THE FIRM, PRODUCTIVITY AND THE EMERGING TECHNOLOGY

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1. Introduction

> "The firm is a technical unit in which commodities are produced." Its entrepreneur "transforms inputs into outputs, subject to the technical rules specified by his production function". (Henderson & Quandt, 1971, p. 52.)

The opening quotation is a typical example of how the firm is introduced in the established, neoclassical theory of the firm. The business unit is treated as a profit maximizer which obtains the maximum output from every input combination according to its production function. Firm behavior is characterized by complete rationality in a world of certainty.

A theory should always be a simplification of reality - but not to the extent that it neglects or distorts important factors that guide the behavior of what is being modeled. Attempts to add empirical content to the theory of the firm have essentially followed two different routes. Along the first, firm *environment* has been made more realistic. The second route has led to more realistic assumptions regarding firm *decision processes*. This, more revisionist, approach takes into account that rationality of the economic actors is "bounded", due to "failures of knowing all the alternatives, uncertainty about relevant exogenous events, and inability to calculate consequences" (Simon, 1979, p. 502). Concepts such as search and "satisficing" are now common ingredients in economic analyses of firm behavior.

However, the diversity of the modern corporation, and its internal, organizational problems still escape the received theory of the firm. The notion of the firm brought forward, is that of a single factory, in which all activity is associated with mechanical hardware production. The firm is insufficiently treated as an *organization*. The article focuses on how this theoretical influence manifests itself in analyses of firm productivity and the (potential) effects of electronics and computer technology on corporate performance.

2. The Modern Firm

The modern industrial firm is a multiproduct/multiplant (and frequently multinational) corporation. It is often part of an industrial group controlled by a corporate headquarters. A mapping of the corporation would typically show a network of a head office, branch offices, factories, sales offices, service stations, warehouses and research laboratories. Such an organization requires a great deal of administration, planning, coordination and control. Those are tasks normally associated with the head office. They include personnel administration, payroll accounting, training, computer support and service, external information service, pricing, budgeting, accounting, cash management, investment planning and decision making, financing, etc.

The degree of centralization of those functions varies from firm to firm, depending on such factors as size of operations, type of products and management style. With increasing size and complexity of the corporation, the *central* administrative involvement tends to become less detailed. Profit targeting and control, risk management and strategic planning are then taking a larger share of head office operations. Thus, much *administrative work* of the type listed above is often performed also at lower levels in the organization. And it is not a negligible part of total work input.

In order to maintain a competitive position, the firm has to invest a significant amount of resources into *sales, marketing and service* efforts. A product is rarely sold by just offering it to the market at the going price. An active role is required on the part of the seller. Potential buyers have to be made aware of the product. A fast and dependable delivery and a good after-sales service are often more effective sales arguments than the features of the product itself.

Most firms are also forced to engage in *research and development.* Relative changes in production costs and product prices will sooner or later make a product outdated. To ensure long run viability, the firm must therefore anticipate and adjust to new market conditions. It must introduce new products and improve the design and physical properties of its products already in the market. New products and designs not only create demand; they often enable a more efficient production.

IUI estimates show that R&D investments in Swedish manufacturing in 1973-76 amounted to approximately one-fifth of the investments in machinery and buildings (Örtengren, 1981). In 1978-80, this ratio increased to about one-third. In many firms, immaterial investments (which include R&D, and investments in training, marketing, and the sales and service organizations) are already of greater, or much greater, magnitude than material investments.

Even the production process itself requires a substantial amount of non-physical (software) activities. Besides direct physical production, it involves such key functions as customer order handling, design and technical preparations, production planning, inventory management, materials control (to ensure that necessary components and raw materials are available), purchasing, quality control, supervision, maintenance, delivery service, cost planning and control. A case study of a Swedish engineering factory showed that the amount of labor, that went into direct hardware production activities, only accounted for about one third of total labor use in the plant.

Software activities, such as those listed above, thus made up for the remaining two thirds of labor input (Eliasson, 1982).

The purpose of the IUI project "The Modern Corporation" (see p. 118) is to measure the proportions of the various activities going on in Swedish manufacturing firms. Tentative results indicate that the administrative, customer-oriented and innovative functions generally account for a large, and growing, share of total resource use. Table 1 shows that the production process in a large engineering firm accounted for less than half of total costs (excluding depreciation and interest expenses). A good theory of the firm should recognize the internal diversity of firm operations.

