such a reallocation, however, takes time and incurs costs. As we have already discussed, retraining labor and scrapping existing capital equipment will burden us with such costs. Or we may recall the discussions of irreversibility of investments by Ramey and Abel.[8] We may regard the time and costs as alternative causes of the time lag already discussed.

Another implication of the change in relative prices is that the IT paradox may be more serious than it appears. Greenwood, Hercowitz, and Krusell (1997) show empirically that the price of capital equipment has fallen at an average rate of 3 percent per year from 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 of 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 impact of IT innovations with the help of existing theoretical models and empirical results.

A. The Impact of New Technology

We begin with a review of the effects of innovation in IT within the standard framework of economics. A firm introducing new 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 the firm's goods or services may fall, and their quality may be improved.

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.

In addition, new goods and services may be developed with the new technology. Firms other than those introducing new technology may also benefit from such improvements, since they use the new products as capital equipment or intermediate inputs. The effects of network externalities and increasing returns to scale can also be expected. As a result of all the above effects, 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 (1986) 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 exist, we will see some special characteristics such as a non-convergence of economic growth rates, as Fukuda (1997) shows. We should note, however, that recent empirical results on a macroeconomic level are mixed.[10] Some academic economists in the Real Business Cycle school, including Hall (1988), suggest that we have increasing returns to scale at the macroeconomic level. On the other hand, a series of analyses by Aiyagari (1994), Burnside (1996), and Basu and Fernald (1997a, b) deny such results by taking into consideration 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 Jorgenson, which covers only the period up to the mid-1980s. In spite of its lack of new data, this line of argument 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 approach, we may even have overestimated TFP during these years. Although their analyses say little about the growth rate of TFP, this may further deepen the IT paradox.[11]

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

9. The 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. Empirical results are mixed at the microeconomic level as well. Some studies, including Morrison (1997), suggest the existence of an 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 the firm level.
11. We should note that it remains a difficult question whether to use gross product or value added for calculating TFP. For example, if we consider this question in relation to measurement errors in economic statistics, both alternatives have problems of quality adjustment; for gross product, we may have the problem of aggregation; for value added, we may have the problem of capital and labor inputs.

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 difficulties in identifying the ways of propagation of new technology itself. Some academic economists have begun to tackle this difficult problem by analyzing huge amounts of information on patent registration and citation in the United States. Their results provide 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 its benefits, and the stability of this relationship. As for studies using patent information, we may be at the stage of accumulating empirical results to form some stylized facts.[12]

B. The Adjustment Costs of Introducing New Technology

Although new technology may improve our economic performance through various mechanisms, it may not be easy to see such results in so short a time. As lessons from past industrial revolutions suggest, various kinds of adjustment costs may play a role 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.

1. Adjustment costs at the microeconomic level

In a market economy, for each firm the aggregate results of introducing new technology are uncertain, because the result itself will be the collection of decisions by each firm. In addition, the standard of technologies may change more frequently because of the increasing productivity of R&D activities, as is clear from recent developments in the operating system of the 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 cost of developing new software, retraining staff in the information system department, and changing the usage of computers at the end-user level.

When a switching cost exists, we have the lock-in effect of the so-called *de facto* standard, as shown by Farrel and Saloner (1986), or Klemperer (1987a, b). 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 hastily conclude 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,” an idea first expressed

