
LAPPEENRANNAN TEKNILLINEN KORKEAKOULU
LAPPEENRANTA UNIVERSITY OF TECHNOLOGY

TIETEELLISIÄ JULKAISUJA 45
RESEARCH PAPERS

HANNU RANTANEN

THE EFFECTS OF PRODUCTIVITY ON PROFITABILITY

A case study at firm level using an activity-based costing approach

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Thesis for the degree of Doctor of Technology to be presented with due permission for public examination and criticism in the auditorium of the House of Student Union at Lappeenranta University of Technology (Lappeenranta, Finland) on the 4th of August, 1995, at 12 o'clock noon.

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ABSTRACT

Productivity and profitability are important concepts and measures describing the performance and success of a firm. We know that increase in productivity decreases the costs per unit produced and leads to better profitability. This common knowledge is not, however, enough in the modern business environment. Productivity improvement is one means among others for increasing the profitability of actions. There are many means to increase productivity. The use of these means presupposes operative decisions and these decisions presuppose information about the effects of these means.

Productivity improvement actions are in general made at floor level with machines, cells, activities and human beings. Profitability is most meaningful at the level of the whole firm. It has been very difficult or even impossible to analyze closely enough the economical aspects of the changes at floor level with the traditional costing systems. New ideas in accounting have only recently brought in elements which make it possible to consider these phenomena where they actually happen.

The aim of this study is to support the selection of objects for productivity improvement, and to develop a method to analyze the effects of productivity change in an activity on the profitability of a firm.

A framework for systemizing the economical management of productivity improvement is developed in this study. This framework is a systematical way with two stages to analyze the effects of productivity improvement actions in an activity on the profitability of a firm.

At the first stage of the framework, a simple selection method which is based on the worth, possibility and necessity of the improvement actions in each activity is presented. This method is called Urgency Analysis.

In the second stage it is analyzed how much a certain change of productivity in an activity affects the profitability of a firm. A theoretical calculation model with which it is possible to analyze the effects of productivity improvement in monetary values is presented. On the basis of this theoretical model a tool is made for the analysis at firm level.

The usefulness of this framework was empirically tested with the data of the profit center of one medium size Finnish firm which operates in metal industry. It is expressed that the framework provides valuable information about the economical effects of productivity improvement for supporting the management in their decision making.

Keywords: Productivity, Profitability, Activity-based costing

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Lappeenranta, June 1995.

Hannu Rantala

CONTENTS

LIST OF SYMBOLS

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a	Coefficient which expresses the importance of worth (W)
AC_{kj}	Activity cost of product k in activity j
b	Coefficient which expresses the importance of possibility (P)
c	Coefficient which expresses the importance of necessity (N)
C	Sum of capital inputs
C_j	Capacity of activity j in a period
CA_j	Cost per activity measure unit in activity j
ΔCA_j	Change of cost per activity measure unit in activity j
CU_j	Capacity utilization of activity j
DC_k	All activity product costs of product k excluding the cost of activity j
E	Sum of energy inputs
EC_j	Excess or free capacity in activity j in a period
g	Change of total productivity , (100 · g) percent
h_k	Change of the quantity or amount of activity measure units that product k uses in activity j, (100 · h_k) percent
i	Input factor i, i = 1...n, (resource or another activity, presented also by labels of input factor; T, L, C, M, E, X or Z)
I	Amount of input factor in a period (indicated in equations by label of input factor; T, L, C, M, E, X or Z)
I_{ij}	Amount of input factor i in activity j in a period
j	Activity j, j = 1...m
k	Product k, k = 1...p
L	Sum of labor inputs
L_k	Production quantity or amount of product k in a period
M	Sum of material inputs
MC_j	Material costs of activity j in a period
MC_k	Material costs of product k
MC_{kj}	Material costs of product k in activity j
N	Necessity of improvement actions
NC	Sum of the costs which are not assigned to any activity
O	Amount of output in a period
O_j	Amount of the output of activity j in a period
P	Possibility of improvement actions
P1,P2	Calculation periods (indicated in equations by numbers 1 and 2)

ΔPC	Change of product cost (unit cost)
PC_k	Product cost of product k
ΔPC_k	Change of product cost of product k
PC_{kj}	Activity product cost of product k in activity j
ΔPC_{kj}	Change of activity product cost of product k in activity j
PD	Productivity (sometimes indicated in equations by label of input factor; T, L, C, M, E, X or Z)
ΔPD	Change of productivity
ΔPD_j	Change of productivity in activity j
PF	Profit of a firm in a period
ΔPF	Change of profit of a firm
PF_k	Profit of product k
ΔPF_k	Change of profit of product k
PR_i	Price of input factor i
PR_k	Price of product k
TC_j	Total costs of activity j in a period
TT_j	Throughput time in activity j
UP	Urgency point
V_j	Volume of activity j in a period measured by activity measure
W	Worth of improvement actions
X	Sum of other inputs
Y_{kj}	Quantity or amount of activity measure units that one unit of product k uses in activity j
z	Change of productivity of input Z , (100 • z) percent

1. INTRODUCTION

1.1. Background

Productivity has gained increasing importance in public discussion in recent years. Until the 1980s Finnish industry developed mostly by increasing the use of resources. This is no longer possible, or even reasonable, for example from the environmental point of view. In the long run, increasing productivity is perhaps the only meaningful way[1] to develop industry and enhance the prosperity of citizens.

Productivity and profitability are important concepts and measures describing the performance and successfulness of a firm. Common sense tells us that there has to be a relationship between these two. We can acknowledge that increases in productivity decrease the costs per unit produced and leads to better profitability. This common knowledge is not, however, enough in the modern business environment. We might know some examples where the profitability of a firm is handsome but productivity is poor, or a firm with high productivity is not profitable. Thus the relationship between productivity and profitability at firm level is not clear and fixed (see e.g. Leinonen 1993, p. 66 or Rantanen 1992 p. 2-4). There are many factors, internal or external, which can obscure this relationship.

When companies earn a reasonable overall margin, they often do not worry about the margins individual products make (Cooper 1989, p. 81). Unfortunately in the modern business environment of metal industry competition is so hard and the changes so fast that a big overall margin is very difficult to achieve for a long time. The firms must concentrate on the profitability of operations and products all the time. This presupposes for example cost efficiency and developing production and management systems almost continually. The aim of every manufacturing unit should be to organize their

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[1] In the short run the increase of the use of human resources is also a meaningful way to develop industry. In the present recession the large unemployment makes it difficult to improve the prosperity of citizens.

operations so that they can use their resources efficiently to produce products which are competitive with regard to costs, quality and timing (e.g. Uusi-Rauva 1989, p. 17).

Productivity improvement is one means among others of increasing the profitability of actions. There are very many means of increasing productivity. The use of these means presupposes operative decisions, and these decisions presuppose information about the effects of these means. If we accept the fact that profitability is the most important objective in the operation of a firm, we also accept that information about the effects of productivity improvement actions on profitability is the most important kind of information we can have.

There are many models in the literature for analyzing the effects of different factors on the costs and profit of a firm. For example variance analysis with sales activity, price recovery and productivity, and total-factor productivity measurement (TFPM) models are some of these (see e.g. Kaplan & Atkinson 1989, pp. 321-350, Horngren & Foster & Datar 1994, pp. 753-782 or Pineda 1990, p. 2). These models often approach the problem from the point of view of different kinds of costs.

The problem with these models is that they do not usually operate on a relevant level of actions. Productivity improvement actions are in general made at floor level with machines, cells, activities and people. This is the level where productivity should be influenced and measured. Profitability is most meaningful at the level of the whole firm. Another problem is how to unite the properties of two different processes in a firm. Productivity reflects the performance of the real process of a firm, whereas profitability is a property of the monetary process. In addition to this, the traditional costing systems set their own restrictions to this problem. It has been very difficult or even impossible to analyze the economical aspects closely enough at floor level. New ideas in accounting have only recently brought in elements which make it possible to consider these properties where they actually appear.

Before considering the question about the effects of productivity improvement actions, the management should have a few others. Which are the objects of improvement actions and how can they be improved? What is the source of ideas for improvement? Is the basis for improvement investments the list of defects in the order of appearance or is there some systematic way to plan and realize the improvement projects?

On the basis of the points above we can claim that this area is rather wide and problematic. For instance in metal industry and in manufacturing of individual products, it is not meaningful or even possible to analyze all areas and all activities in the production process. It is obvious that there is a real need for a systematic tool to analyze the activities. In addition to this there is also a need for additional and especially more accurate information about the relationship between productivity and profitability and tools for managing manufacturing processes on the basis of this information.

1.2. Scope and objectives

We know that productivity improvement decreases the costs per unit produced and this can lead to better profitability. Productivity improvement is usually done at floor level e.g. in the activities. The scope of this study is the change of productivity in an activity and the economical effects of this change. This contains the changes both in total productivity and in partial productivities. The scope of this study can be described as in figure 1.1. There the goal of a firm's operation is profitability. Productivity improvement is one means among many others to increase the profitability of operation. Productivity improvement happens at floor level and here the objects are those improvement actions which are made in the activities. The aim is to produce information about the effects of productivity improvement in the activities on the profitability of the firm and for the basis of the selection of improvement objects. The information is important both before and after improvement actions. Information is needed beforehand for selecting the improvement

object. After these improvement actions, it is valuable to analyze the realized effects and how these differ from the effects forecasted and why.

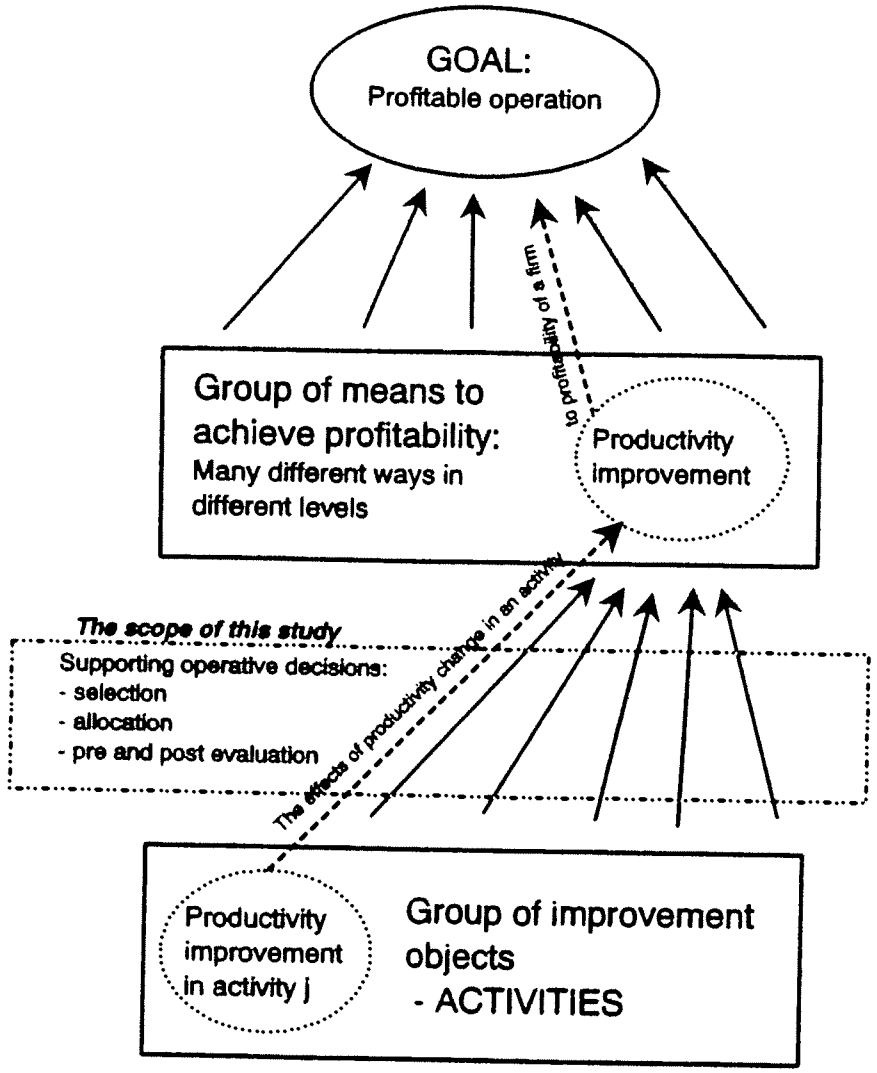

Figure 1.1. The scope of this study.

More generally the scope of this study can be defined as comprising both productivity and profitability at firm level. The relationship between productivity and profitability at firm level is often described by models. These models are largely total-factor productivity measurement (TFPM) models. This study can also be defined as belonging to the TFPM models. TFPM, according

to Pineda (1990, p. 13), directly measures and relates productivity with profitability and uses dynamic productivity ratios and their effects on profitability in dollars. About the models he (p. 14) has said that "the TFPM model deals with the mathematical concepts, relationships, and derivations. This model is the theoretical basis for the set of methods, principles, and rules or the methodology for doing Total-Factor Productivity Measurement."

In this study activity-based costing (ABC) is used as an environment for the framework developing. It is a good tool for connecting the effects of productivity in an activity on the profitability of a firm. ABC is the way to get sufficient cost information about the activitles and to utilize it in the continuous improving process of production. Activity-based management (ABM) guides us for focusing on the value added and non-value added activities.

The aim of this study is to support the selection of objects for productivity improvement, and to develop a method for analyzing the effects of productivity change in an activity on the profitability of a firm. So the objective is to create a systematic way to manage and control the productivity improvement from the economic point of view. That means also creating a tool for producing information about the effects of productivity improvement for supporting the management decision making. The second objective of this study is to evaluate the functioning of this method and the tool developed in practice. The objectives of this study can be classified on two levels as follows:

Main objective:

1. Create a framework for economic management and control of the productivity improvement.

Subordinate objectives:

2. Evaluate the functioning of the framework in different kinds of environments.

3. Evaluate the effects of individual factors in production to the functioning of the framework.

The scope of this study is very important but also very problematic and even thankless. There are several factors affecting the profitability of a firm. It is very difficult to separate the effects of one specific factor from the effects of the others. To construct a model which describes the effects of productivity change on the profitability of a firm, many limitations and assumptions are needed. The increasing amount of limitations reduce the operativity of the model in practice. One purpose of this study is to find out whether it is possible to find a balance between the limitations and relevance.

1.3. Research strategy and methodology

The main objective of this study is to create a framework for the economic management and control of productivity improvement. This means the construction of a systematic way to manage and control the productivity improvement from the economic point of view. The aim is to support the management in their decision making. So the research strategy can be determined as decision oriented.

In the literature there are many different classifications for research strategies or approaches. According to the classification often used in Finnish accounting research (see for example Neilimo & Näsi 1980, p. 33 or Näsi 1983, p. 37) this study can be defined as a decision making methodological approach[2]. When the main contribution of a study is the development of a theory, method or model, the need for large empirical testing of the hypothesis is small.

Studies which concentrate on one or a few empirical cases for testing the ideas developed or for searching better understanding about the object of research are called case studies[3]. What is needed in a case study? Ryan, Scapens & Theobald (1992, p. 121) have said: "What is needed is a case

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[2] The name of the approach translated by the present author.

[3] More about case study research can be found e.g. in the books of Robert K. Yin (1989) or Ryan, Scapens & Theobald (1992).

within the relevant area which will enable the researcher to begin the process of theory development." Multiple case study has more than one case and the objective of such multiple cases is to develop a rich theoretical framework, capable of explaining a wide range of circumstances (see Ryan, Scapens & Theobald 1992, p. 121).

There are many steps in a case study. For example Ryan, Scapens & Theobald (1992, p. 122-124) give six different steps. These are preparation, collecting evidence, assessing evidence, identifying and explaining patterns, theory development, and report writing. They have also described the order in which to realize a case study as follows:

> ".. case study is a complex interactive process which cannot be characterized by simple linear model. In the course of a case study, the researcher may have to iterate through these steps many times, possibly in different orders and with different interactions between the individual steps."(Ryan, Scapens & Theobald 1992, p. 122).

So the present study can also be defined as a decision oriented case study. Because of the four case activities used in the empirical part of this study it is also possible to call it a multiple case study. The purpose of the cases is practical testing of the operativity of the framework developed in the theory. There is no strive to generalize the usefulness of the framework or the calculation model and find evidence to support it. The understanding approach which is often enclosed in case studies is lacking in this study.

1.4. Terminology and limitations

Some phenomena described and terms used in this study are best to explained right away. These terms are considered in greater detail later in this study. There are many ways to define and understand these terms. In this study the following definitions are used:

Productivity is a measure of a firm's ability to utilize its inputs to make as much output as possible.

Profitability is the ability of a firm to produce profit.

Activity is a combination of people, technology, raw materials, methods, and environment that produces a given product or service.

Framework is a basic structure of ideas presented.

Model is a combination of mathematical equations describing the problem under consideration.

Tool is a means to realize the model in practice, for example a software made for computer.

It is also important to define here the main limitations made in this study. The change of productivity in one activity is in the scope of this study. The simultaneous changes somewhere else in production are eliminated from the analysis. This means the assumption of ceteris paribus. Only the effects of one change at a time in production are considered here. The other functions of the firm, like sales and marketing, are restricted from the framework.

The calculation model developed here doesn't include the increase in the quality of product as an increase of productivity. The price of the product is assumed to be constant.

Profitability of operations is assumed to be the main objective of the management. Profit maximization may not be a good description of individual decision making practices (see e.g. Ryan, Scapens & Theobald 1992, p. 45). However, at firm level it is a reasonable goal of operation. The improvement of productivity has been seen as one means among others for achieving profitability.

Since the end of the 1970s it has been recognized that accounting cannot give an exactly correct solution to managers' decision problems. Accounting information needs to be used with caution and together with other sources of information (see e.g. Ryan, Scapens & Theobald 1992, p. 53).

1.5. Outline

This study consists of theoretical background (chapters 2-4), construction of theoretical framework (chapter 5), empirical testing of this framework (chapter 6) and discussion and conclusions (chapters 7-8). The contents of these chapters is briefly reviewed here.

The main purpose of chapter 2 is to have a closer look at productivity and profitability in a firm. To understand the relationship between these two, it is important to understand the substance of both. In chapter 2.1. there is a survey on the nature of productivity. The concept of productivity, the approaches to productivity and total and partial productivities are presented. The measurement of productivity and productivity management have been also considered. The focus is on the firm level. In chapter 2.2. there is a short review of the concept and measurement of profitability at the firm level. Profitability is dealt with in this connection only to the extent which is needed for the purposes of this study.

In chapter 3 there is a short overview of the effects of productivity on profitability at firm level. Productivity and profitability are both measures of performance and successfulness of an organization (and in this context of a firm). In spite of the fact that they are close to each other, they approach evaluation from different directions. Productivity reflects the performance of the real process of a firm, whereas profitability is a property of the monetary process.

Chapter 4 takes a look at activity-based costing (ABC). There is a short review of the principles of ABC (chapter 4.1.) and activity-based management (ABM) (chapter 4.2.). ABC is handled here only to the extent that is needed for the purposes of this study. After that the usefulness of ABC in analyzing the effects of productivity change on profitability is discussed briefly (chapter 4.3.).

