HACETTEPE ÜNİVERSİTESİ
İKTİSADİ VE İDARİ BİLİMLER FAKÜLTESİ DERGİSİ
CİLT 13/1995

REALIZING TECHNOLOGICAL CHANGE: THE NEW TECHNO-ECONOMIC PARADIGM

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1. INTRODUCTION

Technology is an engineering concept explaining the current state of pruduction structure. It has to do with the relationship between factors and output in a production process over time. It is not a concrete variable to measure readily. It has never been a crucial matter with some exceptions, such as K.Marx and J. Schumpeter, in the history of economic theory; i.e., it is a sort of "black box" and needs to be taken as "given".

It has different stages and takes place in different forms depending on the size of the change and environment where it is applied for. When the changes and diffusions of technologies emerge, they become clusters of technological change, and, affect the whole social and economic structure of the nations. Thus, economists today can not ignore what is going on with the changes in technology; because, it is changing our daily life, so we have to consider it. To help that purpose, this study first generally analysis technogical change in detail in different perspectives - process of technological change, whether it is embodied or disembodied, neutrality of it, measurement of it and taxonomy of it - and second, discusses the new techno-economic paradigm which is defined as the recent advancements in technology.

2. TECHNOLOGICAL CHANGE

The word "technology" can be defined as "knowledge about scientific applications"; or "the stock of knowledge (technical or

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management) which permits the introduction of new products or process"; i.e" it is a method of production at a given time (Chesnais, 1986, p, 93). According to Dosi, technology is a "set of pieces of knowledge, both directly practical (related to concrete problems and devices) and theoretical (but practically applicable although not necessarily already applied), know-how, methods, procedures, experience of successes and failures and also, of course, physical devices and equipment" (Dosi,1984, p.13-4).

Technological change refers to the changes in a production process as a result of the application of new knowledge in science and technology. It is an explanation of changes in production structure by the application of a new scientific discovery. To make this change unable in a production process, changes in science and education have to go together with a successful promotion strategy.

Another way of defining technological change can be done by distinguishing "product innovation" and "process innovation" although the distinction is not always clear cut (Heathfield and Wibe,1987, p.118; Freeman,1979, p.183). Sometimes technological change appears as a transformation of process of factors into output (new production process), which is called "process innovation"; and sometimes it also appears as a production of entirely new goods, which is called "product innovation".

2.1. Process of Technological Change

It has been traditional to analyze technological change in a Schumpeterian way distinguishing it into three stages: invention, innovation and diffusion. Technological change is an aggregate of these three stages.

Invention is a joint set of new ideas in many different related fields with clear interrelationships and applicability. In other words, it is a discovery of a new scientific and technological advance and its possibility to translate into a prototype (Cyert and Mowery,1987, p.25).

While invention suggests the possibility of something new, innovation is the application of this possibility with market activities. Innovation is a transformation of clear applicable ideas into production process, which is a new production function (Diwan and Chakraborty, 1991, p. 192), such as what is happening today in microelectronics, biotechnologies, etc.

Finally, diffusion has to do with the attempts of firms in the market to imitate and adopt the new way of production, which is expectedly cheaper and more profitable. When the market is saturated with the new process and product, investors (inventors) will be looking for a new technique and product to keep competing in the market.

2.2. Embodied and Disembodied Technological Change

If the technological change is realized through the existing factors to produce more of the same product, it is called "disembodied" technological change. This type of technology "consists of particular expertise of past attempts and past technological solutions, together with the knowledge and the achievements of the state-of-the-art" (Dosi 1984, p. 14) On the other hand, if technological change is accompanied with some new factors and changes in factor quality, it is called "embodied" technological change.

2.3. Neutrality of Technological Change

In a production function, the state of technology can be shown as:

$$Q = f(X_1, X_2, \ldots, X_n, T) \qquad (1)$$

where Q denotes possible output, X_i denote inputs and T denotes the current satate of technology. The production function, as in equation 1, is an engineering relationship reflecting technology and the laws of nature. Laws of nature do not change over time while our understanding of technology and nature has improved over the years. (Berndt, 1991, p. 63). This improvement in technology is expressed as a shift in the production function implying more output (Q) with the same factors (X_i).

The change in technology can also be explained through an isoquant map. Assuming two inputs, capital (K) and labor (L), the isoquant curve will shift towards the origin since fewer factors will be needed to produce the same amount of output.

As long as the consequences of technologial change is concerned, economists have usually considered whether it is "biased" or "neutral". There are three kinds of neutrality related to technological change: Hicks neutrality, Harrod neutrality and Solow neutratity.

If the technological advancements leave the capital-labor ratios unchanged when the factor prices remain constant, it is called "Hicks neutrality". In this case, the isoquant will shift parallel towards the origin.