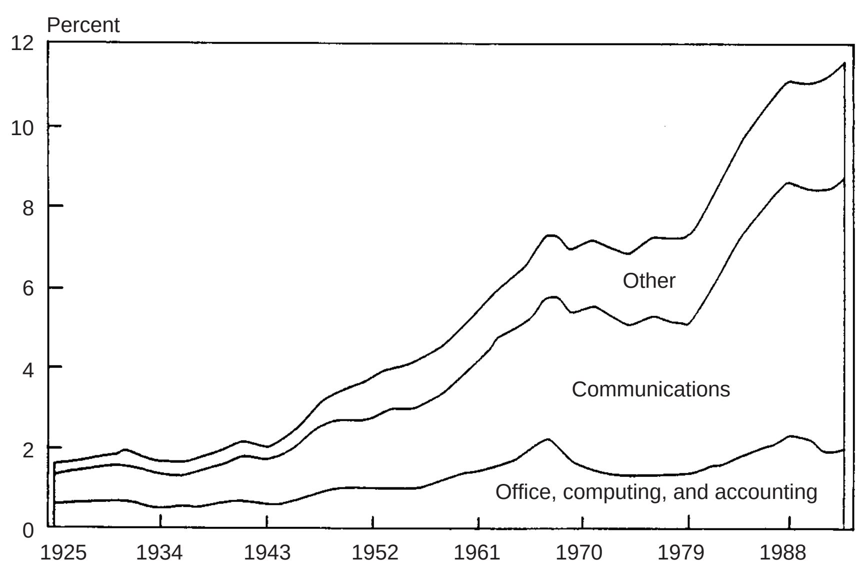
12. Caballero and Jaffe (1993) also report that the number of patent registrations per cost of R&D activities has been decreasing in the United States. Although this is indeed a very interesting finding, we should check the relationship between the contents of a patent and its results before we conclude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

by Schumpeter, refers to the phenomenon in which the endogenous introduction of new goods and services or new methods of production incessantly destroys the old ones. Stein assumes that the switching cost for buyers is increasing in time because of "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 probable it becomes that 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. The current industrial revolution is characterized by systems of computers and communications networks. Milgrom and Roberts (1990) illustrate that, by connecting computers via communications networks, a firm can improve its efficiency in production with the integration of CAD and a flexible manufacturing system (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 communications in recent years (Figure 1), these effects should have a large impact on business activities as a whole.

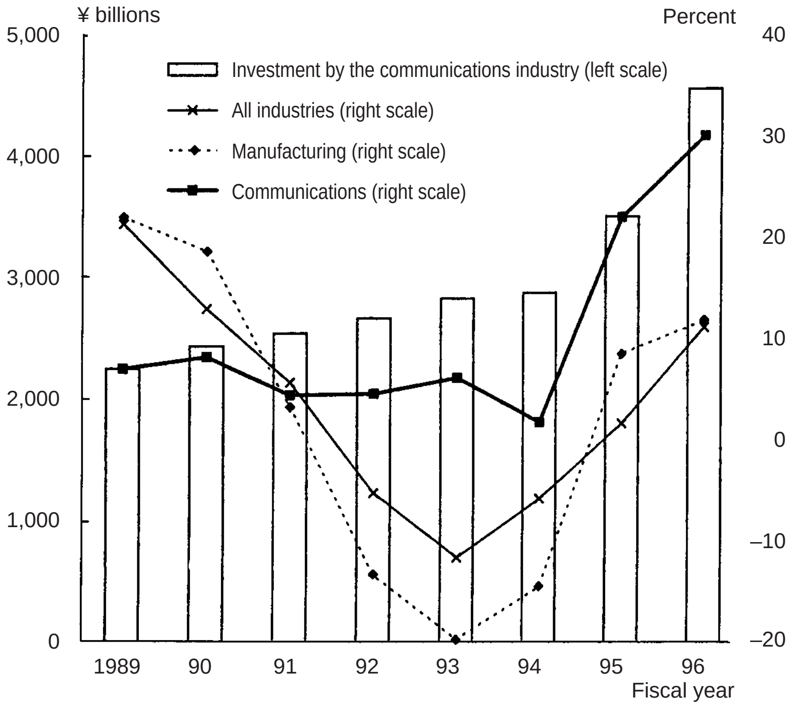
Figure 1 Investment in Communications in the United States and Japan

[1] Information Processing Equipment as a Share of the Net Capital Stock (1925–93)



13. Aghion and Howitt (1992) insist, however, on 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. Some empirical studies deny the existence of the cleansing effect that has also been discussed in the literature on "Creative Destruction." See, for example Caballero and Hammour (1994).

[2] Investment by the Communications Industry and Its Annual Growth Rate



Sources: Sichel (1997), Ministry of Posts and Telecommunications.