Chapter 5 deals with the construction of the theoretical framework for the economic management and control of productivity improvement. First (chapter 5.1) the background of the framework in general is discussed. It is argued that it is better to do the analysis in two stages. The first stage which concerns the selection of the activities for deeper analysis, is presented in chapter 5.2. For the purposes of selection a simple selection method called Urgency Analysis is presented. In chapter 5.3. the theoretical foundations for stage two are presented by means of a theoretical calculation model. This model shows how it is possible to calculate the effects of the change of productivity in an activity on the profitability of a firm. After that (chapter 5.4.) the structure of the theoretical framework is introduced.

In chapter 6 the results of the empirical test of the framework are presented. The framework is tested with the data from one medium size Finnish firm operating in metal industry. In chapter 6.2. the use of Urgency Analysis in the production function of a profit center is presented. It is showed that it is an operative tool in selecting the objects for a deeper analysis of the effects of productivity improvement. In chapter 6.3. the operativity of the theoretical calculation model is tested. The economical effects of productivity increase in four case activities are calculated using a tool constructed with Microsoft Excel. The tool which is based on the theoretical model, provides additional information about the economical effects of productivity improvement to support management decision making. In chapter 6.4. the problems and restrictive elements perceived during the empirical part of the study are analyzed.

In chapter 7 the benefits and limitations of this study are considered. First the limitations and problems are presented. After that the benefits and the contribution of this study are stated. In chapter 7.2. there are conclusions and some recommendations for further study. Chapter 8 is the summary of this dissertation.

2. PRODUCTIVITY AND PROFITABILITY IN A FIRM

Productivity and profitability are concepts and measures which describe the performance and successfulness of a firm. Common sense tells us that there has to be a relationship between productivity and profitability. This relationship is not clear and fixed. There are many factors, internal or external, which can obscure this relationship.

The profits (profitability) of a firm can grow in many ways. The affecting factors can be e.g. new products, new markets and trends in economic activity. However, the profit (profitability) per unit produced can be increased only in two ways (see Fenton 1985, p. 92). The first is increasing the selling price of output faster than the input prices are being increased. The second way is to make better use of the physical inputs, converting these inputs to physical outputs with increasing efficiency. This means in other words increasing productivity. This better use of physical inputs might be seen as a decrease of costs, but not always. Sometimes high productivity and cost reduction may be contrary to a company's goal of profit maximization (Doost 1989, p. 39).

On the other hand, it is possible that the profitability of a firm is handsome but the productivity is poor (see e.g. Chew 1988, p. 110), or a firm with high productivity is not profitable. This question about why productivity and profits do not go hand in hand is sometimes called a "productivity paradox" (see e.g. Young K. Song 1990, p. 38).

In general the relationship between productivity and profitability can be described by using Donald J. Wait's (1980, p. 27) words:

> "However, changes in productivity are basic determinants of changes in costs, in productive capacity and of the potential benefits of changes on product mix - all bearing significantly on enterprise profitability. Profits represent the 'bottom line' financial measure in a business enterprise while productivity measures represent the 'bottom line' physical measurement independent of costs and prices in the market place."

Next, we take a closer look at productivity and profitability in a firm. In chapter 2.1. there is a survey on the nature of productivity. This contains the concept of productivity, the approaches to productivity and the total and partial productivities. There is also a little about productivity measurement and management. The focus is on the firm level. In chapter 2.2. there is a short review of the concept and measurement of profitability. Profitability in handled here only to the extent that is needed for the purposes of this study.

2.1. Productivity in a firm

When we have productivity under examination we must always keep the concept of productivity and the measures of productivity separate. The "concept" of productivity includes among others things like, how the word productivity is understood in different connections, how it is determined theoretically, and how to formulate it mathematically. When the measures and measurement of productivity are dealt with it is important to discuss also problems related to measurement.

Changes of productivity can be measured on different levels of economy. The real changes are, however, mostly carried out at the level of individual work and machines in the firms. That is why the measurement and improvement of productivity usually has to happen at that level[1]. However we must always keep in mind that productivity or an increase of productivity is not the final aim of operation. These are only a way to strive for the profitable action of a firm. Unfortunately the lack of overall outlook when new solutions are adopted is a problem e.g. in Finnish metal and engineering industry (see Eloranta & Räisänen 1986, p. 13). This might cause suboptimization on the organization level while maximizing an individual area, department or function (Ostrenga 1990, p. 46).

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[1] Significant improvements in the overall productivity trend can be made if productivity improvement actions are taken at the individual business level (Wait 1980, p. 25).

Increasing productivity is important for many reasons. It is possible to describe the advantages of productivity increase as Mammone (1980, p. 36) has done:

> "Improved productivity would result in higher wages to labor, more jobs and incremental gains in standards of living; greater profits for management through greater output at reduced costs; and lower prices to consumers."

At firm level the increase of productivity means inter alia slowing down the progress of cost level, improvement of price competitiveness, improvement in the ability to pay salaries, and money for the development of the firm and for environmental control.

2.1.1. The concept of productivity

Productivity is a rather common and confused concept (see e.g. Ghobadian & Husband 1990, p. 1435). It is used by economists, politicians, engineers, consultants etc. They all have their own idea about the nature of productivity. Below, there is review of how productivity is defined in literature and on which levels it is examined. Some other concepts which are close to productivity are also described.

Originally the concept of productivity comes from agriculture. It means how much harvest is received from a certain area of land[2]. In general productivity means the ability to be productive or ability to produce. In the economic literature the word "productivity" was mentioned the first time in an article by Quesnay in 1766. More than a century later, in 1883, Littre defined productivity as the "faculty to produce" (Sumanth 1984, p 3.). Also Adam Smith, in 1776, and David Ricardo, in 1817, (see e.g Fenton 1985, p. 11-13) have dealt with productivity[3] in their writings. The main objects of their work

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[2] More about words behind productivity can be found e.g in "The Oxford English Dictionary" (Simpson & Weiner 1989, p. 568) and "Dictionary of Scientific and Technical Terms" (Lapedes 1974, p. 1174).

[3] Actually Fenton (1985, p. 11) noted that Adam Smith never used the term productivity.

was labor and capital as productive powers. An interesting point was the substitution of labor and capital for each other.

During the last two decades of the nineteenth century reigned the "Scientific management" movement, which started in metal fabricating companies. The goal of the scientific management engineers, such as Frederic Taylor, was to improve the efficiency and utilization of labor and materials (Johnson & Kaplan 1987, p. 10). They determined "scientific" standards for the amount of labor and material required to produce a given unit of output. These standards were used to provide a basis for paying workers on a piece-work basis, and to determine bonuses for workers who were highly productive (Kaplan 1984a, p. 393).

In this century the word *productivity* has established its positions in the economic discussion. The term productivity has been defined in many ways in the 1900s. There is an abundance[4] of different kinds of definitions in the literature of this area. In general it is possible to divide the definitions of productivity into two categories (see Rantanen 1992, p. 4). The first one includes the verbal definitions which broadly describe the nature of productivity. The other category consists of those definitions which verbally describe the formal or mathematical way of presenting productivity.

Some of the definitions in the first category are rather broad. For example the European Productivity Agency conference in Rome 1958 defined productivity inter alia as a "way to think" and "belief in human progress" (e.g. Välitalo 1989, p. 10). One of the narrowest definitions is the one where productivity is considered equal to labor productivity and it is defined as the workers' ability to produce output. Usually the economic or production level under examination affects definition of the concept. Most often these definitions highlight the efficiency of the production process (see e.g. Lehmus 1976, p.

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[4] About the variety of definition tells also the fact that in the ANSI standard there are different definitions of productivity in the six sub-areas of industrial engineering (ANSI Standard Z94.0-1989).

2 or Chew 1986, p. 47) or the relationship between the outputs and inputs (see e.g. Craig and Harris 1973, p. 14 or Ammer & Ammer 1984, p. 369).

One of the outstanding persons in the field of productivity research at present, D. Scott Sink (1985, p. 3), has illustrated his opinion about productivity as shown in figure 2.1. and he has defined it verbally as follows:

> "Productivity is simply the relationship between the outputs generated from a system and the inputs provided to create those outputs. Inputs in the general form of labor (human resources), capital (physical and financial capital assets), energy, materials, and data are brought into a system. These resources are transformed into outputs (goods and services). Productivity is the relationship of the amount produced by a given system during a given period of time, and the quantity of resources consumed to create or produce those outputs over the same period of time."

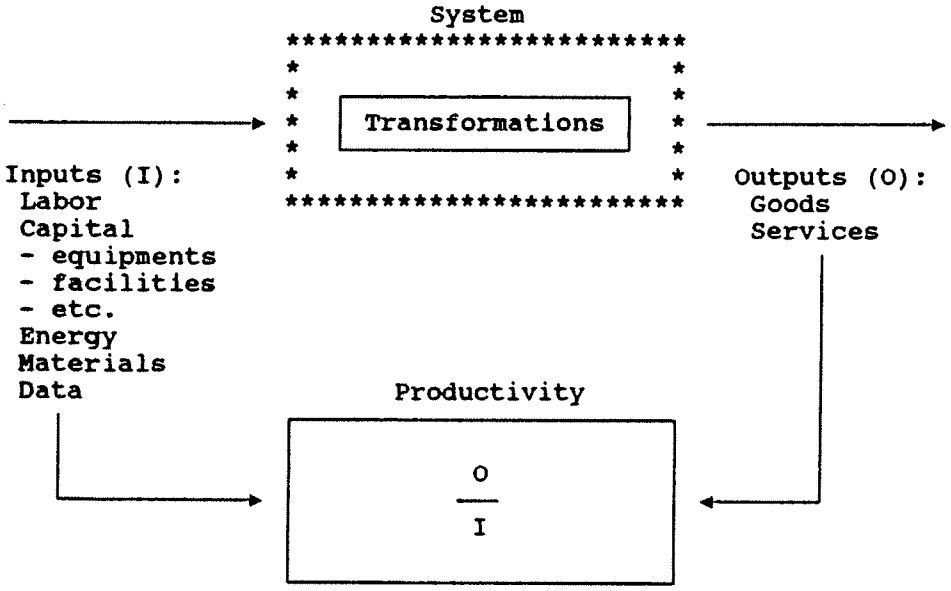

Figure 2.1. General Productivity Concept.

Almost all definitions of productivity formulate it as follows:

$$Productivity = \frac{Output}{Input} \qquad (2.1.)$$

Brozik (1984, p. 7) has presented an extension for this general formulation of productivity. He has stated

> "The basic definition of productivity only concerns the relationship between inputs and outputs, and formulations other than ratios are conceptually possible e.g. (Inputs - Output)."

Productivity thus comprises the relationship of outputs and inputs or production process. What are these outputs and inputs? The content of these depends on the level under examination.

At the firm level the output consists of all that the firm produces during a given period of time. There is no distinction made on the basis of whether the product is made for sale, or for internal use, or whether these are finished goods or work in process. If the output is expressed as money value, it is sometimes possible to join the monetary incomes[5] to it (see e.g. Sumanth 1984, p. 153). The inputs can be divided to groups e.g. as follows; labor, capital, material, energy and other inputs (see e.g. Sink 1985, p. 3 or Sumanth 1984, p. 154). Kendrick (1977, p. 15-16) divided inputs only into two groups, human and non-human, when he considered productivity at the national level. Usually the outputs and inputs are expressed as quantities or values. Sometimes it is also possible to connect the quality aspect to the definition of productivity (see e.g. Rationalisointineuvottelukunta 1988, p. 23)

There are also some other concepts which are near productivity. Among others concepts, effectiveness and efficiency are considered equal to productivity. For example Sink (1985, p. 64) states these both with quality as prerequisites of productivity. For specifying these we can use the following definitions (Horngren & Foster 1987, p. 184):

Effectiveness	the degree to which a predetermined objective or target is met
Efficiency	the degree to which inputs are used in relation to a given level of outputs.

[5] Monetary incomes mean here the sum of dividend from securities, interest from bonds and other incomes.

In the literature effectiveness is defined rather unanimously (compare e.g. Sumanth 1984, p. 6, Sink 1985, p. 42, or Ostrenga 1990, p. 47). In the definition of efficiency there is a little variation. Sumanth and Sink have also stressed the utilization of inputs, like Horngren and Foster. Laitinen (1989a, p. 222) has defined efficiency as the rate of discount which makes the discounted amount of produced outputs equal to the inputs needed in production. He has also used terms *productive efficiency* and *economic efficiency* (Laitinen 1989, p. 195-196).

In recent years the scope of the concept *productivity* has extended. New areas of productivity are e.g. social productivity (see e.g. Kurosawa 1991, p. 22 or McDermott, 1994) and green productivity (see e.g. Shih 1994). These both concern with the "soft" part of productivity.

2.1.2. Approaches to productivity

As mentioned above the definition of productivity and how productivity is understood depend on the level under examination. What are these levels? Sumanth (1979, p. 2.1 and 1984, p. 57) among others has presented one basic division on the levels for examining productivity. There are four different levels; international, national, industry and company (firm) level. The international level is the most contradictory of these. Sumanth deals with e.g. comparisons between competing countries in this level. Most of the writers include the international level in the national level. The three other levels presented by Sumanth are analogous with the other writers.

The firm level is often divided into different sub-levels for the sake of simplicity (see e.g. Sumanth 1979, p. 2.1 or Rationalisointineuvottelukunta 1988, p. 8). Because the real changes of productivity are mostly carried out at the level of individual work and machines in the firms, it is reasonable to handle that level as its own. Lehmus (1976, p. 1) has also handled the level

of the individual as its own. It is possible to summarize the division of levels as follows (Rantanen 1992b, p. 8):

National
Industry
Firm
Individual human / activity

The way of how to understand, examine and express productivity depends not only on the level but, also on the perspective that one has. The perspective depends on education, work, view of life, public information and other things like these. It is clear that a politician understands productivity in an other way than a lawyer or an economist. In spite of the different kinds of emphasis the basic idea of productivity should be the same for all the groups of people. Sink (1985, p. 3) has stated the same as follows:

> "Regardless of perspective (political, economic, psychological, engineering, managerial, and so fort), the basic definition for productivity always remains the same. What does change, based on perspective, are the boundaries, size, type, and scope of the system being examined".

If we put together the level and perspective, we can consider how it is possible to understand, examine and express productivity on different levels. Here this question is discussed from an academic and research oriented point of view (see Rantanen 1992a, p. 23-25 and 1992b, p. 9-11).

At the **national level** productivity is mostly examined by the economists (see e.g. Sumanth 1979, p. 2.2 and 2.9). The background of considerations is usually the neoclassical theory of production[6] (see e.g. Karko 1983a, p. 39 or Karhu & Vainiomäki 1985, p. 7). In the theory of production a given factor-product transformation process can be described by a production function (Naylor & Vernon 1969, p. 70). The theory of production makes it possible to

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[6] Classical economists (such as Smith and Ricardo) founded their economics on a theory of value based on the notation of production surplus. Neoclassical economists shifted the emphasis from value to utility and from production to demand (see Ryan & Scapens & Theobald 1992, p. 56).

generate for example index theories[7] which are used in analyzing productivity. At the national level it is usually necessary to simplify the problem under examination. In many cases there is oversimplifying, which leads to a uselessness of the results from the point of view of the individual firm and management (see e.g. Okpokwasili 1984, p. 135-136).

On the **industry level** the economists usually use three basic approaches in measuring productivity. These are the index approach, the production function approach and the input-output approach (see Sumanth 1984, p. 77). The approaches are here mainly the same as on the national level. There are also other possible approaches for the industry level. These are based on studies made in specific sectors and development of the methods used in practice. At the industry level it is also possible to use the same approaches and methods as on the firm level. For example the financial ratios approach is possible if the objects and questions of study presume that (see e.g. Rantanen 1992a).

On the **firm level** and its sub-levels there are many different approaches to productivity. Sumanth (1979, p. 2.54 and 1984, p. 98) has presented an interesting classification of approaches in measuring[8] productivity at the firm level. There the approaches are classified on the basis of the occupation of the person analyzing. This classification is as follows:

Economists:	- Index approach - Production Function approach - Input-Output approach
Engineers:	- Index approach - Utility approach - Servo-system approach

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[7] The purpose if index theories is to provide, in a world of different priced and heterogeneous products, functions which describe as well as possible the progress of general price level and total amount of individual products (Karko 1983b, p. 26).

[8] Hawaleshka and Mohammed (1987) have also classified the approaches to productivity measurement based on four criteria. They found five basic categories of industrial productivity measures. These are handled in chapter 2.1.5.

Managers:	- Array approach - Financial Ratios approach
Accountants:	- Capital Budgeting approach - Unit Cost approach

A good review about these approaches is made in Sumanth's dissertation (1979, p. 2.54-2.79) and there is no need to repeat it totally here. It might be reasonable, however, to take a closer look at some of these approaches.

Index approach is an approach were productivity at different points of time is expressed with index numbers. There is a large number of productivity models which can be classified to this group (see e.g. Sumanth 1984, p. 99-112). Some of these models can be also classified as total-factor productivity measurement models (see Pineda 1990, p. 2).

Production function approach is very extensively used by economists. Their basic approach has been developing some kind of a general mathematical expression for output as a function of input factors, by combining observation, economic theory[9]. and mathematics. Sumanth (1984, p. 112-113) divides this approach to three distinct areas of research appearing in literature. These are the pure theory of production functions, the econometric theory of production functions and the applied econometrics theory of production functions. In Finland, Simula (1983) has used this pure theory of production functions. He has examined the productivity differential in Finnish forest industry. In the literature it is stated that the production functions have been principally used to gain insight into the national productivity. However the concept is equally applicable to the individual firm (Fenton 1985, p. 16 or Ghobadian & Husband 1990, p. 1437).

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[9] Most of the production functions used by economists are based on the neoclassical theory of production. In the German literature, there emerged new ideas about the theory of production in the middle 1900's. Erich Gutenberg and Edmund Heinen developed general production models from the models used in firms. These general models are called B and C type theories of production. Limited relationships between factors of production, possibility to adapt the production to time, capacity and quantity of production and domination by machines in production are characteristic for these theories. Neilimo has considered these theories of production broadly in his studies (1972 and 1979). See also Riistama 1969.

Financial Ratios approach is the way where the productivity of a company is considered as a component of a financial ratio. Ratios such as rate of return on investment (ROI) (see e.g. Soini 1991) and (current assets) / (current liabilities) (see Sumanth 1984, p. 117) are often used. Maybe the best known example of financial ratios approach is Gold's model. Gold divided the rate of return on investment into five specific elements of performance (see e.g. Gold 1973 or 1979). This model is considered in chapter 2.4.1. Another example is Aggarwal's model (see Sumanth 1984, p. 118), in which a composite productivity index based on four financial ratios is proposed.

At the **individual human** or **activity level**, the academic research is restricted to the general features of work or production. There are plenty of studies which concern labor productivity, both white and blue collar. There is also much research done concerning advanced manufacturing technologies and philosophies such as JIT, CIM or MRP II. The problem with the academic research at this level is that human beings are individuals and their working environments rarely equal. This level has been under examination in the firms.