If the changes in technology leave the capital-output ratio unchanged when the price of capital remains constant, it is called "Harrod neutrality". In this case, the isoquant will shift biased towards labor, which is a labor-saving technological change. Theoretically, this means that the isoquant curve has moved towards the origin through the advances in techonological change with a bias in the labor-saving direction. This is to say that the same amount of output will be produced with less labor and more capital.

Finally, if technolagical change leaves the labor-output ratio unchanged when the price of labor is held constant, it is called "Solow neutrality". In this case, the isoquant will shift biased towards capital, which is a capital-saving technological change. The same isoquant has moved towards the origin through the advances in technological change with a bias in the capital-saving direction. This is to say that the same amount of output will be produced with less capital and more labor.

2.4. Measurement of Technological Change

Most empirical studies in measuring the economic effects of technological change are based on the econometric production (or cost) function approach (for a detailed discussion on empirical approaches to measure technological change, see for example, Pattel and Soete, 1988). As equation 1 shows, the state of technology is represented in a production function indicating a shift in the production function with more outputs from the same factors. Since the advancements in technology are not easily defined things, the measurement of these changes has always become the heart of practical difficulty. There might be different proxies used to express the state of technology. Each proxy has some priorities to the others in specific circumstances, but almost all of them have serious weaknesses in practical sense. Therefore, it is hard to say which one is the best proper proxy.

One way to measure and represent advancements in technology is to calculate Total Factor Productivity (TFP), defined as the ratio of quantity of output produced to a weighted combination of quantities of different input factors used (Diwan and Chakraborty, 1991, p. 54-5) i.e., TFP relates the value of real output to the associated total inputs. Denoting the level of output by Q, TFP is calculated as follows:

$$TFP=Q/\sum W_i X_i \qquad (2)$$

where xi is the quantity of input factor i and Wi is some appropriate weight.

Since the changes in technology are continuous over time, many researchers used "time trend" as a proxy to express the state of technology. Given the following production function:

$$q=f(x_1,x_2, \dots ,x_n;t) \qquad x_i=1, \dots, n \qquad (3)$$

where xi is the quantity of input factor i, q is output, and t is time trend (To see the usage of technological change in a translog production (or cost) function, see Antle and Capalbo, 1988; and Berndt,1991).

"Research and Development" (R&D) has recently become a favoured explanation of the state of technology in the literature. Different R&D indicators can be used in different studies for different countries by different authors, such as total R&D expenditures, indusrtrial R&D expenditures, R&D capital stock, and number of scientists working in R&D jobs. If:

$$t=g(R\&D), \qquad (4)$$

equation (3)becomes

$$q=g(x_1,x_2, \dots,x_n; R\&D), \qquad x_i, i=1, \dots,n \qquad (5)$$

The difficulty with R&D is that, there is no well-specified production function for knowledge (Heathfield and Wibe,1987, p.129), there is no standard R&D indicator to express technological change, and also many small firms are involving in the high-tech market without investing for R&D.

"Education" and "labor training", such as the number of graduates from the colleges or number of trained people might be a good proxy to express the changes in technology (Dönek, 1994). It can be calculated as in the equations (4) and (5) just defining t as E, instead of R&D.

There are some other methods and proxies to measure the state of technology, such as "patent", "papers and publications", and "learning by doing". For example, "papers and publications" might be an appropriate measurement of the technological change in some cases, such as biotechnology (Chakraborty, 1989, p. 114). Finally, "learning by doing" offered by Arrow (1962), again assumes that technological change is a function of time, and it is a kind of measurement of "experience" to produce (Berndt, 1991, p. 66). Of course, all these have specific significance in different occasions.

2.5. Taxonomy of Technological Change

Freeman (1987) organizes four types of technological change: First are "incremental innovations", which are continuously occurred events in any industry or service activity, as a result of inventions and improvements suggested by the scientists. Second are "radical innovations", which are discontinuous events and usually occur as a result of an R&D activity. Third are "the technological systems", which are the clusters of new innovations, and include numerous radical and incremental innovations in both product and processes. The final ones are "changes of techno-economic paradigm" which are far-reaching and pervasive changes in technology. They affect all the branches of the economic and social system and brings out some new sectors. Indeed, a new techno-economic paradigm is a new way of solution of current technological problems based on the latest principles from science.

3. THE NEW TECHNO-ECONOMIC PARADIGM

The last type of technological changes affect the factor cost structure and conditions of production for almost all branches of the economy and give rise to entirely new sectors. They also comprise clusters of incremental and radical innovations as well as new technological systems. This type of technological change, change in techno-economic paradigm, does not frequently happen although the frequency of it is becoming more and more short.