Table 1. *Total costs*[a] *of engineering firm distributed on functions, 1981* (percent of total)

	Percent
R&D, engineering design and documentation	17
Work scheduling	15
Production	44
Marketing and distribution	9
Financing and administration	5
Other	10
TOTAL	100

[a] Excluding depreciation and interest expenses.

An interesting question is whether the crude, price-taking firm gives us any help in understanding *macro behavior*. The argument behind several current micro based IUI projects is that it rather distorts understanding or gives erroneous predictions.[1] The need for a realistic and dynamic micro foundation of existing macro theory is the main idea of the IUI micro-to-macro modeling project MOSES (see p. 102).

In narrowing the gap between theory and reality, a problem arises, however, in that the required micro data are generally not available. At IUI, a substantial amount of work has therefore been devoted to collecting and organizing real firm data bases, designed to fit the micro oriented research going on at the institute.

[1] See also the articles by Brownstone and Klevmarken in this volume. For more in-depth discussions on the problems of basing economic policy on current macro theory, see Eliasson, Sharefkin & Ysander (1983).

3. Firm Productivity Potential

Standard macro production function analysis of productivity does not adequately identify what lies behind changes in productivity. Above all, it fails to capture organizational and allocational effects on productivity change. If, as is our hypothesis, organizational techniques within firms are the main vehicles for productivity change we have to develop the appropriate analytical tool. By substituting the microscope for the macroscope in the study of productivity change, it is possible to more closely examine the origin of productivity growth. A number of IUI studies in recent years have set out to analyze productivity change at different levels of aggregation; from the macro level down to the workshop floor (Grufman 1978, Carlsson et al. 1979, Carlsson 1980, Eliasson 1976, 1979 and 1980, Nilsson 1981).

The results of these efforts strongly suggest that pure technical change does not play the dominant role in explaining total productivity growth. More important are the effects of the *organization* of resources already in use (labor being very important), and of the *allocation* of new investments. And this conclusion seems to be valid at both the macro and the micro level.

For the economy as a whole, the most significant productivity gains arise from structural change. When more productive firms expand in relation to less efficient units, productivity of the total economy is improved, and vice versa (see Carlsson's article on subsidies in this volume).

Also within the firm itself, the organization of resources appears to be the main source for efficiency improvements. This phenomenon is well-known as the "Horndal effect" (Lundberg, 1961) or as learning-by-doing (Arrow, 1962). It is often a question of removing bottle necks and increasing the throughput speed of intermediate parts, goods in process, final goods and – not the least – information. This requires that the "critical links" in the chain of activities can be identified. There is no point in installing machinery with greater capacity if, for instance, the additional materials needed cannot be provided or the paint shop is already working at full capacity. Hence, the ability to monitor and coordinate the operations is crucial for total firm productivity.

To sum up, a productivity analysis heavily influenced by the prevalent theory of the firm is apt to overemphasize the role of technical change, and to overlook the productivity potential inherent in the organization of existing resources and the allocation of new resources.

4. The Emerging Technology

The questions brought up thus far are highly relevant for the much debated issue of the productivity impact of the rapidly spreading use of electronics and computer technology in manufacturing activity. To a large extent, the debate centers around substitution possibilities between the new technology and manpower. The labor saving effects of introducing industrial robotics and numerically controlled (NC) machines on the workshop floor, and wordprocessors in the office, are typically emphasized. A widely held view, is that the essential effect of the improved technical capabilities, is to increase productivity by way of reducing blue collar and routine clerical employment.

This and the following section give a summary account of case studies of the computerization process in several large manufacturing firms. They illustrate that the non-physical side of firm production involves a heavy load of information processing, often entailing communication between geographically different locations, and thus provides a wealth of potential applications of information technology. And in most of those applications the new technology enters as a *complement* to labor rather than as a substitute.

Of the typical head office functions, the heavy volume routines – such as accounts payable and receivable, payroll, invoicing and accounting – are usually the first that are computerized. Together with the ongoing office automation, this normally increases the demand for computer-experienced and technically skilled personnel, whereas the amount of low-skilled clerical work is reduced. A good illustration of this is provided by a major Swedish corporation. The share of routine personnel in total salaried employment was almost constant during the 1960s. But the share dropped from 52 percent in 1971 to 28 percent in 1981, due to a concentration of administrative development efforts on mechanizing manual work. No employees were laid off, however, as a direct result of the rationalizations.