2.1.3. Total productivity and partial productivities

Irrespective of the perspective or level under examination there are always two basic types[10] of productivity. These are total productivity and partial productivity. The measures of productivity do not follow this classification. They are very often something like partial output per partial input. **Total productivity** is the ratio of total output to the sum of all input factors. Total productivity measure reflects the joint impact of all the inputs in producing the output (Sumanth 1984, p. 7). Total productivity can be presented for example as follows[11]:

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[10] Sumanth (1984, p. 7) has stated that there are three basic types of productivity. The third according him is total-factor productivity. This is the ratio of net output to the sum of associated labor and capital inputs. In the connection of productivity measurement some (see e.g. Hawaleshka & Mohamed 1987, p. 133) have used the name "multifactor productivity" about measures like this.

[11] In the different references there is some variation in the quantity and the names of inputs included. Labor (human), capital and material are always there.

$$PD_T = \frac{O}{L + C + M + E + X} \qquad (2.2.)$$

where:

PD_T	= total productivity
O	= total output
L	= sum of labor inputs
C	= sum of capital inputs
M	= sum of material inputs
E	= sum of energy input
X	= sum of other inputs

Change in total productivity means the part of the total growth of outputs which cannot be explained by the growth of inputs. The growth in the use of inputs explains usually a smaller part of output growth than increase in total productivity (see e.g. Okko 1985, p. 57-58).

Partial productivity means the ratio of total output to one class of input. It describes the efficiency of the use of one input factor. Labor productivity is the best known type of partial productivity. Increase in partial productivity means that the use of this input is more efficient than earlier. Changes in partial productivities can be substituted for each other. For example investing in new machines can increase labor productivity if the quantity of labor remains unchanged. At the same time capital productivity may decrease[12]. This also means that partial productivity measures do not tell the whole story about change in the total efficiency of a firm. It is possible to calculate partial productivities for every remarkable resource in the system under examination. Usually partial productivities are calculated e.g. for labor, capital, energy and material. Sometimes also the other inputs (expense) productivity is used (see e.g. Sink 1985, p. 8). Partial productivities can be formulated for example as follows:

[12] It is known that in the short run new capital reduces total productivity, but in the long run it is an important source of productivity growth (see e.g. Chew 1986, p. 1).

Labor productivity

$$PD_L = \frac{O}{L} \qquad (2.3.)$$

where:
PD_L = labor productivity
O = total output
L = sum of labor inputs

Capital productivity

$$PD_C = \frac{O}{C} \qquad (2.4.)$$

where:
PD_C = capital productivity
C = sum of capital inputs

Total productivity and partial productivities can be compounded so that the sum of partial productivities as reversed is equal to total productivity as reversed. This can be expressed as follows:

$$\frac{1}{PD_T} = \frac{L}{O} + \frac{C}{O} + \frac{M}{O} + \frac{E}{O} + \frac{X}{O} \qquad (2.5.)$$

This equation describes how total productivity changes when one or more partial productivities change. On the other hand, total productivity may stay unchanged if the changes in partial productivities compensate for each other.

2.1.4. Productivity management

Productivity management is a process where the productivity of the object under examination is evaluated, improved and controlled. This process includes the following parts: (1) measuring and evaluating productivity, (2) planning for control and improvement of productivity based on information

provided by the measurement and evaluation process, (3) making control and improvement interventions, and (4) measuring and evaluating the impact of these interventions (Sink 1985, p. 23).

For productivity management a formal definition is proposed as follows (see Sumanth 1984, p. 51):

> Productivity management is a *formal* management process involving all levels of *management* and *employees* with the ultimate objective of reducing the *cost* of manufacturing, distributing, and selling of a product or service through an *integration* of the four phases of the productivity cycle, namely, productivity measurement, evaluating, planning, and improvement.

The five key elements (italicized) in this definition are: formal, management, employees, cost and integration. Management sets up the objectives and structures. Both management and employees strive for these objectives. The objective is the reduction of product cost or service cost. Integration means that productivity measurement and improvement need to integrate with productivity evaluation and planning[13].

Productivity management cannot be a separate process. It must be connected to the firm's overall management and information system at least in two points. Productivity management needs information from the firm's information system and it provides information from management to the firm's information system. The main objective of productivity management is to lead and control the productivity improvement actions. The main objective of these actions is reducing costs per unit of the product or service produced and via that achieving sufficient profitability in all the actions of the firm. Increasing productivity is only one way among others to affect the profitability of a firm.

The increase (or change) in productivity can be considered in many ways. Sink (1985, p. 26) has stated that productivity improvement will occur if any of the following conditions are made to exist:

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[13] Sumanth (1979, p. 3.4-3.6) has presented a productivity cycle or MEPI process which includes four stages: measurement, evaluation, planning and improvement.

1. Output increases; input decreases.
2. Output increases; input remains constant.
3. Output increases; input increases, but at a lower rate.
4. Output remains constant; input decreases.
5. Output decreases; input decreases, but at a more rapid rate.

On the other hand a change in productivity can be of two kind;

I) Change in efficiency which emerges without any structural changes in the object under examination. This means better use of existing resources.

II) Change in efficiency which emerges due to the structural change in the object under examination. This means the use of new resources or withdrawal from existing resources.

In the first group the reasons for change can be for example new methods for work, new principles of action or increased working motivation due to new form of payment. This kind of productivity increase is progress with small steps. Usually it is not necessary to do any capital investment when improving productivity (see e.g. Kotiranta & Molander 1993, s. 75).

In the second group there are for example capital investments (or divestments) which cause the structural change. In this case there is always change in the level of output and input. In these structural changes it is important to verify that capital investment does not cause decrease in total productivity. Pure capital investment to increase productivity is very uncommon. Usually there are also some kind of changes in methods or working conditions. That is why it is possible to say that a third group of productivity changes is the combination of both major types of change. This third type is very common in the connection of active productivity improvement.

Productivity improvement can also be seen from different perspectives of time. Robert H. Hayes and Steven C. Wheelwright have considered productivity improvement process in their book "Restoring our Competitive Edge" (1984, s. 6-7) from three different term of time points of view. There are clear

points of contact between this and the considerations above. They state that managers can increase efficiency through a combination of three basic approaches:

1. Short term. Use existing assets more efficiently on existing products; this requires toughness, determination and attention to detail.

2. Medium term. Substitute a new set of resources for existing ones - such as equipment for labor, or high-skilled labor for less-skilled labor; this requires capital and willingness to take financial risks.

3. Long term. Develop new products and processes that readdress the same sequence of decisions at a higher level of productivity; this requires both imagination and daring.

All these are means to improve a firms overall performance. To achieve predetermined goals of a firm, the development of productivity management system must be extended to all levels and time horizons in the firm.

2.1.5. Measurement of productivity

Behind the measurement of productivity there is a need to get information about the performance of the organization under examination. The need for information can be caused by many reasons. Teague and Eilon (1973, p. 133) have stated that guidelines as to how to measure productivity may be gained from the analysis of why we should wish to measure it. They propose that the reasons are fourfold:

(i) *for strategic purposes*, in order to compare the global performance of the firm with that of its competitors or related firms,

(ii) *for tactical purposes*, to enable management to control the performance of the firm via the performance of individual sectors of the firm, either functional or by product,

(iii) *for planning purposes*, to compare the relative benefits accruing from the use of different inputs or varying proportions of the same inputs, and

(iv) *for internal management purposes*, such as collective bargaining with trade unions.

In the literature there can be found also other lists and classifications of reasons for measuring productivity in firms or in other organizations (see e.g. Shu 1983, p. 4). The most important reason for productivity measurement is the aspiration for improve productivity and via it the profitability of a firm.

In spite of the need of productivity information the profound measurement has not come into general use in firms. Steedle (1988, p. 15) has reported the results of a survey of 1000 U.S. controllers. Roughly 40 % of the respondents reported that productivity improvement programs and productivity measurement models are not in use, and only about one in four reported moderate or extensive applications. According to the same survey about 75 % of respondents reported a maximum of five different productivity measures used in their organization. The most commonly reported (over 90 %) measure analyzed labor productivity. Vora (1992, p. 47) has reported equal results. These results indicate that productivity measurement is inadequate in many firms. Another explanation may be that other measures than the examined are used in the firms.

There are many different approaches to productivity measurement. For example Eilon and Soesan (Eilon & Gold & Soesan 1976, p. 7-13) present five alternative approaches. There are also five different approaches in Hawaleshka's and Mohamed's (1987, p. 133) classification. However, only one common approach is presented in these two studies. In addition there are plenty of different classifications of productivity measures (see e.g. Shu 1983, p. 11-23 or Brozik 1984, p. 9-13). Characteristic for the diversity of approaches to productivity measurement is that there are many ways to classify these approaches. In other words, there is no one and only right way to consider productivity measurement, not even at firm level. As an example Hawaleshka's and Mohamed's (1987, p. 133-136) classification[14] can be presented. According to them the industrial productivity measures fall into five basic categories:

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[14] This Hawaleshka's and Mohamed's classification should be compared with the classification presented by Sumanth (see chapter 2.1.2.). There is very little similarity between these two.

1) Single-factor productivity (SFP)
2) Multifactor productivity (MFP)
3) Total productivity (TP)
4) Managerial control ratio (MCR)
5) Productivity costing.

Single-factor productivities (SFP), or partial productivities in another name, are measures where the relationship between total output and one group of input is measured. Multifactor productivity (MFP) has been established to measure the ratio of output or value added to the sum of labor and capital inputs. MFP is almost the same as total-factor productivity (TFP[15]) presented by Sumanth (1984, p. 7). Total productivity (TP) measures, according to Hawaleshka and Mohamed (1987, p. 135), the effects of change of total output relative to the change of all input. Managerial control ratio (MCR) is presented through a network of productivity relationship among direct input factors. MCR suggests that the variations in the rate of profit to total investment are traceable to changes in, and interaction among the factors behind it. Productivity costing (PC) is a system approach to the recognition of cost minimization in the measurement of productivity based on the capacity of production.

There are some general features which should be considered in the connection of productivity measurement. The levels under examination and the perspec-

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[15] There is a great confusion with the terms total-factor productivity, multi-factor productivity and total productivity (see e.g. Sink 1985, p. 26). Behind this confusion there is often the level under examination and the perspective of person considering productivity. Both total-factor productivity and multi-factor (or multifactor) productivity have been used to describe productivity as a ratio of output and sum of labor and capital input (see e.g. Kendrick 1991, p. 42, Fenton 1985, p. 121 and Sumanth 1984, p. 7), whereas both total-factor productivity and total productivity have been used to describe productivity as ratio of output and sum of all inputs (see e.g. Hayes & Clark 1985, p. 153 and Poeth 1985, p. 5). In addition, multifactor productivity has also been used to describe productivity as ratio of output and sum of all inputs (see e.g. Dean 1994, p. 17). More confusion causes also the term total-factor productivity measurement (TFPM) which directly measures and relates productivity to profitability (see e.g. Pineda 1990, p. 13).

Sink (1985, p. 26) has made his own rules for using these terms. If only one class of input is captured this can be called a partial-factor measure (partial productivity). If more than one class of inputs are captured this can be called a multifactor measure (multi-factor productivity). If all classes of inputs are captured this can be called a total-factor measure (total-factor productivity). He also equates total-factor productivity with total productivity (see also Pineda 1990, p. 53).

tives to productivity have been discussed above. One question which emerged is whether we should measure quantities or values of outputs and inputs. The definition of productivity as its own does not give us any limitation on the use of physical or financial measures. However, the nature of productivity as the portrayer of the efficiency of physical transformation process presupposes the use of physical measures rather than financial measures (see also Chew 1985, p. 47 or Rantanen 1991 p. 9-10).

At the firm level there is usually more than one output and almost every time more than one input. This leads to the problem of how to combine the factors with different measuring units. This is the reason why financial measures are used in practice more often than physical measures. The physical measures can be used only when we are analyzing the productivity of a minor specific action. It has also been stated that there are two types of productivity: physical productivity and economic productivity (see e.g. Shu 1983, p. 1 and Laitinen 1989, p. 198). In my opinion, this is a bit too strongly put. The physical and financial measures are only two sides of the same object. The physical measures are theoretically better but in practice it is usually necessary to use the financial measures of inputs or/and output. Thor (1986, p. 25) has said that in productivity the quantities of outputs and inputs are expressed in physical terms, or alternatively in *constant* dollar terms which is the *best available surrogate*.

Productivity has two measuring facets. The first is the measuring of the level of productivity at one specific time period. It is called absolute productivity (see e.g. Chew 1983, p. 1). The other aspect is measuring the change of productivity from one time period to another[16].

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[16] Sink (1985, p. 25) has considered the same thing when he stated that there are two basic categories of pure productivity measures. The first is called *static productivity ratios*. These are simply measures of output divided by measures of input for a given period of time. The second is called *dynamic productivity indexes*. These are essentially a given static productivity ratio in one period of time divided by the same ratio at some previous period in time. He has also said (1983, p. 44) that there is a third type of productivity measures. That is called a *"surrogate" productivity measure*. It represents the factors that are not included in the concept of productivity but are highly correlated with productivity.

The measuring of the level of productivity is most fruitful when there is some benchmark where to compare the achieved level. At the firm level and specially inside of firms these benchmarks are usually the standards or results of earlier periods. This is due to the fact that firms and their production systems are rarely similar enough for comparing.

When we are measuring the change of productivity we must be careful in comparing the results with the results of other firms. The level of productivity always affects the rate of change which it is possible to achieve. For example comparing productivity change in Finland with change in Sweden or Germany, it is apparent that the better results of Finland are due to a lower level of productivity compared with the other two countries (Airaksinen & Spolander 1989, p. 20-21). The effect of the level achieved works also inside a firm. It is easier to achieve a high percent of increase in an activity with low productivity than in an activity with high productivity.

In the following, the measures of productivity and the estimates[17] of inputs and output within these measures are discussed. There is no common measure for **total productivity**. In the literature total productivity is usually considered with the help of different models or networks of financial ratios. In these models there are many individual measures or indexes for total productivity. However, these are usually the fixed part of that model and not useful as such. In these models there is also often a connection to profitability.

The output at firm level is usually the total production of the firm. Because there are several different products, the sales (adjusted by certain base period) is a much used estimate of production. However, the sales are generally a function of market conditions, not the ability to produce (see e.g. Wait 1980,

[17] In the literature, there is much information about the estimates of output and different inputs (see. e.g. Fenton 1985, p. 138-156). In this study, only few aspects of these questions are considered. Fenton (1985, p. 129-138) handles also the elements of productivity measurement. These are base year, deflation and weighting. In this study these are considered under various different titles.

p. 29). So, the productivity measures of a firm can reflect market conditions or the efficiency of the sales department more than the productivity of a firm.

Labor productivity is the most often used measure of productivity. For example in one study (Fenton 1985, p. 175) of US firms it was found that all (100%) the firms examined used labor productivity measures. Same kind of results have been presented by Steedle (1988, p. 15) and Vora (1992, p. 47). In the early years of productivity thinking labor was the most remarkable factor of production and so it was natural to measure it. At present labor is less meaningful because the share of labor and especially direct labor of the total costs is low, from 5% to 15 % (see e.g. Drury 1990, p. 122 or Raffish 1991, p. 36-37). However, labor is still the most measured partial productivity. One reason for this is the easiness of measurement.

One question which emerges in the connection of measurement of labor productivity is how to combine different kinds of work. Solutions for this problem can be for example the use of some weighting scheme (or factors) or the use of value (sum of payments) of work (see e.g. Brozik 1984, p. 17-18 or Karko 1989, p. 2-3). From a theoretical point of view the working hours are the best estimate for the quantity of labor.

The share of capital is also more and more remarkable in modern companies. However, only a little over 40% of firms measure **capital productivity** (Fenton 1985, p. 175). Behind the low measurement of capital productivity are the problems concerning the definition and measurement of capital input (see e.g. Mohanty & Rajput 1987, p. 69 or Kallinen 1986, p. 5).

The definition of capital included in measuring is inconstant. The content of capital input depends among other things on the level under examination and the meaning of measurement. It is possible to measure only the productivity of machines in a production cell. On the other hand, at firm level the content of capital input can be rather broad. For example Sumant (1984, p. 154) has presented a rather large amount of capital input elements. He has divided

these in two groups; fixed capital and working capital. According to him fixed capital includes land, plants, machinery, tools and equipment and others, such as amortized R&D, etc. Working capital includes inventory, cash, accounts receivable and notes receivable. Another very difficult problem is the valuation of capital. How to valuate e.g. the machines of different age and type?

Generally, two possible ways of handling capital input are presented (see e.g. Mammone 1980, p. 40). The first way is the value of capital and the second way is to use the flow of capital. Here, depreciations and interests are included in the flow of capital. The problems in the definition and valuation of capital has lead, especially on the national and industry level, to a use of surrogate measures, like machine power or consumption of energy (see e.g. Kallinen 1986, p. 5).

The most often used measures of **other partial productivities** (Fenton 1985, p. 175) are material productivity (48.2%) and energy productivity (47.1%). Only 20% of firms measure other partial productivities than these. Material input includes all raw materials and purchased parts. Energy input includes all forms of energy such as electricity, oil, gas, steam, coal etc. In practice the consumption of energy is measured more often than energy productivity. Normally the measurement of other partial productivities (R&D, marketing, travel etc.) depend on the circumstances of the firm. There can be some special inputs which are remarkable for an individual firm. Then it is meaningful to measure the productivity of these special inputs.

There are various **problems in productivity measurement**. These are mostly general problems of measurement and accounting. The general problems of measurement concern the relevance, validity and reliability of measurement. The general problems of accounting are the width problem, valuation problem, matching problem and allocation problem (see e.g. Artto et al 1984, p. 55-68 or Rationalisointineuvottelukunta 1988, p. 76). The first problem in productivity measurement is how to combine the outputs and inputs of the object under examination when there is large variation in the measuring units (such

as hours, tons or pieces). This problem is the worse the bigger the object under examination. Theoretically the physical units are better, but often the financial measures are the only possible solution. This leads to the emerging of general accounting problems. Another solution for this combining problem is the use of partial measures.

Relevance of measurement means that there is no reason to measure something for interest only. Only relevant information is valuable and irrelevant information has no value although it might be excellent from the theory of measurement point of view. The management of a firm has an abundance of different kinds of information. That is why the productivity measurement system has to provide a suitable amount of important information. Validity and reliability are the two parts of accuracy problem in measurement (Vehmanen 1979, p. 131-132). In the width problem, the question is in what width the outputs and inputs should be included in the calculations, so that they could be used as support in the management's decision making. The valuation problem is concerned with what is the right value of inputs and outputs for measurement. The matching problem and the allocation problem are the two parts of the dividing[18] problem. In the matching problem, it is strived for find which inputs (costs) and outputs can be assigned to one certain period of time. In the allocation problem the question is to find which costs can be assigned to one certain action and through it to a certain input.