3.1.The Old Paradigm

The mass-production techno-economic paradigm started just after the Second World War with the leadership of the U.S. It was pretty much consistent with the neo-classical factor substitution and cost minimization theories.

The old techno-economic paradigm has been defined by oil energy, product standardization and mass scale production. The features of standardization and mass production has ensured cost reduction through economies of scale. These techniques have been pervasive indeed, and as a result, one has witnessed the growth of mass markets, such as mass media, mass transit systems, mass education and mass consumption. The mass production techniques are based on massive capital investment and large unskilled labor inputs. Underdevelopment, in this paradigm, is considered analogous to lack of capital.

3.2 Transition From the Old to the New Paradigm

This paradigm has been started to be replaced by the new techno-economic paradigm that depends on information technology since the mid'1970s. It has already taken place in many key industries, such as microelectronics, computers, data processing micro-processors, robotics, aerospace, new materials, optoelectronics, biotechnology and telecommunications systems. It will affect all the branches of the economy (from national to international level), but not in an overnight. There will be a structural transition from the old paradigm to the new one. According to a study (The World Bank 1993, p. 9), the transition will take place in three main stages. In the first stage, "Industrial Economy in Transition", information demand growth is concentrated in a couple of sectors, such as banking, international trade, government administration of tax and security. In the second stage, "Limited Information Economy", the new paradigm (informatics) is diffused to other sectors like manufacturing while the leading sectors will be experiencing more institutional and structural transformation. In the final stage, "Information-Based Economy", there will be a profound structural transformation in the economy with necessary social and economic institutional environment.

3.3. Defining and Distinguishing the New Paradigm

The new paradigm is called differently by different authors, like "the Third Wave" (Toffler, 1980), "the era of the Great Divide" (Piore and Sabel, 1984), "Information Technology" (Freeman, 1987), "Informatics" ('The World Bank (1993), and some others theorize it as "the new techno-economic paradigm" (Diwan,1989; Diwan and Chakraborty,1991; Diwan and Desai,1990; Dönek, 1994; Freeman, 1987; Freeman and Perez, 1988; and Kodama,1990). But the meanings are same; they all explain the recent revolutionary developments in technology.

Basically, there are four approaches to this paradigm: The first approach sees the new paradigm as a continuation of the "automation" debate of the 1950s, which talks about process innovation. The second approach identifies a group of industries and services around computer, electronic, and communication sectors which have the most dynamic employment gnowth recently. The third approach concerns with the "information society" as a result of modern industrialized societies that shift the work force from unskilled to skilled jobs. The fourth approach comprises elements of all previous three approaches. According to Freeman, the last approach, which belongs to him, is the best one that explains the new paradigm (Freeman,1987, p. 50).

The new techno-economic paradigm is determined by information technologies that involve segmented markets, customized production and economies of scope. The continuously changing technologies are science-based and require both R&D and skilled labor in addition to capital in which these technologies are embodied. Furthermore, these technologies are international in the sense that the production process can be carried on in different parts of the world in the face of globalizing markets. Such "market segmentation and globalization go together and set a dynamic process of self propagation" (Diwan and Chakraborty, 1991, p. 6). There are also more entry points in the new paradigm, and many newly industrializing countries can, and do enter.

3.4. Characteristics and Implications of the New Paradigm

According to Freeman (1987) and Diwan and Desai (1991), some of the charasteristics of the new paradigm are as follows: One, because of the continuous fall in costs (prices), the new product is becoming cheaper. Two, the supply of commodity is unlimited. Three, it is pervasive. Four, markets are getting more segmented. Small production units are becoming more economic in terms of flexibility and speediness in model and equipment changes. Therefore, the standardized, homogeneous products of the old mass-production paradigm can no longer compete with the new paradigm based on more flexible production structure. Five, the quality of products, process, services proceed the price. Six, it leads to saving in all the production factors, but increases the need for skilled labor. Finally, the new paradigm requires a strong network of component and material suppliers with assembly type firms or with service firms as well as between producers, wholesalers and retailers for a quick response to changes in consumer demand.

It is now recognized that the electronic and semiconductor-based technologies satisfy all these conditions. The price of chips has been continuously falling while its processing speed and scale of integration has been increasing. Generally, the supply of these chips is largely available as desired, and they are now embedded in virtually every consumer and producer goods. This condition also ensures continuous cost reductions of goods and processes in which these technologies are embodied. Their pervasiveness enlarges old and establishes new markets for products. Cost reductions and enlarged markets make them competitive and are the necessary conditions for a self-perpetuating process.