As is clear from the above discussion, network externality plays a major role in the current industrial revolution. Network externalities, as first discussed by Katz, Shapiro, and Berg, are the externalities by which each buyer or user benefits from the increase in their number. This line of argument is, of course, applicable to the analysis of actions of firms, by focusing on their demand for goods and services in the form of capital equipment and intermediate inputs. The effect of externalities may then be regarded as the increase in the 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 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 a more realistic situation where there is no unification of such networks, we may have some difficulties in reaching optimality. For example, as shown by Katz and Shapiro (1985) and Matutes and Regibeau (1988), if each firm incurs costs to adjust its product to make it compatible, a firm may choose not to supply compatible products, since the benefit of increased demand may leak to other firms just because of network externality. In such a situation, a firm will deliberately supply a product that is incompatible with the standard product. In addition, in a period of rapid innovation, it may be quite hard for a firm to correctly forecast what kind of specification will be the standard. Thus, network externality may delay the propagation of new technology in some cases.

2. Adjustment costs 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, 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 must wait before accelerating 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 transition. On the other hand, the fruits of this innovation will be realized and the growth rate will be accelerated during the second stage. For our discussion of price mechanism in the following chapter, we should note that the relative price of labor and capital as well as the relative wages of skilled and unskilled labor play important roles in the reallocation of such productive resources.

Another source of adjustment costs 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 classical general equilibrium model, capital and labor will move from other firms seeking these excess returns, and in the end, we reach another equilibrium with no excess returns. However, in reality a cost must be paid to reallocate productive resources which were originally specified to comply with a certain method of production. In the literature on "irreversibility of investment," Abel and Eberly (1995, 1996) illustrate the effects of the cost of reallocation of capital equipment. Their main conclusion is that even if there is an excess return on 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 Caballero and Hammour (1994) also show that the costs of reallocation may enhance the effects of "Creative Destruction" discussed above.

Human capital is of course another important source of productive resources. We will review the impact of IT on the compensation to human capital before we consider the effects of the costs of reallocation. A representative analysis is done in Krueger (1993), who insists that the wage premium of computer users is about 10 percent of the average wage. However, a series of analyses by Goldin and Katz (1996), Entorf and Guellec (1997), and DiNardo and Pischke (1997) points out that there might be an error in the regression specification; Krueger's result only shows that most computer users are high-ranking officers at their firms.[15] On the other

15. For example, DiNardo and Pischke (1997) report that they found the wage premium of telephone users as 9–14 percent of the average wage under the same framework as Krueger (1993).

hand, Kremer and Maskin (1996) and Agénor and Aizenman (1997) empirically find the wage premium of skilled labor in more articulate models.[16,17] There is also a positive correlation between IT investment and the average level of skill in labor, which is shown by Wolff (1996), Doms, Dunne, and Troske (1997), and Motohashi (1996) in most 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 Lichtenberg (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. 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 of Uzawa or Lucas. Alternatively, using the more simple models of Grossman and Helpman (1991) or Caballero and Hammour (1994) with a Leontief production function, we can show that if the cost of moving capital or retraining skills increases, the effect of IT investment decreases, since the supply of skilled labor decreases.

C. Information as an Input of Production

Information itself plays two different major roles in IT innovation. The first role is as 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, when a firm buys market research data for more efficient marketing. People also consume the kind of information presented by the Internet or satellite communications. In the last part of this chapter, we will briefly discuss the implications of the second role.

Almost 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 owing to the existence of externalities. Innovations in IT may improve the situation, since they may make it feasible for suppliers to exclude "free riders" or to collect fees at lower cost. In addition, there may even be an excess supply of information, since the costs of delivery and storage of information have rapidly decreased. We may also suspect that increasing returns to scale operate in the information-delivery industries such as market research.

In addition to these stereotyped arguments, we wish to discuss whether the innovations in IT affect the asymmetry of information[18] or the formation of expectations

16. Agénor and Aizenman (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 supplied by the Department of Labor or the Census Bureau.
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.

of future events, because this question has very important implications for financial markets where market participants consume the second type of information when deciding on their transactions. With the introduction of IT, it is much easier and cheaper to collect information on the developments of markets—for example, historical price data. It is unclear, on the other hand, whether innovations in IT make it easier to access or produce information concerning the credit risks of other participants. Even when market participants have the same information content, we have little idea whether they form the same expectations or not. Considering the importance of this area of discussion, we hope there will be further development in both theoretical and empirical studies.