There is also a large variation of other[19] problems emerging in productivity measurement. Time causes some problems for productivity measurement; inflation, changes in the prices of outputs and inputs and so on. The problem

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[18] The term allocation problem is also used in this context. To avoid confusion the term dividing problem is used here.

[19] There are in the literature many lists which concern the problems associated with the measurement of productivity. For example Shu (1983, p. 5-9) has presented five problems which are commonly encountered in productivity measurement. These are (1) tangibility of inputs and outputs, (2) measuring units, (3) base period selection, (4) incorporating quality into value measures and (5) time lag in productivity information. He has said that this list is not exhaustive, but does cover the principal problems. Sink (1985, p. 68-69) has presented a list of criterias with which the quality of measurement can be evaluated.

is how to consider the quality of inputs and outputs. It is commonly assumed that the market price reflects the quality of the input or output factor. However, the market price reflects merely competition in markets rather than the quality of products. A serious question is also how to handle the intangible factors in the production of both the inputs and outputs. Some factors, tangible by definition, may become intangible because the cost of data collection is too high (Shu 1983, p. 5).

As a summary it can be said that productivity is a very broadly understood and used concept. The definition of productivity depends on the level and perspective. In general, productivity can be described at firm level as the ability of the firm to utilize its inputs to make as much output as possible.

2.2. Profitability of a firm

Profitability is an essential and common concept in accounting and economic discussion. Because of its commonness, profitability is a very many-faceted term. It is used on various levels of economy (see e.g. Airaksinen 1978, p. 1). Profitability is examined and measured for example at national, industry, firm, investment and product level. On all these levels it is possible to consider profitability from many different perspectives[20]. In this study the subject of interest is the profitability at the firm level, and the approach is a combination of managers and engineers.

Profitability is one of the three parts of the financial performance of the firm. The two others are liquidity and solvency (see e.g. Laitinen 1989b, p. 189). In the long run, profitability is a prerequisite for the continuation of a firm's functioning. Next, there is a short review of profitability as a concept and a measure, and the measurement of profitability. Profitability is considered here only to the extent which is needed for the purposes of this study.

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[20] The classification of levels and approaches to profitability is rather equal with that of productivity (see e.g. Sumanth 1984, p. 57 and 98).

2.2.1. The concept of profitability

Profitability has been important probably as long as some kind of bargaining has existed. Already the ancient merchants, bankers and lenders strived to achieve some profit of their actions[21]. However, financial ratio analysis did not appear until the 1800s, and profitability measurement was part of it. Managers were mostly interested in profitability, whereas lenders were interested in the firm's ability to pay. In 1919 the du Pont Company began to use a ratio "triangle" system in the evaluation of its operation results. The top of the triangle was the return on investment ratio (ROI) (see e.g. Horrigan 1968, p. 284-286). The history of profitability forms a fixed part of the history of financial accounting or financial statement analysis. A good review of these can be found for example in the publications of Horrigan (1968, p. 284-294), Neilimo (1982, p. 67-75), Kaplan (1984, p. 390-418) and Laitinen (1989b, p. 42-61). The development of profitability and accounting thought in Finland is considered broadly in Näsi's dissertation (1990).

In the literature there is a large variation of different definitions for the profitability of a firm. Laitinen (1989b, p. 190) has stated that in general profitability is an ability of a firm to provide incomes by sacrificing expenses. He also stresses that the time lag between expenses and incomes should be considered in the definition of profitability. Profitability can be defined as the rate of discount by which the benefit (incomes) is exactly as great as the sacrifice (expenses). If this is done the definition of profitability corresponds the concept of internal rate of return (IRR). Another way to approach profitability is the owner's point of view. Here profitability is defined as the ratio of income to capital. By this way the definition of profitability corresponds the concept of return on investment (ROI) (see also Tamminen 1976, p. 9). The basic idea in almost every definition of profitability is the ability of a firm to produce profit which is incomes minus expenses.

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[21] Luca Pacioli advised the computation of a periodic profit and the closing of the book as early as 1494 (see e.g. Belkaoui 1992, p. 3)

Profitability is important property for every firm. Profitability or providing profit is the economic[22] objective for every individual firm (see. e.g. Artto et al 1984, p. 15). Gold (1981, p. 88) has stated this same as follows:

> "In the private firms of the United States, the basic objective of such decisions is neither to increase productivity nor to improve technology, but rather increase profitability."

In this study profitability is defined as an ability of a firm to produce profit. So when the effects of productivity on profitability are considered, the effects on the profit of a firm are in fact considered.

2.2.2. Measurement of profitability

Profitability measurement is part of the measurement of organizational performance on all levels under examination, just as productivity measurement. However, the point of view is somewhat different and the objectives are not the same. In profitability measurement the objectives are mostly economic, whereas the goals in performance measurement in general as well as with productivity can be of many kinds (compare Ijiri 1975, p. 34).

Profitability as a measure of overall organizational performance captures all of the firm's activities, good and bad. The National Research Council defines profitability as follows (see Brozik 1984, p. 53-54):

> "Profitability is the best overall indicator of company performance: it measures the outcome of all management decisions about sales and purchase prices, levels of investment and production, and innovation as well as reflecting the underlying efficiency with which inputs are converted into outputs."

---

[22] There are also many other objectives which can be possible with firms. They can be concerned for example for providing services, employment, continuity, environment etc. There is also a group of organizations which don't have the same economic objectives as firms in general. These are so called non-profit organizations.

According to the above mentioned, it can be understood that the measurement of profitability should provide almost all the information that a firm needs. This is not true, however. Measurement of profitability can be seen as measurement of achieving the extreme objectives of a firm. But in order to be profitable, there is need for the measurement of many dimensions in a firm's actions. On the basis of the results of this measurement, decisions can be made which help the firm achieve the predetermined objectives.

The profitability of a firm can be measured in many ways. The need for information and the data available determine the way how to measure. Financial ratios based on financial statement analysis are the most often used measures of the profitability of a firm. There are also plenty of different ratios based on the flows of money. There are two basic types of profitability measures: absolute and relative measures. The absolute measures describe the profit or some margin as such. The relative measures proportion this profit or margin to some dimension which describes the power (revenues, total assets etc.) needed to earn this profit or margin. In the literature there are many classifications of profitability measures. For example Foster (1986, p. 67-68) presents three ratios which illustrate the alternative ways of expressing relative profitability. These are:

* $\frac{\text{Net income}}{\text{Revenues}}$

* $\frac{\text{Net income}}{\text{Shareholder's equity (average)}}$

* $\frac{\text{Net income}}{\text{Total assets (average)}}$

There is some similarity between this classification and the three branches of the skeleton of ratios presented by Laitinen (1980, p. 93). Two of these branches are here in Foster's classification, only the assets-liabilities ratios are

missing. The first ratio indicates how much net income is earned from each money unit of revenue. The second measures the efficiency with which the shareholder equity is being employed within the firm. The last ratio measures the efficiency with which total assets are employed within the firm.

Because there is a large number of different measures and ratios of profitability, it is not reasonable to present them here. Especially because there is no one and only right measure. More about the profitability measures of a firm and the ways to calculate these in general as well as about the measures used in this study can be found for example from the publications of Yritystutkimusneuvottelukunta (1990) and Aho & Rantanen (1993, p. 62-69).

For the purposes of this study two measures of profitability are selected to be used in the empirical test of the framework developed in this study. These measures can be considered from the Foster classification point of view. They represent the first and the third group of measures.

The **operating margin ratio** (OMR) is the ratio of operating margin to the revenue of the firm. OMR represents the first group of Foster's measures. The problem with this ratio is that the profit used in calculations includes the depreciations in the costs of capital. The **return on investment** (ROI) represents the third group of Foster's measures. The measures which highlight the position of the shareholders are not in the calculations. The information available for the calculations makes it possible to use these two selected measures of profitability.

The basic problems in profitability measurement are mostly the same as with productivity measurement (see chapter 2.1.5.). Because profitability reflects the monetary process of firm and all components are expressed as monetary units, the combining problem is not with profitability measurement.

As a summary it can be stated that profitability is also a broad concept. Profitability reflects the monetary process of a firm, is measured usually in money values, and describes the ability of a firm to produce profit.

2.3. Summary

The main aim of this chapter was to take a closer look at productivity and profitability in a firm. Both of these two are concepts and measures which describe the performance of a firm. To understand the relationship between these two it is important to know the substance of both.

There are many ways on different levels to consider productivity. In general we can determine productivity as the relationship between the outputs generated from a system and the inputs provided to create those outputs. At the firm level productivity can be defined as the measure of a firm's ability to utilize the inputs to make as much output as possible. In practice productivity is most useful when we are analyzing a limited area or object in a firm. In chapter 2.1. there is a survey of the nature of productivity. The concept of productivity, the approaches to productivity and the total and partial productivities are presented there. The measurement of productivity and productivity management has also been considered. The focus is on the firm level.

Profitability is an essential and common concept in accounting and economic discussion. There is a large variation of different definitions for the profitability of a firm. In this study profitability is defined as the ability of a firm to produce profit. In practice profitability is usually used in analyzing and comparing whole firms. In chapter 2.2. there is a short review of the concept and measurement of profitability at the firm level.

3. THE EFFECTS OF PRODUCTIVITY ON PROFITABILITY

Productivity and profitability are both measures of performance and successfulness of an organization (and in this context of a firm). In spite of the fact that they are very close to each other, they, however, approach the evaluation from different directions. Productivity reflects the performance of the real process of a firm, whereas profitability is a property of the monetary process. Another difference is that profitability is usually used and measured at firm level, whereas productivity is most useful as a measure at action (machine, person, activity and so on) level. In the following, there is a short overview about the effects of productivity on profitability at firm level.

3.1. Overall connections between productivity and profitability

In the literature there are many different approaches for analyzing the relationship between productivity and profitability. The effects of productivity on profitability can be analyzed on many levels of accuracy. There can be for example general speculations or schemes about the causality between productivity and profitability (see e.g. Peltonen 1991, p. 32-33). There are also many different ratios, models and frameworks which concern this same question. The type of some approaches is hard to specify.

In this study the main assumption is that the change of productivity is one prerequisite[1] among others for change in the profitability of a firm. In other words it is assumed here that change of productivity precedes in time the change of profitability.

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[1] The causality between productivity and profitability is not necessarily clear. A good profitability (profits) creates the necessary conditions for actions which increase productivity. The relationship is like a spin where change in productivity causes change in cost per unit produced and that causes change in competitiveness. Further, these cause changes in sales and profitability. Changes in profitability have effects on capital, materials and people which further increase or decrease productivity (see e.g. Sink 1985, p. 8 or Peltonen 1984, p. 41-42 and 1991, p. 32-33).

One way for analyzing this relationship is the scheme of effects where the factors affecting profitability are presented as circle or spin (see e.g. Sink 1985, p. 8 or Rantanen 1991, p. 11-15). Sink (1985, p. 64) has presented also one scheme where the hypothetical cause and effect relationships between and among organizational system performance measures or criteria are presented (figure 3.1.). There are other criterias of performance besides productivity and profitability. These are based on the list of seven criteria of performance presented by Sink (see e.g. 1983, p. 36). According to him the performance is a broad concept and comprises at least of seven criteria which are effectiveness, efficiency, quality, productivity, quality of work life, innovation and profitability. The way how these are put in order is interesting. In this scheme there is also the assumption that productivity is a prerequisite for profitability.

Laitinen (1989b, p. 275) has presented a scheme where eleven factors are affecting the profitability (and increase) of a firm. It shows clearly that productivity is only one factor among others affecting profitability. This scheme shows clearly how difficult it is to analyze the effects of one factor, e.g. productivity, on the profitability of a firm. There is no classification of these factors. These are, however, different on the basis of significance, time horizon etc. If a closer look is taken, productivity is the only one which a firm can affect in the short run. The prices are not present in this scheme. They are present indirectly through profit and competition.

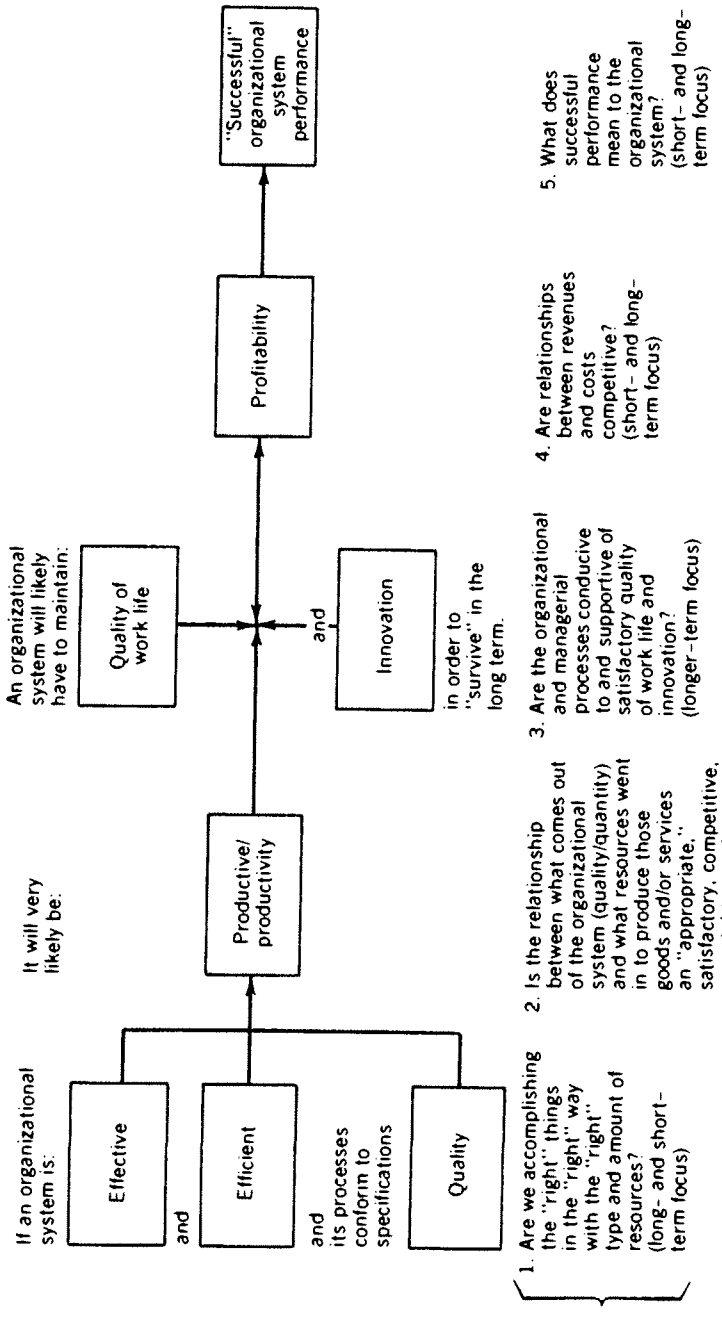

Figure 3.1. Hypothetical cause and effect relationships between and among organizational system performance measures or criteria (Sink 1985, p 64).

3.2. Models dealing with the effects of productivity on profitability

Usually the relationship between productivity and profitability at firm level is described by models. Most of these models are total-factor productivity measurement (TFPM) models or models which are based on managerial control ratios. There are also other types of models.

Pineda (1990) has dealt with the TFPM models rather broadly in his dissertation. TFPM, according him (Pineda 1990, p. 13), directly measures and relates productivity with profitability and uses dynamic productivity ratios and their effects on profitability in dollars. About the models he (p. 14) says as follows:

> "The TFPM model deals with the mathematical concepts, relationships, and derivations. This model is the theoretical basis for the set of methods, principles, and rules or the methodology for doing Total-Factor Productivity Measurement."

If TFPM and TFPM models are understood broadly, all kinds of models which try to identify the relationships between total or total-factor productivity and profitability can be dealt with under the title TFPM model. However, all TFPM models do not seem to stress this connection to profitability as strongly as Pineda does. Some of these merely concentrate on analyzing the total productivity of the system and the affecting factors behind it (e.g. Shin 1991).

From the literature Pineda (1990, p. 2) has found 13 different TFPM models. He has divided these in three categories: 1) the Productivity Indices (PI) Models, 2) the Profitability = Productivity + Price Recovery (PPPR) Models and 3) the Econometric Models. Table 3.1 summarizes the available TFPM model types, versions and their features. After this summarization made by Pineda at least two more TFPM models have been made. First Pineda himself developed the teaching TFPM model which is actually a version of the PPPR model (see e.g. p. 231). Shin (1991) has also developed a TFPM model. This is a system dynamics model for JIT environment. Two of the TFPM models are presented in more detail in chapter 3.3.

MODELS	VERSIONS	MAIN FEATURES
Productivity Indices		
	Davis (1955)	- inclusion of all inputs (including capital)
(deflates all values to	Kendrick and Creamer (1965)	- book value used for capital
constant dollars;	Crag and Harris (1973)	- lease value used for capital input
productivity index =	Hines (1976)	- productivity per product
sum of all output values	Mundel (1983)	- added details for computing input values
over sum of all input	Sumanth (1979)	- firm productivity is the weighted sum of
values)		productivity of all products
		- firm productivity related to profit breakeven
	LTV/Vought Aero	- "challenge budgets"
	Product Division	
Profitability = Productivity + Price Recovery	American Productivity and	- use of Laspeyres and Paasche indices
	Quality Center (APQC, 1978)	- dollar effects, partial productivities and price recoveries portrayed in base period dollars
(Productivity is related to		- capital compensation
accounting profitability	REsource ALlocation	- clarified conceptual models
and price recovery)	STrategist (REALST, 1982)	- concept of resource variability to break down productivity into capacity utilization and efficiency
		- strategic grids
		- attributes: data aggregation/level of detail
		- dollar effect portrayed in current period dollars
		- difference operators
	Miller (1984)	- cumulative deflation
	Virginia Productivity Center	- multi-factor concept (capital may be
	(VPC, 1985)	excluded)
		- graphics/portrayal development
	Financial Productivity	- productivity, quantity, and price grids
	Measurement (FPM; 1988)	- import/export of data with other software
Econometric	Gollop (1982)	- uses growth rates of outputs and inputs

Table 3.1. The TFPM models (Pineda 1990, p. 2).

There are also other kinds of models than these TFPM models. Gold's model is based on the composition of the ratio of profit to total investment. This model is also presented in more detail in chapter 3.3.

Touche Ross & Co. (Brayton 1983, p. 49-56) have developed their own total productivity measurement system on the basis of the APQC model. In it the effects of input factors on the profitability of firm are analyzed. The effects of inputs are divided into the effects due to productivity and the effects due to price recovery.

Bao and Bao (1989) have developed an empirically tested model where the association between productivity measures and firm value is analyzed. They have tested the valuation model where the firm's value is a function of the expected productivity, the standard deviation of productivity, and the growth of productivity of the firm. They have compared this model with another one where the firm's value function is based on the earnings.