Along with substantial reductions in the price/performance ratio of hardware[1], with the development of more sophisticated software, and with improvements in the techniques for data communications and data base handling, the electronics technology is finding applications also in higher managerial functions. Computerized systems for budgeting, reporting, group consolidation, cash management, financial planning and control, are becoming more and more common. Less structured functions, such as risk management and strategic planning, are frequently supported by computerized calculations and simulations. At this level of firm operations, the new technology yields faster and more reliable information flows, provides more sophisticated tools for analyses, and enables managers to concentrate on their qualified tasks (up to 95 percent of a manager's time is spent on written and verbal communication (Mintzberg, 1973)). Decisions can be based on

[1] It has been estimated that the price/performance ratio has improved by a factor of 10^6 over the last two decades (Stübner, 1981).

better data and more thorough analyses. Control of the organization is facilitated and problems can be detected and corrected more rapidly.

We underlined above that suppliers are judged not only on the basis of the price and quality of their product, but also on the efficiency of the service they offer. This has made computerized customer order receiving systems increasingly popular. These systems interlink the order entry function with, for instance, finished stock control, invoicing and the accounts receivable ledger. Aided by such a system, and equipped with a display unit, the order receiver can rapidly and accurately give information to the customer regarding prices, available quantities, options, terms of delivery, discounts, etc. More time can be spent on discussing the needs of the customer. Delivery time can be shortened and made more reliable. The result should be increased sales and customer satisfaction. Also, with direct access to the accounts receivable ledger, over-due claims on customers can be collected more effectively.

Modern information technology is increasingly being utilized also in the production process, which, as we noted above, includes many important functions other than direct physical production. Indeed, individual efficiency of most of those functions can be increased by mechanizing some of their subroutines. Engineering design is one area in which the new technology has proven to be very useful. It has been estimated that an engineering designer devotes, on average, only about one-fourth of his working hours to creative work. The rest of his time is spent on searching for information and turning out engineering documentation (such as drawings, workshop instructions, manuals and detailed product specifications). But with a computerized data base system, storage and retrieval of drawings and basic engineering data is greatly facilitated. The designer can re-utilize and reproduce information more easily, and will thus have more time and better support for his creative work. This should enable him to design products which are less costly to manufacture and more attractive to potential buyers.

5. Improving Coordination and Control

It is important to understand, however, that partial productivity gains rarely affect productivity of the whole organization to a corresponding degree. As we pointed out earlier, a capacity improvement in one activity is often "blocked" by bottle necks in other activities. In Swedish manufacturing, for example, waiting for the next operation often makes up for 90-95 percent of the throughput time from filing a production order to final shipment. Obviously, substantial productivity gains can be reaped by improving the coordination of the different functions. Table 2 indicates the effects a large Swedish corporation obtained by installing a worldwide, integrated system for automatic order processing and inventory control. It illustrates that by

Table 2. *Qualitative effects of an installation of a computerized system for order processing and inventory control*

Routine personnel	↓
Throughput time for customer orders	↓
Delivery security	↑
Relative stock levels	↓
Stock replenishment times	↓
EDP costs[a]	↓

[a] Costs for electronic data processing were cut by using inhouse computers instead of hiring service bureaus.

making information flows more efficient, modern technology has important potential effects besides labor saving.

Modern computer-based data communications systems are of particular value for the coordination and control of large, multiplant corporations. Vast quantities of data need to be transmitted over long distances from peripheral to central coordinating units, and vice versa. And the information must be processed and digested before it is passed on to the end users. Improved capabilities in those areas enable top managemet to monitor the organization more effectively from a distance.

That, in turn, can pave the way for a *decentralization* of profit responsibility. With more effective tools for controlling target fulfillment, top management can delegate a larger share of decision making. Divisionalizing, establishing profit centers and giving subsidiaries greater freedom of action are steps frequently taken to push profit thinking down the hierarchy. A divisionalization normally requires more sophisticated group budgeting and reporting systems. Therefore, computer support is often necessary for making such a reorganization workable.

In a more decentralized organization, top management can devote more time to its principal task; allocating available financial resources in such a way that long run profits are maximized. The corporation's ability to react quickly and accurately to market signals is enhanced, since decision-making becomes less bureaucratic and takes place closer to the markets. Also, decentralization normally makes it possible to relocate qualified personnel from central staff positions to more operative functions in subsidiaries and lower level profit centers.

The conclusion suggested is that the greatest productivity potential of modern information technology probably lies in improving the *coordination* of firm activities. This side of the emerging technology is usually overlooked in discussions on the impact of computerization. One problem in studying the effects mentioned in this section, however, is that they are difficult to measure properly. The aim of several, recently started micro studies at IUI (see p. 117) is to get a both theoretical and empirical grasp of the potential effects of computer-based information systems on total firm productivity.

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