IV. The Impact of IT on the Price Mechanism and Implications for Monetary Policy

In this chapter, we discuss the implications of innovations 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 conduct of monetary policy. Because a literature on such a specific line of argument does not yet exist, our analysis here will be a patchwork of various theoretical models. We hope, however, that this will be a starting point for future discussions by those who have an interest in this area.

Our strategy here is focused 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 between firms and the effects of quality changes and substitution, the relative prices of productive resources, goods and services are changed. These changes of relative prices should be regarded as desirable, since they play the role of guideposts enabling firms and households to make optimal decisions. Under the standard framework of the Phillips Curve or NAIRU, effects of innovations in IT can be regarded as "supply shocks," 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 the conduct of monetary policy. As we have seen in Chapter II, 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 damage to the credibility of central banks. As for the "supply shocks," a standard discussion will guide us to the conclusion that we need not make any accommodation at all. It may be necessary for us, however, to reexamine the optimal conduct of monetary policy if the changes in relative prices have a simultaneous influence on the general price level. This is because, if uncertainty exists regarding the general price level, we may also lose efficiency, since we cannot accurately observe changes in relative prices. Or, if nominal rigidities exist in some part of our economy, even perfectly foreseen fluctuations in the general price level will make our economy deviate from optimality. We will discuss these issues in the following sections in order.

A. Mismeasurement of Price Index and Monetary Policy

Concerning the conduct of monetary policy, confidence has been the key concept since the seminal work by Kydland and Prescott (1977). In order for our economy to be efficient, they argue that it is of the utmost importance for central banks to enhance confidence in monetary policy, since doing so will stabilize 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. Taylor emphasizes that such targeting policy definitely differs 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 to achieve money supply targets alone under a rule of money supply, we do not in principle have any operational target or medium-term target under a system of targeting policy. There are two lines of opinion as to which economic indicator serves better as a target. For example, Mishkin (1997) supports inflation targeting, since the price index is better in terms of 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 (1994), for example, support nominal GDP targeting, since inflation targeting may have 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 mismeasurement of the price index. If such mismeasurement 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 a target is being 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 an error is stationary in a time series, it may not cause much trouble. The reason is that both central bankers and private agents can estimate the true rate of inflation by taking into consideration the average rate of errors. We should note, however, that such stationary errors may cause trouble when average errors are large, since we must set a wide target range. Alternatively, there may be 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. Given the errors of such characteristics, it may be almost impossible for us even to estimate the inflation rate, or needless to say, judge whether the target has been achieved.

Although examining the characteristics of measurement errors of a price index is a very important task, very few theoretical or empirical studies exist on this issue. The reason, of course, is that we cannot directly observe such errors from economic statistics. From the analysis of the effects of the hedonic approach by Shiratsuka (1995) and numerous empirical studies on quality adjustment quoted by Boskin (1996), we may at least suppose that measurement errors resulting from quality changes and substitution effects are volatile in a time series. Although Gordon (1992) shows that this kind of error may disappear at the time of revision of a price index, we might say that 5 or 10 years are relatively long lags 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.