Suorsa (1990, 1991 and 1994) has developed the productivity measurement system which is nowadays called OS-measurement, and the software based on it is called OSM3. Suorsa (1991, p. 50-51) has presented four factors that influence profit. These are volume, productivity, product mix and margin proportion[2]. This measurement system produces the calculations of profitability and productivities in production. Suorsa has also presented the term genuine productivity which means productivity where the output depends only on the input under examination (see 1991, p. 13).

3.3. Closer look at some examples of models

In the following, three different models which concern the relationships between productivity and profitability at firm level are presented. Gold's model is a good example of managerial control ratio models. The American Pro-

[2] These terms are presented in Finnish and the translation is made by the present author.

ductivity and Quality Center (APQC) has developed a widespread TFPM model in the 1970's. REALST is a modification of the ideas of the APQC model. There are, however, some new dimensions in it.

3.3.1. Gold's model

Professor Bela Gold has developed the model which bears his name in the 1960s and 1970s. This model is intended for analysis at the level of firm and production process. This productivity-cost-profitability (P-C-P) system has been proved applicable to a wide array of plants and firms in the U.S.A. (see Gold 1982, p. 207). The model is a systematic analysis, where the managerial control ratios (the components of the ratio of profit to total investment) are integrated with the network of productivity relationships and with the structure of cost relationships to provide a unified framework for systematically exploring the complex of interactions linking changes in factor input and factor prices to unit costs and cost proportions and to the other determinants of changes in the rate of profits of investment (see Gold 1973, p. 16).

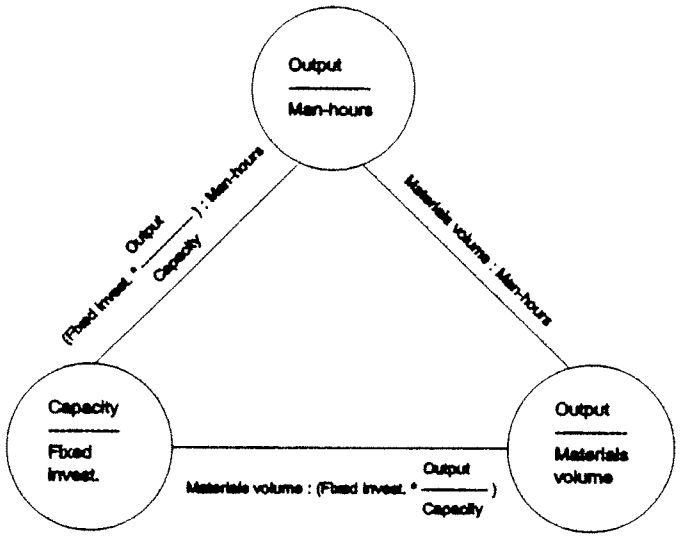

Figure 3.2. The network of productivity relationship among direct input factors (Gold 1973, p. 11).

One of the bases for Gold's model is the network of productivity relationships (figure 3.2.). It is comprised of six components, three representing the unit input requirements and three more representing the proportions in which these are combined together. Here with the fixed investment the output is replaced by capacity (see Gold 1982, p. 206). This is done because the capacity is provided by capital goods while actual output may fluctuate with demand.

Another basis for the model is the firm's profitability expressed by the rate of profit on investment. The ratio of profit (before tax) to total investment is divided first in two parts (see e.g. Eilon & Gold & Soesan 1976, p. 22-23). In Gold's model there is physical output instead of the normally used sales. This can be stated as follows

$$\frac{Profit}{Total\ investment} = \left(\frac{Profit}{Output}\right) \cdot \left(\frac{Output}{Total\ investment}\right) \qquad (3.1.)$$

Then these two parts can be divided further into their components as presented in equations 3.2. and 3.3. Because the profit is incomes minus costs the profit per unit of output is defined by the difference between the average gross receipts per unit of output and average total costs per unit of output. The ratio of output to total investment is determined by the ratios of output to productive capacity, productive capacity to fixed investment and fixed investment to total investment.

$$\frac{Profit}{Output} = \left(\frac{Product\ value}{Output}\right) - \left(\frac{Total\ cost}{Output}\right) \qquad (3.2.)$$

$$\frac{Output}{Total\ investment} = \left(\frac{Output}{Capacity}\right) \cdot \left(\frac{Capacity}{Fixed\ investment}\right) \cdot \left(\frac{Fixed\ investment}{Total\ investment}\right) \qquad (3.3.)$$

These two equations 3.2. and 3.3. can be unified as the ratio of profit to total investment which can be presented as follows

$$\frac{Profit}{Total\ investment} = \left(\frac{Product\ value}{Output} - \frac{Total\ cost}{Output}\right) \cdot \left(\frac{Output}{Capacity}\right) \cdot \left(\frac{Capacity}{Fixed\ investment}\right) \cdot \left(\frac{Fixed\ investment}{Total\ investment}\right) \qquad (3.4.)$$

This means that the variations in the rate of profit on total investment are traceable to changes in and interactions among average product prices, total unit costs, capacity utilization, the productivity of fixed investment and the internal allocation of investment between fixed and working capital (Gold 1973, p. 16).

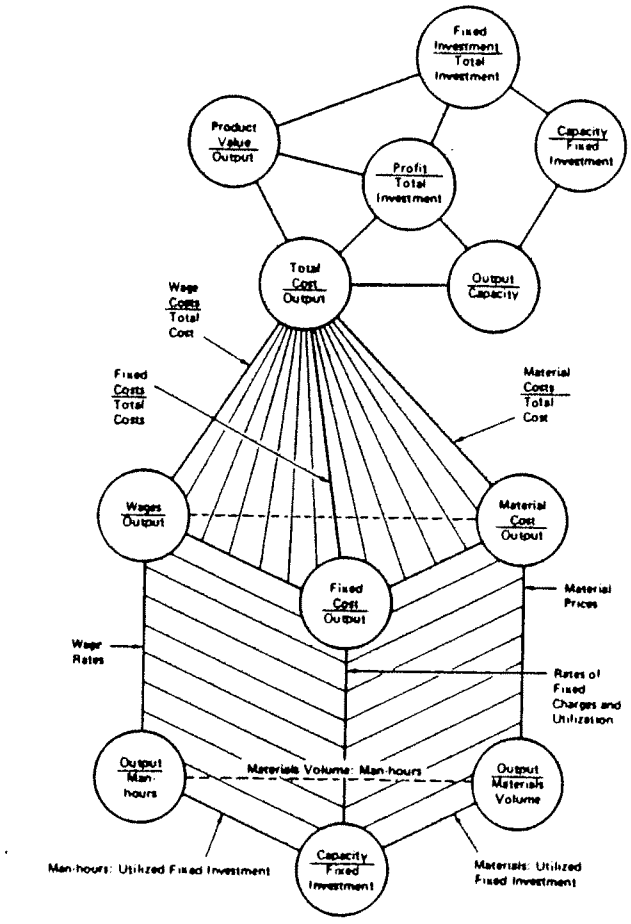

Figure 3.3. Productivity network, cost structure and managerial control ratios (Gold 1979, p. 50).

The managerial control ratios expressed in equation 3.4. are integrated to the network of productivity relationships through the structure of cost relationships as shown in figure 3.3. This framework is a tool to help the management to diagnose and develop means of improving productivity and to differentiate the internally controllable and the externally uncontrollable factors affecting productivity, costs and profitability (see e.g. Gold 1982, p. 207). Gold (1973, p. 16) states that

> "This framework may be used in analyzing past performance; in developing integrated plans for achieving specified future targets; or in appraising alternative innovations, even when their initial impacts focus on different parts of the system".

This model is used in analyzing the relationships at the process and plant level (e.g. Eilon & Gold & Soesan 1976). The level where the improvement of productivity is usually done stays outside consideration.

3.3.2. APQC model

In the American Productivity and Quality Center (APQC, formerly APC), there was developed a new model based on the relationships between profitability, productivity and price recovery in the late 1970's. This model is built on the works of Davis, Kendrick and Creamer, and Craig and Harris, and has been developed with the help of Kendrick and van Loggerenberg (Pineda 1990, p. 44).

In the APQC model the relationships between profitability, productivity and the price recovery factor are derived as in equation 3.5. (see e.g. Sumanth 1984, p. 105 or Adler 1987, p. 78).This means that if we multiply a productivity ratio (or index) by a price recovery ratio (or index) we can get a profitability ratio[3]. The change in the price recovery factor over time indicates whether the changes in input costs are absorbed, passed on or overcompensated for in the prices of the firm's output (see Sumanth 1984, p. 106).

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[3] Instead of these two components Banker et. al. (1989, p. 537) have proposed that changes in profitability can be decomposed into three components: changes in sales activity, changes in productivity and changes in price recovery.

$$
\begin{aligned}
Profitability &= \frac{sales}{costs} \\
&= \frac{output\ quantities \cdot prices}{input\ quantities \cdot unit\ costs} \\
&= \left(\frac{output\ quantities}{input\ quantities}\right) \cdot \left(\frac{prices}{unit\ costs}\right) \\
&= productivity \cdot price\ recovery\ factor
\end{aligned}
\qquad (3.5.)
$$

The quantities of outputs and inputs from each year are multiplied by base year prices to derive a productivity performance index. Prices and unit costs for each year are multiplied by current-year quantities, resulting in a price recovery performance index (Sumanth 1984, p. 106). This means that the productivity ratio is expressed as a Laspeyres index number and the price recovery ratio as a Paasche index number. Another way is using the pure quantity change ratios to compute the productivity ratio and the pure price change ratios to compute the price recovery ratio (see e.g. Pineda 1990, p. 44-45).

Usually this relationship is expressed mathematically as a product according to equation 3.5. In the literature, there is also used the formulation where the variation of profit is explained as the sum of the impact of the total factor productivity and price recovery. It is expressed as follows (see e.g. Pineda 1990, p. 44 and 54): profitability = productivity + price recovery[4] .

The APQC model is suitable for analyzing the effects of partial productivities and changes in prices on profitability at firm level. The changes in the index numbers point out what are the causes of changes in profitability[5]. It is also possible to analyze the weight and directions of the effects.

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[4] More about how this equation is formed can be found e.g. in Miller 1984, p. 147-150 and Garrigosa & Tatjé 1992, p. 557-558.

[5] To have a good example of calculations with the APQC model see e.g. Sumanth (1984, pp. 106-109).

3.3.3. REsource ALlocation STrategist (REALST)

REALST is the name given to a computerized performance measurement approach (Parsons 1986, p. 1). It is based on the ideas[6] of the APQC model. The difference is that REALST breaks down productivity into capacity utilization and efficiency and it takes strategic aspects to productivity analysis.

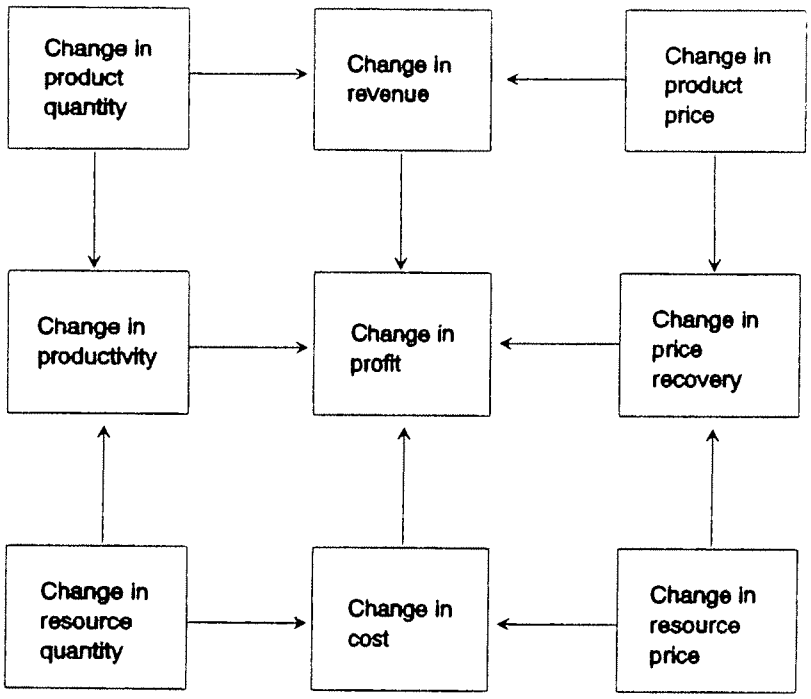

Figure 3.4. The sources of change in profit (van Loggerenberg & Cucchiaro 1981, p. 90).

The basis of REALST is presented in figure 3.4. Changes in profit are driven by changes in revenue and changes in cost (center column). Changes in revenues are consequences of changes in product quantity and changes in product price (top row). Changes in cost can be derived from changes in

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[6] This is natural because the author of the REALST model, Bazil J. van Loggerenberg, has also been developing the APQC model (see e.g. Pineda 1990, p. 44).

resource quantity and price (bottom row). The left column links changes in product quantities with changes in resource quantities. This indicates the change in productivity. The right column links the changes in product and resource prices. It creates the relationship called price recovery (see e.g. Parsons 1986, pp. 1-2).

The productivity analysis with REALST uses the mathematical formulation of sum in the description of relationship between profitability, productivity and price recovery. Thus the change in profits is the sum of change in productivity and change in price recovery. In REALST change of productivity consists of two measurable components: change in capacity utilization and change in efficiency. All the measurable sources of profit change in a business unit can be described as in figure 3.5.

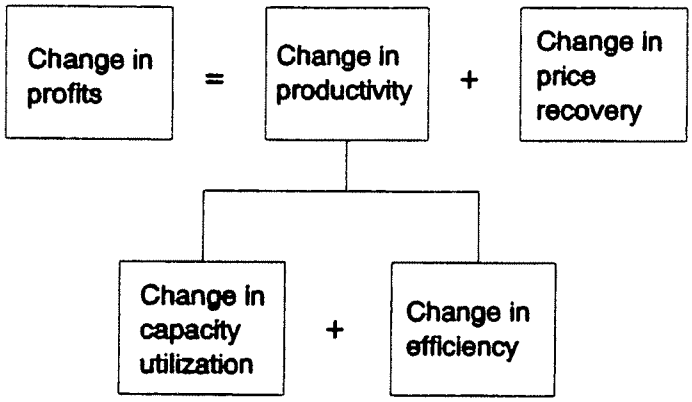

Figure 3.5. The measurable sources of profit change in a business unit (van Loggerenberg & Cucchiaro 1981, p. 90).

With this model it is possible to analyze which proportion of change in profit is caused by change in productivity and which by change in price recovery. Further, it is possible to analyze how much change in capacity utilization and change in efficiency affects the change in profit (see van Loggerenberg & Cucchiaro 1981, pp. 91-96).

The REALST model can also be used in strategic analysis. The strategic segment grid (figure 3.6.) presents an analysis of change in profits over time. The horizontal axis scales the price recovery contribution to a change in profit. The vertical axis scales the productivity contribution. The broken diagonal line connects all the points where the productivity term is offset by an equal and opposite price recovery term. Along this line there happen no changes in profit. A positive profit change would appear above this line and below it there appears negative change. There are six segments in the grid. These segments are described with names characterizing the typical strategic responses in these segments. The names are "Scuttle", "Salvage", "Scramble", "Awaken", "Pursue" and "Finetune". More about these segments and the use of REALST in strategic analysis can be found in articles of van Loggerenberg and Cucchiaro (1981, pp. 96-98) and Parsons (1986, pp. 2-5).

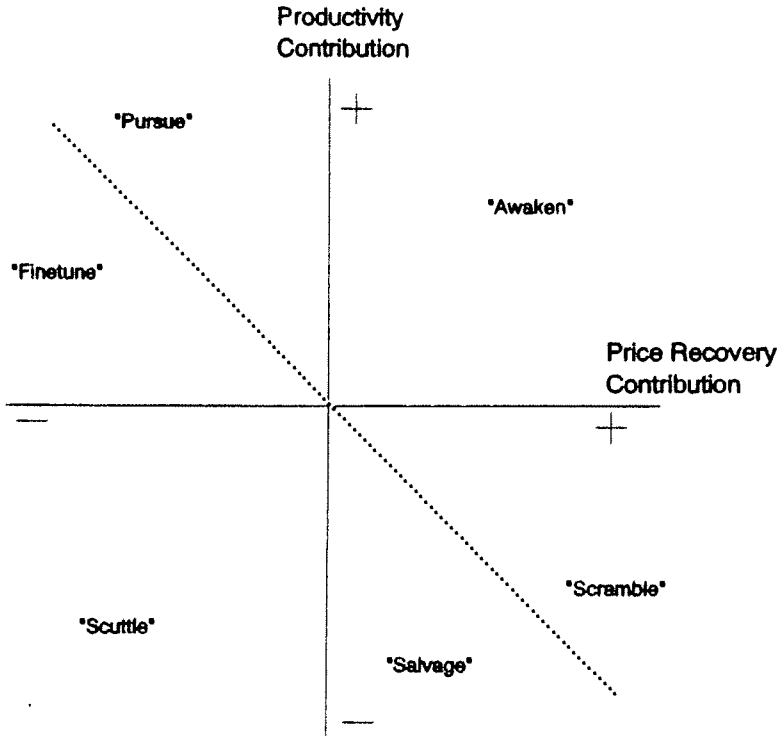

Figure 3.6. The strategic segment grid in REALST (van Loggerenberg & Cucchiaro 1981, p. 96).

REALST is mostly used in the analysis at firm level. There are also some examples about the use of REALST at industry or national level. In the literature there are only few articles about using the ideas of the APQC model and REALST in the activities (e.g. Ochs & Bicheno 1991).

3.4. Empirical studies

In the literature there is also a large number of empirical studies where the relationships between productivity and profitability are analyzed. Many of these studies consider the empirical application of the models (see e.g. Eilon & Gold & Soesan 1976 or Miller 1984). Next, some empirical studies made in Finland are presented.

Airaksinen (1978) has also examined profitability, partial productivities and price factors at industry level. He developed a composition model of profitability. He found that there are very many factors affecting profitability (see p. 79-80). He also made regression models, but the empirical test of these did not give any significant results (see p. 66-70).

Kettula and Pirttilä[7] (1985) considered in their study how Gold's model works at industry level with statistic data. Due to the data they were forced to simplify the model presented by Gold. It was possible to use this model but the data caused various problems.

Rantanen (1992a) considered the relationship also at industry level. The results of the Finnish metal product and engineering industry indicated that in every line of business there are different factors which are among the four best interpreters of profitability.

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[7] Kettula & Pirttilä (1986) have also tested the action of the composition model of profitability developed by Airaksinen at industry level.

Storhammar (1992) has studied the progress of productivity on the plant level at Finnish metal industry in the years 1980-1989. He found that plants with high productivity have better profitability than plants with low productivity (see p. 27). Especially the correlation between labor productivity and profitability was high.

3.5. Summary

In this chapter the purpose was to give a short review about how the relationship between productivity and profitability at the firm level is considered in the literature. The focus was on the models dealing with this relationship.

As a summary of the relationships between productivity and profitability it can be said that these concepts are quite common and there is some confusion in their meaning. If we consider these from the managerial point of view in a firm it is possible to accept the common knowledge about the effects of productivity on profitability. It is known that increase in productivity decreases the costs per unit produced and this can lead to better profitability. There are for example various TFPM and other types of models for analyzing this relationship.