The old mass production paradigm is now in crisis, and the new paradigm has already taken place among the fastest growing industries such as computer and electronic equipments with a remarkable cost reduction. It satisfies all above conditions, and therefore, gives an edge over the old mass-production paradigm. The need is for more skill, training and appropriate social and economic institutional change.

According to Diwan and Desai (1991), two major implications of the new paradigm can be observed today: (i) On the demand side, there are two important features. One, markets are getting segmented. Product differentiation and product customization are very important; the new product can be adjusted to the desires of customers through the flexibility of production. Thus, quality has the priority rather than price. Production with small micro-chips are beceoming more flexible, quality and cheaper than the old mass-production units. Two, markets are becoming global. Therefore, a firm has to produce for international markets. But, it requires to develop international market networks. (ii) Similarly, on the supply side, there are three features. One, entry is not that difficult; for entry R&D, capital investment, skill and geographical advantages are required. Two, the production process is becoming international now. Three, technological change becomes a continuous process, the entry for a firm and a country will not be difficult.

The effects of technological change are very important especially in two areas: One is the competitiveness efect, and two is the labor market effect. The competitiveness effect of technological change has been found positive in many studies in the literature, which means that, competitiveness of a country increases as the advancements in technology are applied to the economy.

On the other hand, the second effect of technological change is not that clear. These are some of the possible outcomes of the applications of new technologies considering labor market: A surplus of some skills, a shortage of skills related to the development and implementation of new technologies, emergence of new skill requirements and occupations, and internal shifts of skill requirements towards newly industrialized countries (CDEI, 1985, p.86). However, the general consensus from the previous techno-economic paradigms is that the direct labor market effects of modern technologies are, on the whole, negative (Warnken and Ronning 1990, p. 215). The overall direct effect on labor market will be the sum of the impacts on industry growth rates, occupational profiles of industries and skill profiles of occupations (CDEI,1985, p. 83). To see the two effects together, some studies capture both competitiveness and employment data in their model (such as, Cyert and Mowery,1987; Erber and Horn,1990; and Foley, Watts and Wilson, 1992). The general finding is that, the long-run employment gain through international competitiveness may compensate the short-run employment losses by technolagical change in the future.

On the other hand, the studies (such as the ones of Groshen and Williams, 1992; Topel, 1993; Murphy and Welch,1993; and Farber, 1993) concentrating on the period of last two decades (taking the new techno-economic paradigm into consideration) find that the new technologies have increased the demand for high skilled workers while they have decreased the demand for low-skilled workers. Hence, this causes technological unemployment mostly to be seen among low-skilled workers and an increase in skill requirements. Technically saying, technological change is becoming more and more labor saving for low-skililed workers and labor using for high-skilled workers.

4. CONCLUSION AND SUGGESTIONS

Technological change refers to the changes in a production process as a result of the application of new knowledge in science and technology. Today, science and technology are changing very fast. As a result of these changes, our daily life is also changing continuously. These changes in technology can happen in three stages: Invention, innovation and diffusion. These changes may be embodied or disembodied, and/or biased or neutral in nature. Technological change can be measured and represented in empirical studies in different ways, such as Total Factor Productivity (TFP), time trend, learning by doing, R&D, education and labor training. On the other hand, changes in technology is seen in the following forms: Incremental innovations, radical innovations, the technological systems, and changes in techno-economic paradigm that affect all the branches of the economy and brings out some new sectors.

As Diwan and Desai (1990) argue, the businesses that have been conducted according to the old mass-production techno-economic paradigm are losing to international competition not only in international markets but even in their own domestic markets. For example, some large corporations such as IBM and major automotive producers in the U.S. are losing to international competition even in the U.S. market against the Japanese competitors which are considered as the leading examples of the new paradigm.

The situation is to align the present business (as a representative of the old paradigm) with the new paradigm with some radical changes. In other words, the old businesses (in the U.S., in Turkey, for instance) have to learn foreign cultures, and invest more on R&D and skill formation. These are the necessary conditions for growth and changing business culture. Furthermore, it needs to be understood that labor-capital substitution of mass production paradigm is no more accepted in the new paradigm; they are complimentary now. Labor is not a "cost" of production, it has to be treated as an "asset".

To compete in international markets, these old businesses have to seek out market segments that satisfy particular needs of customers, produce quality goods, and maintain employee loyalty as well as intensive distribution of the products and delivery at the promised time. Finally, the domestic firms and governments have to learn and adopt forward-looking and future-oriented strategies based on a dynamic national science and technology policy by initiating and continuing proper science and technology infrastructure, improving the level of education and the quality of population investing more on "human capital" to make the country enable to compete in the international mankets. To achieve the final point, practitioners of economic policy need to maintain the highest closeness between universities and industry as well as between firms.

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