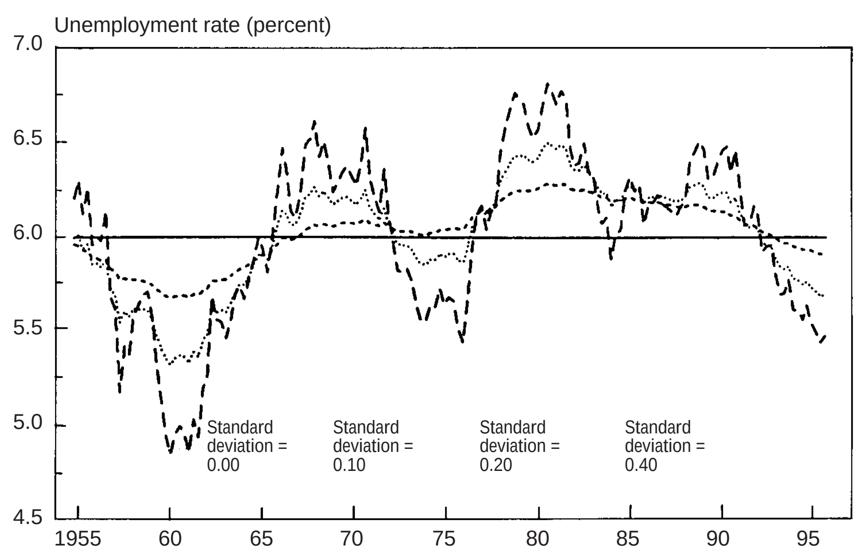
B. "Supply Shocks" and Monetary Policy

1. The Phillips Curve/NAIRU

It may be broadly accepted that the most standard framework for discussing the effects of innovation on the 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 a shift to the left in the Phillips Curve, or a fall of NAIRU in some cases.

The recent macroeconomic situation of the United States at least coincides with such a result. Stiglitz (1997), Gordon (1997), and Lown and Rich (1997) emphasize that NAIRU in the United States has fallen greatly from a rate of about 7 percent in the 1980s to the current moderate rate of 5 percent (Figure 2).[19] In the case of Japan, many academic economists are negative even concerning its existence.[20] They argue

Figure 2 NAIRU for Chain-Weighted GDP Deflator



Source: Gordon (1997).

19. At the same time, we should note that some academic economists, including Chang (1997), deny the usefulness of NAIRU, since the macroeconomic structure underlying NAIRU should always be changing depending on the kinds of shocks that affect the economy.
20. On the other hand, there exist some empirical studies showing that NAIRU has gone up in the 1990s in Japan. For example, see Nishizaki (1997).

that the expected rate of inflation has been insensitive to changes in the actual rate of inflation, and thus inflation has not accelerated since the oil price shock of 1973.

With regard to the reason for the fall in NAIRU in the United States, both Stiglitz and Gordon cite the possibility that improvements in productivity brought about by innovations in IT acted as "supply shocks," in addition to a lower markup 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, 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 mismatch of skilled labor is serious.

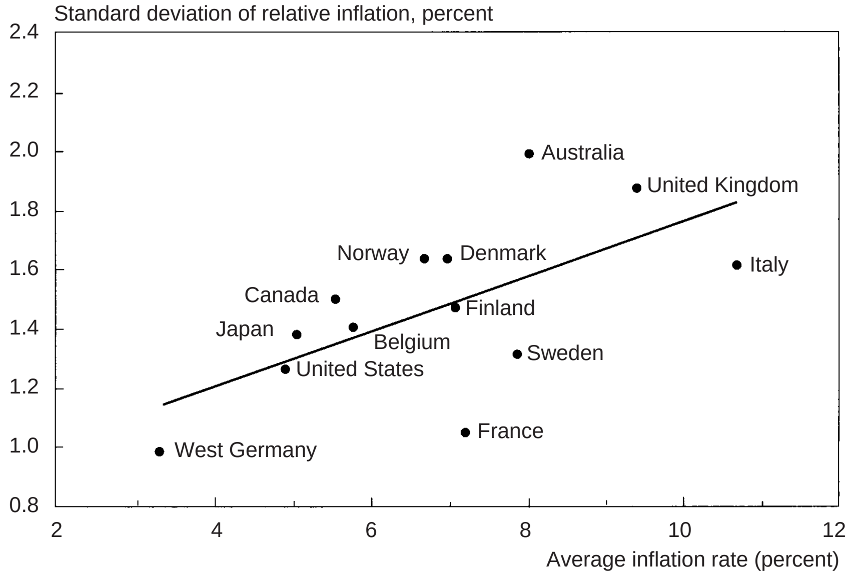
Thus, if we discuss the effects of innovations on IT under the framework of the Phillips Curve or NAIRU, we are led to conclude that such "supply shocks" should be regarded as a desirable change, and that monetary policy should not accommodate them at all. We, however, should be careful about the possibilities of incurring the costs of falling prices of some goods and services. This line of argument 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 the general price level, and the costs of falling prices. We will then reexamine the appropriateness of the "supply shocks" argument above.