However the basic problem with these models presented in the literature is that they do not usually operate at the level where the changes of productivity happen. Most of these models are suitable at the level of firm or department, not in the level of activity or product. Also the empirical studies have examined this topic at a very aggregate level. They present evidence about the general effect of productivity on profitability.

The changes in productivity are produced mainly at the level of an individual activity or a human being. There is very little knowledge about how the changes of productivity at the "root level" affect the profitability of a firm.

Thus there is still a lot to do in analyzing and studying for example how much a certain change of productivity in one certain activity affects the profits and profitability of a firm.

4. ACTIVITY-BASED COSTING

In recent years the term "activity" has become popular in the area of management and accounting. There are many names for the solutions of activity thinking. For example activity accounting[1], activity-based accounting[2], activity-based costing (ABC), activity-based management (ABM)[3], activity-based cost management (ABCM)[4] and even total cost management (TCM)[5] are names of systems based on activity-based information. Even today the variety of names and terms inside these systems is very wide and unstable. Different writers may use different names about same things and same names about different things. For the sake of consistency only one terminology is used in this study. This terminology is based on the one used by Turney (see e.g. Turney 1991).

Because the costs, and especially the product costs are important in this study, the term activity-based costing is used here as a common title. It can be defined as follow:

> "Activity-based costing (ABC) is a method of measuring the cost and performance of activities and cost objects. Assigns cost to activities based on their use of resources, and assign cost to cost objects based on their use of activities." (Turney 1991, p. 72)

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[1] Activity accounting is a process of accumulating and tracing cost and performance data to a firm's activities and providing feedback of actual results against the planned cost to initiate corrective action where required. It is a tool for understanding cost (Brimson 1991, p. 47).

[2] See e.g. Johansson 1990, p. 40.

[3] ABM is a discipline that focuses on the management of activities as the route to continuously improving the value received by customers and the profit achieved by providing this value. This discipline includes cost driver analysis, activity analysis, and performance analysis. ABM draws on activity-based costing as a major source of information (Turney 1991, p. 157).

[4] See e.g. Sharman 1993, p. 17.

[5] Total cost management (TCM) is a business philosophy of managing all company resources and the activities that consume those resources. Managing costs in a TCM environment means focusing on activities and the events, circumstances, or conditions that cause or "drive" these cost-consuming activities (Ostrenga 1990, p. 42).

The basic idea of ABC can be seen in Turney's definition. Products (or other cost objects) don't cause costs directly. The activities consume resources and the products (or other cost objects) consume activities and materials. There are two stages in the cost assignment process. First the costs of resources are traced to activities and then the costs of activities are traced to cost objects on the basis of the usage.

The roots of ABC are found at the early 1960s[6]. In 1963 Peter F. Drucker (p. 59-60) pointed out that the costs depend rather on the number of transactions than the volume. He said that

> "...while 90% of the results are being produced by the first 10% of events, 90% of the costs are being increased by the remaining and result-less 90% of events. ...economic results are, by and large, directly proportionate to revenue, while costs are directly proportionate to number of transactions."

H. Thomas Johnson (1992, p. 27) states that there were two paths that lead to the present-day activity-based pursuit. The older path, which is activity cost analysis, began in the early 1960s at General Electric. GE's 1963 study team proposed a novel technique to control the *activities* that cause the costs. The other path, activity-based cost management, was derived from the efforts of several companies and consultants in the 1970s and early 1980s to improve the quality of product cost accounting information. These two paths were independent according to Johnson. The underlying idea in this development was the need to find better ways for managing indirect costs.

Criticism against the traditional cost systems increased in the 1980s. The major problem was a loss of relevance that occurs when there is a lack of synchronization between management accounting systems and the environment they are intended to support (Johansson 1990, p. 37). Firms are faced with global competition and production technologies, automation and philosophies (JIT, TQM etc.) have developed rapidly. Also the proportions of

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[6] This might be a reasonable starting point for the history of ABC irrespective of the fact that William J. Vatter (1945, p. 167) has presented some ideas of transactions and transaction costs in the middle 1940s. Even more older are Eric Kohler's ideas about "Activity Accounting" from 1930s (Aiyathurai & Cooper & Sinha 1991).

labor[7], material and overhead costs have changed dramatically. Today we have a manufacturing environment where direct labor usually accounts for 5% to 20% of the costs and material accounts for 45% to 55%. That leaves us with a whopping 25% to 50% for overhead (see e.g. Raffish 1991, p. 36-37 or Doost 1989, p. 38). At the same time almost all the management accounting practices used had been developed by 1925 (Johnson & Kaplan 1987, p.12). One of the biggest shortcomings of the traditional cost accounting was the incorrect product costing information (see e.g. Cooper 1989, p. 77). Professor Robert S. Kaplan is one of the best known writers who has pointed out this "new challenge" for management accounting (see e.g. Kaplan 1983, p. 689 or 1984b, p. 101). The other well known writers are professors H. Thomas Johnson and Robin Cooper. In addition to this criticism they have had a great influence on the development of new accounting thinking - the activity-based approach[8].

The practical difference between ABC and traditional cost accounting can be seen more accurately in management of overhead costs (see e.g. Drury 1990, p. 126). ABC shows that high-volume products and customers are more profitable than previously believed, while low-volume specialty products are often unprofitable. ABC provides relative accuracy while the traditional system provides absolute inaccuracy (Sharman 1990, p. 11). Another important point of view is that ABC is a tool for supporting the management's strategic decisions, not only a way to allocate costs. It is possible to realize the connections between products (or other cost objects) and the activities behind the costs. This is one of the strengths of ABC.

In the early 1990s there have been some warning notes about the superiority of ABC (see e.g. Bakke & Hellberg 1991 or Johnson 1992). The presented hopelessness of traditional cost accounting has also become an object of revaluation (Ferrara 1990). In many cases ABC might be a good tool that

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[7] In Finland there are no signs of dramatic change (Lukka & Granlund 1994, p. 26).

[8] See e.g. Johnson & Kaplan 1987, Cooper & Kaplan 1988, Kaplan 1988, Kaplan 1990, Cooper & Kaplan 1991a and Cooper, Kaplan, Maisel, Morrissey & Oehm 1992.

greatly improves cost-focused management practices. But we must keep in mind the fact that it does not solve all our problems. It is not a tool for managing competitive operations in the global economy (Johnson 1992, p. 32). Further, it does not for example directly address the issues of life cycle costing, or performance measurement, although ABC will support those functions with valuable information (Raffish 1991, p. 39).

Next, a short review of the principles of ABC (chapter 4.1.) and ABM (chapter 4.2.) is given. ABC is here dealt with only to the extent that is needed for the purposes of this study. After that the usefulness of ABC in analyzing the effects of productivity change on profitability is discussed (chapter 4.3.).

4.1. ABC building blocks

The following introduction to the structure of ABC is mostly based on Turney's (1991) way to describe the activity-based costing. There are also other possible alternatives to describe ABC and its implementation (see e.g. Cooper 1990, or Brimson 1991, or Sharman 1991b, 1992 and 1993). For the sake of consistency only one structure is used in this study.

According to Turney (1991, p. 77-81) there are two generations[9] of ABC systems. The earlier models were one-dimensional. They were designed and viewed as tools for improving the accuracy of reported product costs. The desire for operational information about activities led to the appearance of second-generation ABC. This was specifically designed to supply information for internal as well as external improvement purposes. This later generation of ABC has two main views: the **cost assignment view** and the **process view**. The overall structure of the ABC model is shown in figure 4.1. The vertical part of the model, the cost assignment view, provides information about how to assign the costs to activities and cost objects. The horizontal part of the

[9] In the literature already the fourth generation of ABC has been mentioned (see e.g. Mecimore & Bell 1995).

model, the process view, provides information about what causes work and how well is it done.

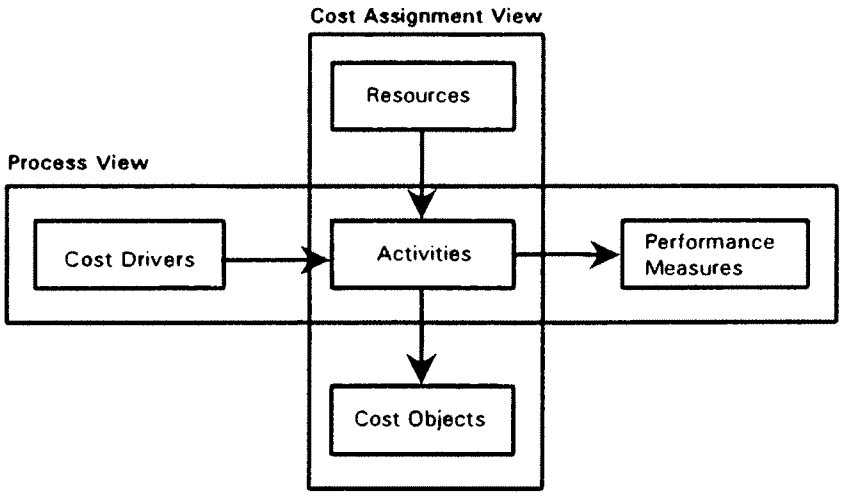

Figure 4.1. The ABC model (Turney 1991, p. 81).

ABC has similarities with Michael E. Porter's value chain approach. There are inter alia the same terms (e.g. activities and cost drivers). Porter, however, has a different point of view for these questions. He stresses the strategic view and says that "Value activities and accounting classifications are rarely the same" (Porter 1985, p. 39). Relatives for ABC are also the so called S-curve which tells the cumulative product cost according to operations structure, and a calculation framework modelling product structure and routing (e.g. Uusi-Rauva 1989, p. 79-86 or Uusi-Rauva & Karjalainen 1989, p.24-28).

4.1.1. Cost assignment view

Cost assignment view is the part of ABC where the calculation of costs is most important. This view provides information about resources, activities and cost objects. Cost assignment is a process with two stages. First the costs

of resources are traced to activities. In this stage the resource drivers are used to assign[10] costs to activities. Then the costs of activities are traced to cost objects. The costs of activity (activity cost pool) are traced to the cost objects by an activity driver. The structure of the cost assignment view is shown in figure 4.2.

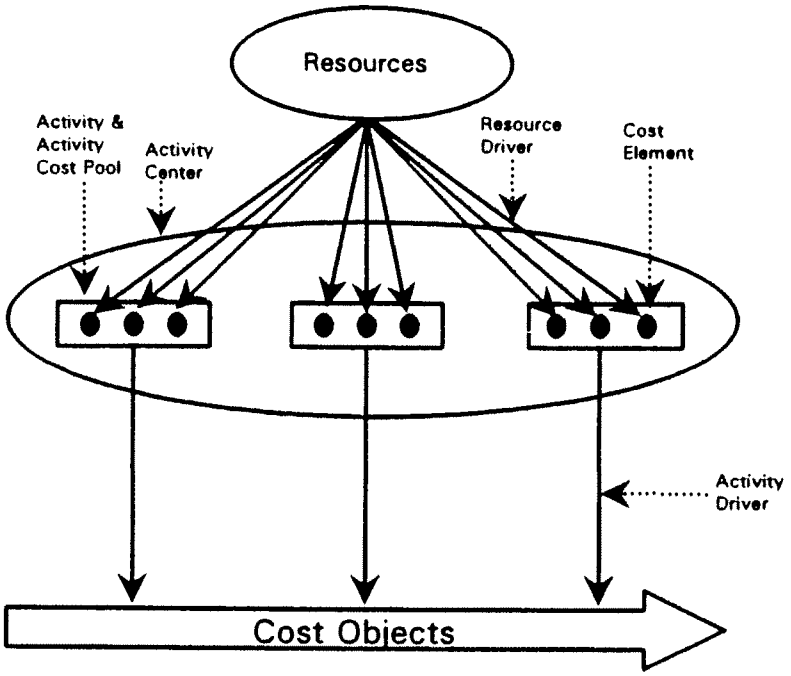

Figure 4.2. The building blocks of the cost assignment view (Turney 1991, p. 97).

The elements of the cost assignment view according to Turney (1991, p. 99-116) are as follows:

Activity — Activities are units of work performed within an organization.

Activity center — Activity center is a collection of related activities, such as those in a particular department.

[10] More about the relationships between the terms assignment, allocation, attribution and tracing can be found in e.g. Cooper & Kaplan 1991b, p. 2 or Horngren & Foster & Datar 1994, p. 28.

Activity cost pool	Total cost assigned to an activity. The sum of all the cost elements assigned to an activity.
Activity driver	A factor used to assign cost from an activity to a cost object. A measure of the frequency and intensity of use of an activity.
Cost element	The amount paid for a resource and assigned to an activity. Part of an activity cost pool.
Cost object	The reason for performing an activity. Cost objects include products, services, customers, projects and contracts.
Resource	Economic element applied or used in the performance of activities.
Resource driver	The link between resources and activities. It takes a cost from the general ledger and assigns it to the activities.

Brimson (1991, p. 46-47) has described activity as follows:

> "An activity is a combination of people, technology, raw materials, methods, and environment that produces a given product or service. It describes what an enterprise does. ... An activity describes the way an enterprise employs time and resources to achieve corporate objectives. Activities are processes that consume substantial resources to produce an output. The principal function of an activity is to convert resources (materials, labor, and technology) into outputs (products)."

Activities can be classified in many ways. It can be done on the basis of level, type or some other property. Porter (1985, p. 39-44) divides activities to two main categories; primary and support activities. Within both categories there are three activity types; direct, indirect and quality assurance. Cooper and Kaplan (1991a, p. 132) have presented "the hierarchy of factory operating expenses". There the activities are divided into four levels. These are facility-sustaining activities, product-sustaining activities, batch-level activities and unit-level activities. Juuti (1993, p. 30-31) has made his own combination of the ones presented above. Activities can also be divided to value-added and non-value-added activities (Turney 1991, p. 166). Brimson (1991, p. 54-56) has five different criteria for dividing activities to different categories.

Turney has also reported about a two dimensional[11] activity-based costing model (see Turney 1991, p 126-129 and Turney & Stratton 1992, p. 49-50). In this model the activities are divided to macro and micro activities. Micro activities, or detailed activities, are part of the process view. The costs are assigned from the general ledger accounts to the micro activities. Also detailed non-cost information is attached to micro activities. Macro activities are an aggregation of related micro activities. Their primary purpose is to facilitate the reporting of accurate product costs. Macro activities correspond to activities in general ABC system. They are part of the cost assignment view.

The aims of information utilization affect essentially the way the activities are classified and how exactly they are defined. The amount of activities in a firm may vary considerably depending on the size of the firm and the accuracy of the ABC system in use. Turney (1992, p. 22) has stated that a typical business can have 200 to 300 activities. However, in this context, we must consider the difference in the size of firm in the USA and in Finland.

4.1.2. Process view

The process view provides information about why work is performed, what factors determine the effort required to perform it, and how well the work is carried out (Turney 1991, s. 92). This part of ABC provides information for operational decision making. It helps management to identify improvement opportunities and ways to improve processes. The critical factors of the process view are the cost drivers and performance measures. These are connected to each activity or process in the customer chain. Cost drivers and performance measures are primarily nonfinancial (Turney 1991, p. 86).

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[11] Turney (e.g. 1991, p. 110) uses the term "dimension" in connection of the cost assignment and process view of ABC.

Cost drivers tell why an activity is performed. They also tell how much effort must be expended to carry out the work. Cost drivers are useful when we are searching for opportunities to improve our processes. Working to reduce the negative effects of cost drivers can yield important gains in efficiency (Turney 1991, p. 110). Brimson (1991, p. 52) mentions that a positive cost driver results in revenue, production or support-related activities that generate profit. A negative cost driver causes unnecessary work and reduced profitability.

Performance measures describe the work done and the results achieved in an activity. They define how well an activity meets the needs of its internal or external customers. According to Turney (1991, p. 88) performance measures include information about the efficiency of the activity, the time required to complete the activity, and the quality of the work done. Performance measures should be compared with other comparable activities inside or outside the firm. They can also be monitored over time.

4.2. Activity-based management

In recent years there have been plenty of articles which describe the solutions of ABC and its implementation in firms (e.g. Wittman 1993, Merz & Hardy 1993 and Norkiewicz 1994). In the last few years there have also been articles which go behind the cost numbers and cost allocations reached by ABC and concentrate on managing and developing the activities and processes (e.g. Turney 1992 and Sharman 1993). These articles can be dealt with under the title activity-based management (ABM) or activity-based cost management (ABCM). There are a number of reasonable factors which have changed the scope from ABC to ABM (see e.g. Lumijärvi 1993, p. 37-38). Some of these are:

- the costs do not decrease by calculating
- if you want to affect the costs, you have to affect the activities
- it is a question of changing the way of managing and thinking.

ABM[12] is, as mentioned above, a discipline that is focused on the management of activities as the route to continuously improve the value received by the customer and the profit achieved by providing this value. ABM utilizes the information of ABC. ABC information helps to direct resources to activities that yield the greatest profitability and helps to improve the way the work is carried out (Turney 1992, p. 20). It is possible to understand ABM as a straight extension of the process view of ABC.

On its own ABC provides better cost information. But its most effective use is in a framework of change and continuous improvement, usually involving process re-engineering and performance measurement. Activity-based management means integrating activity-based costing information into an overall management process (Sharman 1993, p 17).

Activity analysis is an important part of ABM. One of the purposes of activity analysis[13] is to identify activities as value added and nonvalue added using customer requirements (see e.g. Ostrenga 1990, p. 43). There are two categories of value added activities (Turney 1992, p. 22). First, an activity has value if it is essential to the customer. These activities increase the customer value[14]. In the second, an activity has value if it is essential to the functioning of the organization. All other activities are nonvalue added.

In the connection of performance improvement it is important to know which activities are value added and which nonvalue added. Elimination of the unnecessary, nonvalue added, activities is a good way to reduce costs. The performance improvement actions should be directed to the value added

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[12] Brimson (1991, p. 78-79) uses the term "activity management". According to him activity management is the effective and consistent organization of an enterprise's activities in order to use resources in the best possible way to achieve its objectives. ... Activity management reallocates time and systemizes work methods to improve the effectiveness of activities even in dynamic environment.

[13] Brimson (1991, p. 64) uses the term "Non-value added analysis".

[14] Customer value is about what customers get (the realization) and what they give up to get it (the sacrifice). Subtract sacrifice from realization and you have customer value (Turney 1992, p. 22).

activities. The productivity improvement is most useful in those activities which increase the customer value or are essential to the functioning of the organization. If a firm can increase the customer value with constant costs it can get higher prices and higher profits.

4.3. ABC and the effects of productivity on profitability in this study

As mentioned above, on their own, the numbers of cost accounting do not improve anything. Only an analysis of the reasons behind the numbers and development actions based on the analysis can improve the profitability and overall performance of a firm.

In this study ABC is an environment for the framework developed. The cost assignment view is the way to get sufficient cost information about the activities. On the other hand, the process view is the scope where the interest of this study concentrates. Productivity is a important part of performance measurement and improvement, especially in production process.

This study concentrates on productivity improvement and its economical effects in production. The main objective is to find the improvement objects and analyze the effects of productivity change in these activities on the profitability of a firm. It can be assumed that the activities in production are mainly value added. Only testing and inspection can be classified as nonvalue added. The activity analysis, where the activities are classified as value added and nonvalue added, serves the same task as the framework developed in this study, but at a different level. The general aim of both is the improvement of performance. However, in this study also the monetary value of the effects of productivity improvement actions is under the examination. Activity analysis gives the improvement objects at a rough level. In general it is meaningful to improve the performance of the value added activities and eliminate the nonvalue added activities which only increase costs. The scope of this study is more accurate. The rough classification to value added and

nonvalue added is not enough. It is also important to know how worthy it is to improve the productivity in one activity. ABC and ABM give an good environment to analyze these kind of questions.

The cost objects picked out describe the decision situation where the information obtained is intended to be utilized (Juuti 1993, p. 43). The product is one cost object among many others, like e.g. customers and markets. In this study, the product is chosen as the cost object because the product cost in one activity (later called as "activity product cost"[15]) is an important link between productivity in this activity and the profitability of a firm.

The most important part of activity product cost is "activity cost" which is the cost that can be traced from one activity to one unit of a certain product. One question among others here is to define how the change of productivity affects the activity cost. Improvement of productivity occurs in the activities, even in the micro activities. Micro activities are the focal point of improvement effort as Turney & Stratton (1992, p. 47) say. One problem is that the cost information normally available in ABC is at the level of activity (or macro activity), not at the level of micro activity[16]. Activity cost is composed of the cost per activity measure and the quantity of the activity measure units used by the product. A change of productivity affects both of these. Sometimes the cost per activity measure has been called **productivity measure** (see e.g. Brimson 1991, p. 110). The cost per activity measure is the unit cost of activity[17]. In the present study, it is regarded as an important means of connecting the changes in productivity of an activity to the profitability of a firm.

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[15] The terms used in this study are presented more accurately in chapter 5.

[16] Micro activities are not used to cost products - the cost of micro activities is assigned to macro activities, not to products (Turney & Stratton 1992, p. 47).

[17] The costs or unit costs are commonly known as a link between productivity and profitability (see e.g. Gold 1973, p. 14).

Some studies dealing with the problem of the productivity (or wider - performance) and profitability of a firm in an ABC environment have been described in the literature. Juuti (1993) has developed an approach where, by the aid of ABC, the improvement objects are identified and improved. He has concentrated on the implementation of the ABC system. The connections to the profitability of a firm have been only slightly touched. From the point of view of this study, the most interesting part is rather the selection of improvement objects and the calculation of the economical effects than the ABC solution. Ochs and Bicheno (1991, p. 11-16) use the concept "productivity accounting" when they present one approach to total-factor productivity improvement. They combine ABC and the ideas of APQC's TFPM-model[18]. They see this combination as a very effective tool in productivity analysis. They say,

> "Nevertheless, we can now get close to true productivity performance by combining these two powerful and mutually reinforcing techniques - ABC provides more accurate cost information, and productivity accounting uses it more effectively" (Ochs & Bicheno 1991, p. 13).

It is possible to say that almost all productivity improvement techniques have the activities as common elements. Sharman (1991, p. 9) claims that these methods are premised on some kind of activity and resource consumption analysis.

4.4. Summary

One purpose of this chapter was to give a short overview of the basics of activity-based costing. The two main views of ABC, the cost assignment view and the process view, are presented in chapter 4.1. The basic idea of ABC is that the activities consume resources and the cost objects (products or other cost object) consume activities and materials. ABM is a discipline that is focused on the management of activities and so it can be understood as a

[18] There are also some elements of the REALST-model (see e.g. Loggerenberg & Cucciaro 1981, p. 96).

straight extension of the process view of ABC. ABM is presented in chapter 4.2.

The main purpose was to show how ABC (or ABM) is connected in this study to the analysis of the effects of productivity on profitability. This is done in chapter 4.3. The cost assignment view of ABC makes it possible to calculate the accurate cost of activity and the cost per activity measure. The ideas presented in chapter 5 are based on the link between the cost of activity and the product as a cost object. A change in the cost of a product affects the profitability of a firm. In the process view of ABC the improvement of productivity in an activity can be connected to the costs of products.

In this study ABC can be seen as an environment for developing the framework. It makes a good tool for connecting the effects of productivity in an activity to the profitability of a firm. ABC is the means of getting sufficient cost information about the activities and utilizing it in the continuous improving process of production. ABC is used in this study despite of the fact that it is as yet very little used in Finnish manufacturing industry (see e.g. Lukka & Granlund 1993, p. 58).

5. CONSTRUCTION OF THE THEORETICAL FRAMEWORK

The main objective of this study was to develop a method by which it is possible to analyze the effects of productivity change in one activity on the profitability of a firm. This is a way to produce more and better information about the effects of productivity improvement actions. The purpose of this study is to support the management in their decision making.

In this chapter the theoretical framework which aims at meeting the requirements of this study is presented. This framework is built on the basis of TFPM and ABC. The theory presented in chapters 2,3 and 4 is attached to this framework. Because a firm is very complex in its entirety and there are many direct and indirect influences over and between the activities, it has been necessary to do some simplifications. This study and the framework concern only the changes in production and thus the activities which are mainly value added. The effect of a change in productivity (both total and partial) in one activity is analyzed with the assumption that there are no other simultaneous changes in the production (ceteris paribus).

First (chapter 5.1), the background of the framework in general is considered. It is argued that it is better to do the analysis in two stages. The first stage which concerns the selection of activities for deeper analysis is presented in chapter 5.2. In chapter 5.3. the theoretical foundations for stage two are presented. This concerns about how it is possible to calculate the effects of the change of productivity in an activity on the profitability of a firm. After that (chapter 5.4.) the structure of the theoretical framework is introduced.

5.1. The two stages of the framework

When developing management tools, the logical starting point would be the need of information of the managers. To understand the analyzing method

which concerns an individual activity, even micro activity, it is appropriate to trace out the situation of decision making. The underlying assumption is that the main objective in management decision making is profitable action or improvement of profitability. Improvement of productivity can be seen as one means among others for achieving this objective. The essential questions when we are trying to operate more effectively or improve productivity can be as follows.

i) Which are the objects (activities) of improvement actions?
ii) How to improve them?
iii) What are the effects of these improvements?

These questions can be seen also as parts of the general chain of decision making. The first question is clearly connected to planning. It deals with the selection of improvement objects. The second question is connected both to planning and decision making. The third one can, depending on the time horizon, be connected to planning or to control. Here a deeper analysis of the effects of improvement actions is considered. This study concentrates on the first and the last question and mostly on the economic aspects of these.

The first (i) question can be seen as composed of at least three dimensions. It is possible to ask which activities are

a) necessary
b) possible
c) worth improving?

One part of activities in production (ia) are the ones which we know beforehand to be needing improvement actions very soon. The reason for this necessity can be e.g. a bottleneck in production which affects actual or planned production conclusively. The reason can also be a need for reform depending on the physical or technical age of production equipment.

Management can also have knowledge that in some activities (ib) there is potential for more effective action. So there is a clear possibility of improving

productivity in these activities. This information can be based on low capacity utilization or comparison of cost information. In this situation the management normally tries to improve the actions and operate more effectively. The philosophy of lean management is a good example of an action like this. Another alternative is taking the free capacity to use if the demand of products allows it.

The third dimension (ic) means that the improvement actions in some activities are more worthy than in the others. There can be some activities where the improvement causes remarkable savings in costs or increase in incomes. The amount of possible savings depends on the amount of total cost of activity. It is possible to estimate the direct economical effects. The estimation of indirect effects is very difficult or even impossible. The estimation of what happens in activity B when operation in activity A is improved presupposes large knowledge about the production. The question about the worthiness of improvement actions is often very important when planning the allocation of development resources. It is clear that ***the benefits/savings from improvement of activities need to be larger than the sum of the amount sacrificed for these actions and the additional costs of later operation.***

The third question (iii) can be divided into the consideration of economical and physical consequences. The economical consequences culminate in the effects on the profitability of a firm. In connection with planning, this question is considered roughly in the selection stage of improvement objects (ic). A deeper analysis presupposes some kind of estimation or precalculation of the economical consequences. In connection with control, this question presupposes postcalculation about the consequences realized and analysis of the causes of deviation. Examples of physical consequences are changes in the use of resources, in the appearance and removal of bottlenecks in production, and changes in the amount and quality of inventories. Ultimately the physical consequences appear as economical consequences. Some of the consequences are difficult to classify as belonging to one or the other of these two

groups. For example the effects on competitiveness and quality of products or operation are of this kind. Indirectly, these affect ultimately the profitability of a firm.

Another question which needs some consideration in this connection is the nature of change in productivity. This is discussed also in chapter 2.1.4. A rough simplification of the nature of productivity change can be presented in three ways as follows

1) Output changes; input remains constant
2) Output remains constant; input changes
3) Both output and input change.

In the following, these changes are considered from the increase of productivity point of view. These changes of output or/and input can also lead to a decrease of productivity or a situation where productivity stays unchanged. Another case which has been left out of consideration is the effect of changes in the quality of output or/and input.

It is obvious that efficiency and productivity in production increase when the amount of output increases and the amount of input remains constant. In other words, the production system can produce more output in a certain period of time with the same use of resources as earlier, without investments[1]. Behind this kind of change there can be e.g. improvement in layout or in ways of working. An increase in the amount of output as the consequence of productivity improvement actions is not always sure. There can be many factors which prevent the possibility of utilizing the productivity improvement actions. For example poor demand of products, competition, bottlenecks somewhere else in production or the limitations of equipment or other resources can be this kind of factors. To utilize the possibility of savings

[1] The capital investments required in improvement actions are often very small. The source of improvement is usually a change in operation police (see e.g. Eloranta & Räisänen 1986, p. 142).

in unit costs caused by productivity improvement, there cannot be any limitations for increase of output. The increased capability to produce should be able to be utilized with existing or new products. However, new products always cause additional costs (e.g. setup costs) and these must be taken into consideration when the effects on profitability are examined.

It is also obvious that efficiency and productivity in production increase when the amount of output remains constant and the amount of input decreases. This means that the need of resources to produce a certain output in a certain period of time decreases. This gives a possibility to save in the total costs of the system under consideration and in the unit costs of products produced by this system. To utilize the possibility of savings and through it the increase of profitability, it is presupposed that a decrease in the requirement of resources can be realized. This means that resources like work or equipment must be movable to other useful work in the firm or totally out of the firm (notice or divestment). Decrease in materials use is easy to realize. The decrease of inputs can also contain structural change in resources. Then the relationship between the amount of different resources changes. For example the work can be substituted with equipment.

The third alternative for increasing productivity is the one where both output and input change. They can increase or decrease. Productivity increases only if the relationship between output and input is greater after the change than before it. Behind this change there can be a more effective operation, and/or structural changes like investments or divestments. The same questions as the ones above about the limitations for the increase of output and ability to realize the decrease of requirement of resources are relevant also in this case. A way to improve productivity is often capital investment[2] which increases the production capacity and causes some other changes in operations. In this

[2] While new capital is an important source of productivity growth, in the short run it can reduce productivity (see e.g. Chew 1986, p. 1).

case the availability of resources might be a factor that prevents the possibility for increasing the profitability of the firm.

As a summary it is possible to say that the savings in the costs of products required by profitability increase do not exist if one or both of the followings are not realized in the activity under examination:

1) **Increase in capability to produce caused by productivity improvement should be able to be utilized.**

2) **Decrease in requirement of resources caused by productivity improvement should be able to be realized.**

In the framework developed in this study the analysis of the effects of productivity change on profitability is systematized. The framework contains two stages. The structure of the framework is roughly as follows:

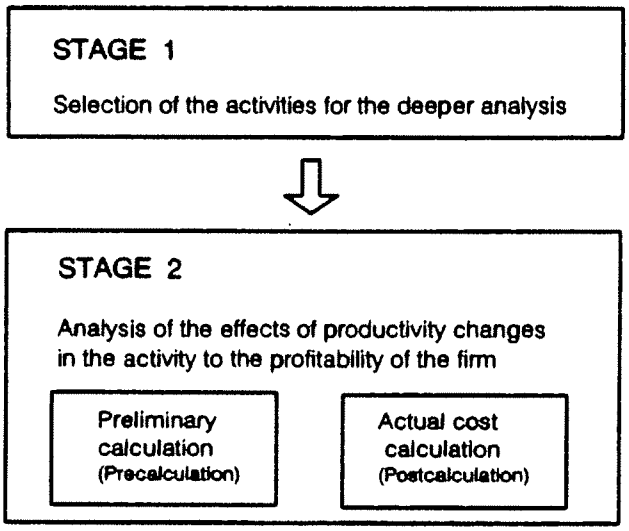

Figure 5.1. A rough description of the structure of the framework.

In the **first stage** the aim is to select the activities as objects for deeper analysis and improvement actions. This stage gives an answer to the question of how to find the objects of improvement in production. In the **second stage**

it is analyzed how much a change in productivity in an activity affects the profitability of a firm. This stage gives an answer to the question whether the improvement actions are valuable.

5.2. How to find the objects of improvement in production?

The question in the heading above is very essential in the connection of the improvement of a manufacturing process. In the literature a large number of methods and systems for supporting production improvement are presented. For example Davenport (1993, p. 24) has presented the approaches to business improvement classified on the basis of two dimensions; time and outcome (figure 5.2.).

Context / Outcome	Project / One-time	Continuous improvement / Ongoing
Incremental improvement	* Activity value analysis * Overhead value analysis * Process value analysis	* Total quality management * Business process improvement * Activity-based costing
Radical Innovation	Process innovation (reengineering, business process redesign)	Not meaningful

Figure 5.2. Approaches to business improvement (Davenport 1993, p. 24)

In Finland Pirjetä (1978) has presented a method for analyzing and finding the requirements to improve the production function of a firm. The last step in this method is proposing the improvement projects. The urgency and significance

of these projects is proposed to be analyzed. Another method for analyzing the production, called "Controllability analysis" is presented by Eloranta and Räisänen (1986). These both are rather large analyses and proposing the improvement objects is only a part of them.

In the literature there are many other methods and tools for selecting the improvement objects. Some of the methods can be classified as "scientific". These are theory-based and supported by empirical evidence. Some of the methods which are used in firms are tools used by consultants and these do not have any strong theoretical basis. There is also a large variation of software which can be used in the selection of improvement objects. These can be classified in three categories. First, there is software which is based on cost modeling. Software utilizing the ideas of activity-based costing like "Cost Control" are of this kind. The second category is the software and techniques which are based on process modeling. Process description tools like "BPwin" may be joined to the process modeling software. Simulation models like "Simfactory" form the third category. The essential property of these models is the possibility to simulate what happens if some factors in production change.

There have been attempts to typify the situations and problems in production. However, any directions for management detailed enough have not been presented (see e.g. Eloranta & Räisänen 1986, p. 130). Most of the methods are rather extensive and require a large amount of work. For example Controllability analysis requires on average 300 hours to complete (Eloranta & Räisänen 1986, p. 119). It is not reasonable that the selection of activities for improvement takes so long. In addition, most of the methods and software have many other aims than the selection of improvement objects.

The insight of the management is always present when the objects for improvement actions are selected. Unfortunately, the insight of the management might often be the only way for selecting the objects for improvement

actions. The insight of the management can be composed of many different areas in agreement with business and production. They can be presented as in figure 5.3. The insight might be based e.g. on the knowledge of equipment, material flow, layout, capacity and performance measures. There can also be information about markets, demand, competition, new technologies and so on. In figure 5.3. these factors are classified in six categories. This classification is not only way to do it. On the basis of the insight and perhaps some systematic method, the management can make a synthesis and select the objects for improvement.

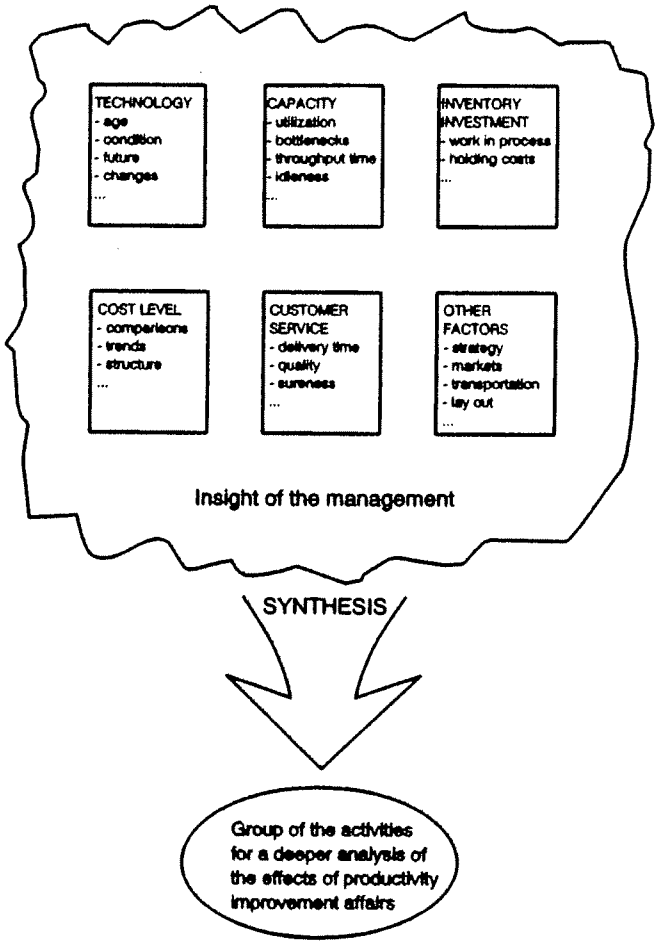

Figure 5.3. The insight of management behind the selection of objects for deeper analysis.

The insight of the management is, however, very important in connection with the selection of improvement objects. It is stated that approximately 2/3 of the needs for improvement can be observed in the connection of production description (Pirjetä 1978, p. 100). The ad hoc decisions which are based on the insight of the management have also some problems. They are not always logical and may not take into account all the factors and alternatives that may be relevant (see e.g. Partovi & Burton & Banerjee 1989, p. 5).

The selection of improvement objects is a semistructured problem situation, like investment decisions. In these situations, management insight alone is not adequate for the decision and these situations are not understood well enough to permit a complete, usually analytical, solution (see e.g. Kivijärvi & Tuominen 1992, p. 353). There are many criteria in use which cannot be converted to monetary values. For example flexibility, links between activities and quality are this kind of criteria. The multi-criteria evaluation techniques are suitable for semistructured problem situations. There it is possible to use e.g. simple weighted evaluation techniques. However, a significant drawback of simple weighted evaluation techniques is that they neglect the issue of inconsistency on the part of the decision maker or evaluator. Inconsistency arises when the evaluation results do not confirm the evaluator's preferences (Frazelle 1985, p. 46). To avoid the problems with simple weighted evaluation techniques it is possible to use the Analytical Hierarchy Process (AHP[3]) developed by Saaty.