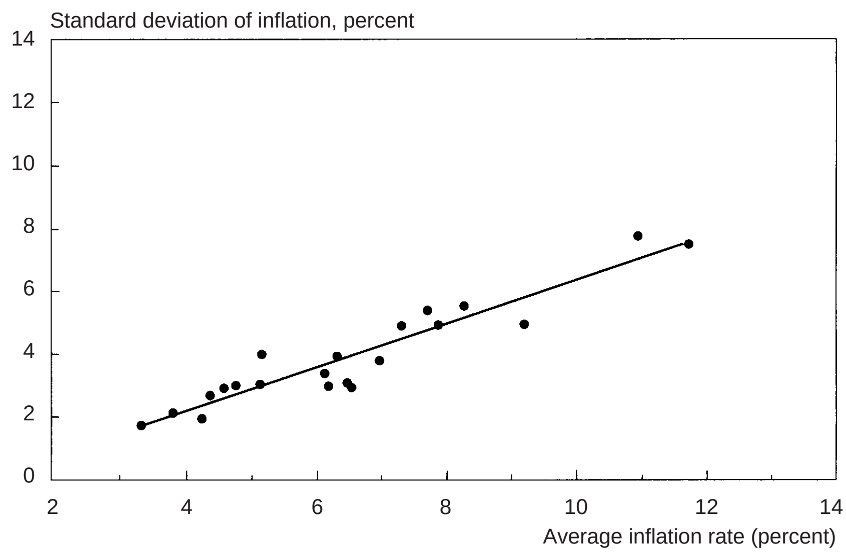
2. Relative prices and the general price level

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 decreased (see, for example, Table 5). Although it may seem natural to consider that this fall in relative prices bears some relationship to the general price level, it appears that academic economists have not reached a conclusion as to what kinds of influence relative prices and the general price level have upon each other. Nor do we understand the direction of causality.

Some of the empirical studies—for example, one of the earliest by Vinning and Elwertowski (1976), and afterward by Parks (1978), Domberger (1987), and Ball and Mankiw (1992)—report that they found a positive correlation between the two. Moreover, Taylor (1981) and Hess and Morris (1996) show that such a positive correlation was identified in many Organisation for Economic Co-operation and Development (OECD) countries in which inflation rates were higher (Figure 3). As for the reasons for this positive correlation, a variety of hypotheses exist, most of which appear in the list compiled by Fischer (1981) (Table 6). 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 the general price level. According to this hypothesis, even when relative price change itself has nothing to do with the general price level, the general price level is changed by monetary policy. Domberger (1987) and Debelle and Lamont (1997) are negative toward macroeconomic reasons, because they observe a positive correlation even in their cross-sectional settings. Because we have not reached a conclusion on the reason for such a positive correlation, we are not able to

Figure 3 Inflation and Volatility of Relative Prices/Inflation, 1960–92





Source: Hess and Morris (1996).

Table 6 Hypotheses for the Relation between Relative Price Change and Inflation

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

Source: Fischer (1981).

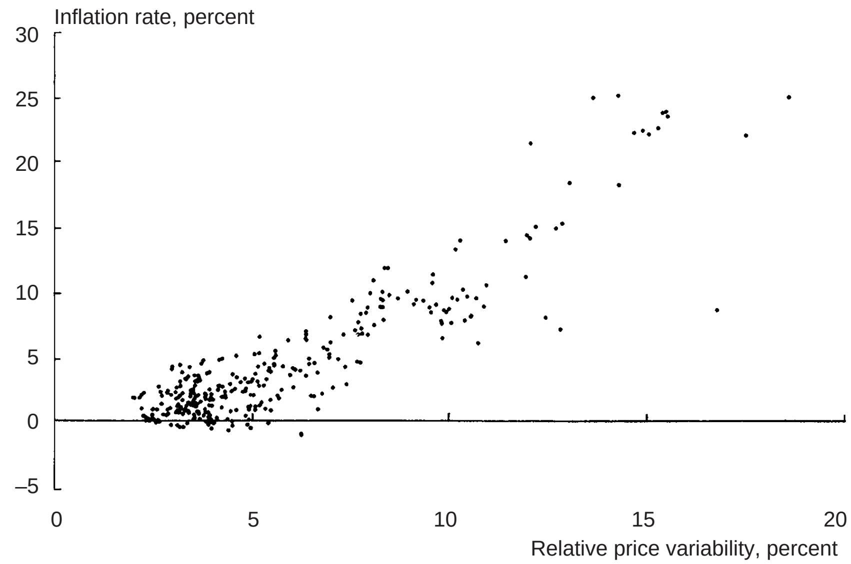
say anything on the direction of causality. We should also note that some empirical results suggest that this correlation is weaker when the rate of inflation is very low. We can observe this characteristic in Japan (Figure 4).

Even in such an ambiguous situation, there is 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 evidence of falling relative prices of goods and services in IT. Although this possibility may appear remote, it deserves careful consideration, since a falling general price level has some important effects, as is shown in the following sections.

3. The cost of falling price-noise in respect to the observation of relative prices

In order to examine the costs of falling prices, it may be useful to start by reversing the argument concerning rising prices. Shoe-leather cost will be a benefit 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 taxpayers. The rest of the argument consists of a problem concerning the informational function of 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

Figure 4 Inflation and Volatility of Relative Prices in Japan (1971/I–1997/III)



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 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 a linear relationship exists between volatility and the level of the inflation rate, then 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 can make two important points. First, innovations in IT 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 whether fluctuations in markup 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 about the cost of fluctuations in the general price level, we might implicitly assume that the accurate observation of changes in relative prices is prevented by

21. In such a situation, suppliers may not want to change their prices frequently, because the benefits of price changes are ambiguous for them also.
22. Baba (1997) shows that, when the fluctuation in markup is considered, the cost of inflation in Japan increased by nearly 1 percent of GDP in the years from 1974 to 1992.

exogenous changes in the general price level. On the other hand, in the argument concerning innovations in IT, if we assume that changes in the general price level occur simultaneously with changes in relative prices related to such innovations, then we will assume in turn that changes in the general price level 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 unable to observe relative price changes other than in the case of a few of the products that are familiar to it.

4. The cost of falling prices: nominal rigidity

We have examined the reversed arguments concerning the costs of inflation. There is, however, another important argument that has no counterpart to the argument of inflation. That is the cost of nominal rigidity. A recent study by Blinder (1997) shows evidence of nominal rigidities and insists that the effects depend on factors such as coordination failures, imperfect competition, and implicit contracts. With nominal rigidities in some prices, as Aiyagari (1990) or Bernanke and Mishkin (1996) show, a fall 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 percentage points when the inflation rate goes down from 3 percent to 0 percent. Moreover, Fuhrer (1994) and Friedman 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 argue against the existence of nominal rigidity. For example, in the comment for Akerlof, Dickens, and Perry (1996), 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 years of relatively high inflation. 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 wages into their component parts; they show that total compensation is very flexible since it is adjusted for overtime pay 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 the general price level falls due to the decrease in the prices of services related to computers and communications, *and if* 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 resulting from innovations in IT can be regarded as "supply shocks" in a framework of the Phillips Curve or NAIRU, it may be optimal for monetary policy not to accommodate such shocks.

23. At the same time, they show that hourly wages are less flexible. Based on these results, if overtime pay and bonuses reach zero due to a long-lasting depression, employment may become more flexible.

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 exist 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 allocation inefficiencies.[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 induced by relative price changes, and the conditions of optimality of monetary policy under volatile inflation and/or nominal rigidity.

V. End Notes

In this paper, we have tried to present the most comprehensive list of issues. 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 a favorable "supply shock," we should also note the following possibilities that might be brought about by the innovation itself. First, the measurement error of economic statistics may damage the credibility of monetary policy, because such errors may make accurate observation of economic performance quite difficult. Second, a fall of the general price level may cause a loss of efficiency, if there exists some correlation between the relative price and the general price level, *and if* there exists nominal rigidity.

As is clear from the discussion in this paper, our existing theoretical models and empirical studies have interesting implications but only limited coverage. In order to understand our changing economy and maintain its efficiency, we should tackle the tasks of further investigation one by one.

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 cannot be set low enough, even if the central bank sets the nominal interest rate at zero.
25. In discussing the optimality of monetary policy, of course, we should also take into consideration the effects of the changes in the expected rate of inflation.

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