Instead of thinking where and how to improve the production, it might sometimes be reasonable to consider whether the activity under examination is necessary in the manufacturing process. ABM, and especially activity analysis is a good tool in this connection. The improvement actions in

[3] AHP is used in very many areas of decision making in the firms. It is used for example with the decision problems concerning automated manufacturing (Weber 1993), intangible investments (Kivijärvi & Tuominen 1992), choice of technology and plant layout design (Partovi & Burton & Banerjee 1989).

nonvalue added activities require mature deliberation. It is irrational to make investments to improve productivity in an activity which may be shut down (see e.g. Kotiranta & Molander 1993, p. 48). This question is also connected to the extent and levels of improvement requirement. It might be necessary to improve only one activity which is perhaps a bottleneck in the production line. It is also possible that the whole plant is so antiquated that partial improvement actions are not reasonable. Between these two possibilities there are many variations of the needs for improvement at different levels.

Bottlenecks in production are often obvious objects for improvement actions. Usually one resource or activity is the factor which prevents the efficiency of operations and the increase of production. If it is possible to improve the productivity of this bottleneck, production increases and perhaps the profitability of the whole firm improves. However, the improvement of bottlenecks is not always the only and best way to increase the profitability of a firm, and sometimes it is not even reasonable.

As mentioned earlier, there are many ways and methods for selecting the improvement objects in production. For the purposes of the first stage of the framework it is not relevant what the selection method is. Below, one possible method, called "Urgency Analysis", for selecting activities for deeper analysis and through it to objects of improvement actions is presented. This method does not require as much time and work as many of the methods and software mentioned above. It requires rather good knowledge about the production process and the firm's operation. It is a simple weighted evaluation technique. Urgency Analysis contains a systematic method for selecting some activities from a large group[4] for a deeper analysis of the effects of productivity change on the profitability of a firm. The selection in this method is based on the analysis of three properties; worth, possibility and necessity.

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[4] A typical business can have 200 to 300 activities (Turney 1992, p. 22).

5.2.1. Urgency Analysis

Urgency Analysis is a tool for realizing the first stage of the framework. In Urgency Analysis the available knowledge about production and the firm, including the insight of the management, is systematized. This information includes the present situation, something about the history and an outlook on the future of the firm. According to this information the activities[5] in the production are classified to three urgency categories (A,B,C) on the basis of three properties: worth, possibility and necessity.

Urgency Analysis is composed of four main phases. In the first main phase the production process is divided into activities. In the second main phase the activities are classified to four categories in all three dimensions. The urgency point for each activity is calculated in the third main phase. In the last main phase, the activities are classified to three urgency categories (A,B,C) on the basis of the urgency point.

The **first main phase** of urgency analysis is presumed as accomplished in the framework. In the second stage of the framework the sufficient cost information produced by ABC is needed. The starting-point is that the production is divided into activities and there is accurate enough cost information in use. In the **second main phase** the activities are classified to four categories with regard to the three properties; worth, possibility and necessity. This classification can be illustrated as in figure 5.4. There each property forms its own dimension. In each dimension all four categories get their own values; 1,2,3 or 4. So in the space there are 64 possible points (W,P,N) where an activity can be located.

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[5] In this connection the activity means the smallest possible unit that is handled in the cost information system of a firm. Micro activities, if they are available, are suitable units for performance measurement and improvement (compare Turney & Stratton 1992, p. 47).

The first property or dimension in the examination is how worthy (W) the productivity improvement in the activity is. According to this examination the activities are classified to four categories which get their own values. Those activities with which the largest savings or increase in incomes are possible, get the value 4. Activities with a possibility to get rather large savings or increase in incomes, get the value 3. Value 2 is given to those activities with which some savings or increase in incomes are possible. The rest of the activities get the value 1. Productivity improvement in these activities does not give any or gives only very little savings or increase in incomes. Sometimes productivity improvement in these activities increases the unit costs.

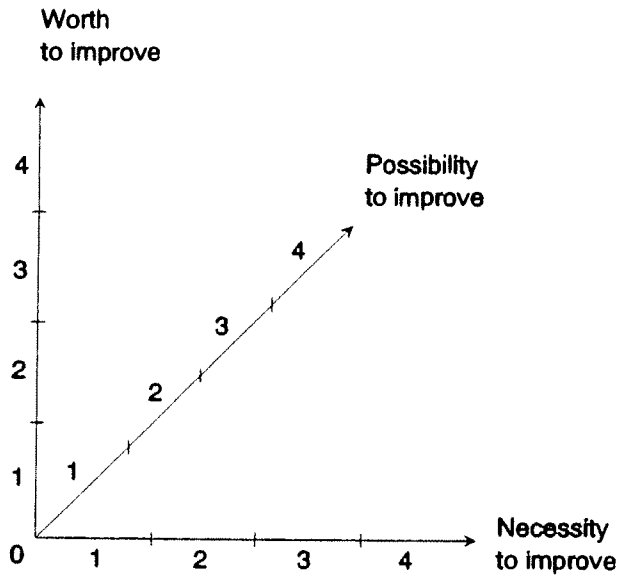

Figure 5.4. The classification of activities with regard to three dimensions.

There are many critical factors which should be taken under consideration when the worthiness of productivity improvement in the activity is examined. For example the following factors are critical (these are not in order as regards importance):

- extent of activity / largeness of costs
- possible consequences (e.g. to the amount of work in the process)
- bottleneck in production; situation and possible removal
- setup times, throughput time
- delivery time and sureness
- material flow, transportation in production
- strategic situation of larger unit (e.g. closing down the factory)
- necessity of activity in production (can it be shut down)
- possibility to increase production
- possibility to realize a decrease of requirement of resources

The second property or dimension in the examination is how possible (P) the productivity improvement is. This means that the management needs to estimate the potential[6] for improvement. In this classification those activities which are assumed to contain the highest potential for improvement in the present level of production, get the value 4. Activities with rather large potential for improvement get the value 3. Value 2 is given to those activities which are assumed to have some potential for improvement. The rest of the activities get the value 1. It is assumed that these activities do not contain any or contain only very little potential for improvement without investments.

There are also many factors which should be taken under consideration when the possibility of productivity improvement in the activity is examined. For example the following factors are critical in this case (these are not in order of importance):

- utilization of capacity (level and variation)
- amount of inventories
- the way the workers spend their working hours
- setup times, throughput time
- delivery time
- technology (present and new possibilities)

The third property or dimension in the examination is how necessary the improvement actions in the activity are. This means in other words, how large

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[6] This is also presented as the most important principle that is used in the selection of activities to productivity measurement (see Armitage & Atkinson 1990, p. 113).

is the necessity **(N)** for improvement actions. There might be some activities where the improvement actions are very necessary or even urgent in short term. Those activities whose need for improvement is very urgent get the value 4. Activities with rather large necessity for improvement actions get the value 3. Value 2 is given to those activities which are assumed to have at least some necessity for improvement. The rest of the activities get the value 1. These activities do not need any or need only very little improvement according to the present information.

The critical factors which should be taken under consideration in this case can be for example the follows (these are not in order of importance):

- utilization of capacity (level and over-loads)
- disturbances of machines
- technical age of equipment
- link between activities
- setup times, throughput time
- delivery time and sureness
- bottlenecks
- material flow, transportation in production
- requirements of customers
- aims of operation
- necessity of activity in production (is it possible to shut down)

In the **third main phase** of Urgency Analysis the urgency point **(UP)** for every activity is calculated. The urgency point can be calculated as follows:

$$UP = a \cdot W + b \cdot P + c \cdot N \qquad (5.1.)$$

where:
UP = urgency point
W = worth
P = possibility
N = necessity
a = coefficient depending on decision situation
b = coefficient depending on decision situation
c = coefficient depending on decision situation; (a + b + c = 3)

It is clear that all aspects in the classification of activities are not equal in importance. Their weights can vary depending on the situation, the aims, values and so on. For example when we are cutting the costs or/and redeveloping the whole firm, the worth of improvement is more important than the possibility or the necessity. The coefficients a, b and c are the means by which the situation and the aims of the firm and the aims of the analysis are considered. These coefficients are defined so that the sum of these is 3. The most important property always affects the urgency point most and still the urgency points of the activities are valid for comparison.

The **fourth main phase** of Urgency Analysis contains the classification of activities to three urgency categories (A,B,C) on the basis of the urgency point. The amount of activities to be placed to each category depends on the decision situation. Critical factors are e.g. is it a question of continuous improvement or a unique improvement project, what the resources on use are, what the aims are and so on. Also the dispersion of urgency points might affect the classification.

To category A are placed the activities with highest urgency points. The improvement actions are most urgent with these activities. The deeper analysis of the effects of productivity change on profitability should be done immediately for these activities. The decision about starting the improvement actions should be made on the basis of the deeper analysis. A rough estimation is that about 10% of the total amount of activities in production should be placed in category A. There can also be only one activity, if the decision situation presupposes it. To the second urgency category (B) come those activities which require improvement actions rather soon, for example within a year or two. The definition of this time period depends on the firm's policy in production improvement. A rough estimation is that about 20% of the total amount of activities in production should be placed in urgency category B. The rest of the activities should be placed in urgency category C. The improvement of these, according to the present information and situation,

is not relevant very soon. In this connection it is important to understand the dynamic nature of the problems. The situation may change very fast and it causes changes in the placement of activities in the urgency categories. There must always be a readiness for analyzing again the needs for improvement.

Above one possible tool for selecting the activities for deeper analysis and through it to objects of improvement actions is presented. Urgency Analysis is a weighted evaluation technique. It is very simple and follows the chain of general multi-criteria evaluation procedure (see e.g. Frazelle 1985, p. 42-44). Urgency Analysis can also be seen as a modified version of the more generally known ABC-analysis. Three dimensions which affect this classification and a simple method of stressing these dimensions are presented. It is also presented how to calculate a numerical value for the basis of classification.

Urgency Analysis is meant to be a tool which can replace the irregular use of the insight of the management and ad hoc decisions in the selection of improvement objects. Unfortunately, the insight of the management is often the only basis for the selection of improvement objects. In practice there can be e.g. knowledge about the level of costs in some cost pool in production. If the cost level is high, the management has to consider whether there are some ways to reduce these costs. There can also be an idea that here we can save something if we improve or move the operations. However, in practice these selections and improvement actions are often realized without any systematic searching and selection for objects, and without analyzing the economical effects of these actions. Urgency Analysis is a rather easy way to classify the activities according to the need for improvement. It does not require much work, but good knowledge about the production and the firm is necessary. The activities for deeper analysis of the effects of productivity change on profitability can be selected also by some other ways or other methods. The first stage of the framework considers the selection of the improvement objects, not the selection method. Urgency Analysis is good and easy tool for this selection.

5.3. Are improvement actions valuable?

In this chapter the effects of productivity change in an activity on the profitability of a firm are considered. The economical aspects of productivity improvement are examined in both stages of the framework. In the first stage, in connection with Urgency Analysis, the economical effects are considered slightly. This is not necessarily based on any calculations. However, behind the evaluation there can also be numerical data produced by the cost accounting system of the firm.

After the first stage of the framework some activities are selected for deeper analysis and through it to the objects of performance actions. These are these which are placed in urgency category A in Urgency Analysis. In the second stage those are taken under more accurate examination. The examination of the economical effects can be divided into two parts in regard to time

1) **Precalculation** to support decision making and planning
2) **Postcalculation** for conclusions and planning anew

With precalculation it is possible to evaluate the economical effects or benefits of productivity improvement actions in advance. This information helps the management to decide whether it is reasonable to sacrifice resources for improving productivity in a certain activity. However, we must remember that this is only one additional piece of information among many others which affects the managements decision making. Postcalculation shows how the productivity improvement actions are affected. When the realized situation differs from the planned one it is necessary to analyze the reasons for the difference. There can be for example a systematic error in the information basis of the estimation, or the realization of operations does not correspond with the estimation. This information can be used as one basis for the planning of future operations.

One basic presumption in this study was the use of activity-based costing in the firm under examination[7]. This creates better possibilities for rough costs estimation than the traditional cost accounting systems. The importance of activity-based costing is emphasized in the second stage of the framework. The economical effects of productivity improvement actions are examined more accurately there.

In the following chapters (5.3.1.-5.3.9.) the theoretical background for analyzing the effects of productivity (both total and partial) change in an activity on the profitability of a firm is presented.

5.3.1. Principles of evaluation

Activity-based costing gives a better possibility than the earlier cost accounting systems for considering the operations of a firm, as well as the cost effects of these operations in the level where they really happen. It also makes it possible to examine the effects of a certain productivity improvement action. The changes in productivity are usually caused by changes of the physical process in the activities. These can be for example more effective operation, and/or structural changes. Productivity can be measured and influenced at the level of the activity.

When a firm has an activity-based costing system in use, it is possible to construct a model like the TFPM models for analyzing the economical effects of productivity improvement. In this chapter the theoretical background for one model of this kind is presented. In the model one certain activity j in a certain period of time (P) is examined. In the firm there are several activities ($j = 1...m$). Several products k ($k = 1...p$) can be produced in the activity. This model is based on the presumption that there are no other simultaneous changes in the production than the one under examination (ceteris paribus).

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[7] Activity-based costing is as yet very little used in Finland (Lukka & Granlund 1993, p. 58).

Another limitation is that changes in the quality of the products due to changes in productivity are not taken into consideration in this model. The model concentrates only on the cost and income effects of productivity change, not on the possible changes in the selling prices or input prices. In reality the presumption of ceteris paribus is not ever realized. Changes in an activity may always affect the other activities in production and/or somewhere else. Also a change in one partial productivity may cause changes in the other partial productivities. There are also some elements outside the firm which can affect the firm because of the changes made in the activities. For example the demand of products may change due to change of quality in one activity. Without some limitations, as e.g. the presumption of ceteris paribus, a simulation of the whole firm would have been necessary for analyzing the effect of change of productivity in an activity on the profitability of the firm. The limitation simplifies the outlining of the problem and the calculations needed.

In the model, the variables are considered in a certain period of time. There are two calculation periods in the model. The first calculation period P1 is the original state. It is the base of the calculations. The second period P2 describes the situation after the change. These periods are indicated in the equations by numbers 1 and 2. P1 and P2 are equal in length, but the length can vary depending on the measurement situation and the firm's needs (for example 1, 3, 4, 6 or 12 months). The essential element in the model is the change between these two periods. In this model, the effects of productivity change between periods P1 and P2 on the profitability or the profit change between periods P1 and P2 are considered. The length of time between these periods can be whatever wished. Usually it is an accounting period used in the management of the firm.

The underlying assumption is that the main objective in decision making is a profitable action or an improvement of profitability. Productivity improvement is one means among others for achieving this objective. So, productivity improvement and the change of productivity precede in time the change in

profitability. While the objective of this study is to analyze the effects on the profitability of a firm, in the model the effects of change of productivity on the change in the amount of profit at firm level are in fact analyzed.

The model presented here makes it possible to calculate the effects of productivity change in an activity on the profitability of a firm. The calculations can be made both as precalculation and postcalculation. On the basis of this model, a tool for analyzing the usefulness of these calculations in practice has been prepared. The results of the empirical test of this model and the whole framework are presented in chapter 6.

The two essential elements in this model are the structural inverse uniformity between the cost per activity measure unit and productivity, and the costs which can be directed from a certain activity to a certain product. In this model the connection between productivity improvement in an activity and the cost of product manipulated in this activity and through it the effects on profitability are presented. In general the effects of productivity improvement and the analogy used in the model can be described as in figure 5.5.

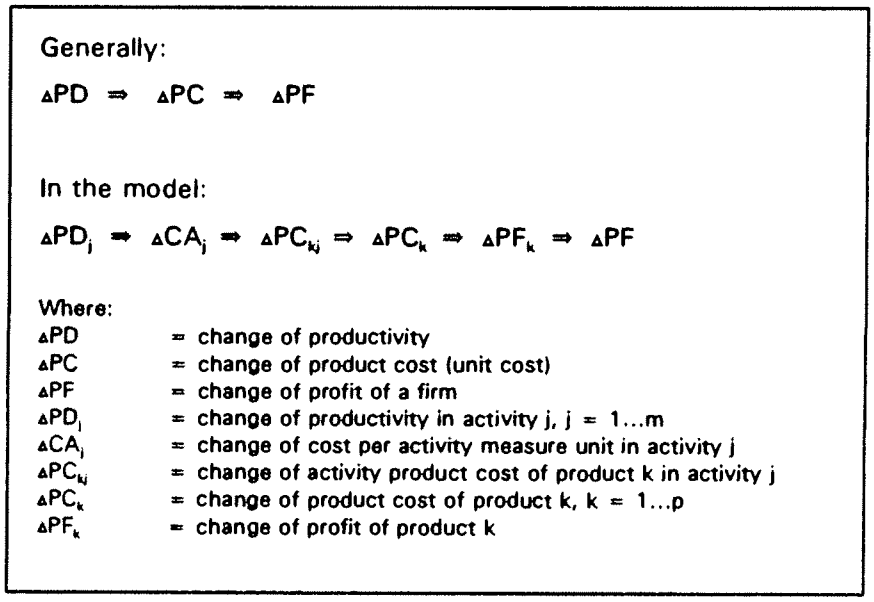

Figure 5.5. The logic of calculation as a chain of influences.

It is generally known that an increase in productivity (change, ΔPD) decreases the unit cost of products produced (change, ΔPC) and this can lead to an increase of profits (change, ΔPF) and profitability. Activity-based costing makes it possible to analyze this general chain with higher accuracy than earlier. This possibility is utilized in the model proposed here. The starting point in this model is a change of productivity in one certain activity (ΔPD_j). This causes change in the cost per activity measure unit in that activity (ΔCA_j). In this connection there can also happen changes in the "use" of the activity and the use of materials (these are considered more accurately later). The change in cost per activity measure unit causes a change in the costs which can be directed to one product from this activity on the basis of the usage (ΔPC_{kj}). As a result of this the total costs of the product change (ΔPC_k). When selling prices are constant and product costs change, the profit of a product (ΔPF_k) and the profit of the firm (ΔPF) change also. These changes happen under the presumption of ceteris paribus. In reality there can be external or/and internal factors which prevent these changes.

The effects of productivity improvement can also be analyzed on the basis of a decrease of total costs in the activities. This decrease of the costs of activities affects the total costs of the firm directly and through these, the profitability of the firm. However, this kind of consideration takes into account only one part of productivity improvement. The increase of production (output) caused by the productivity increase is left without attention.

Another reason why the chain of influences goes through the products, is the possibility that the improvement actions in an activity may affect only one or few products among the all those produced in this activity. For example the fastening of one product may change so that only one setup is needed instead of the two or three needed earlier for this product. This kind of productivity change is directed only to the production of one product in that activity, not to all the products or to the total costs of that activity.

5.3.2. The hierarchy of cost terms

In activity-based costing the costs of a certain product can be calculated on the basis of the usage of materials and activity costs according to the bill of the activities of this product. In the bill of activities (BOA), all the activities which are involved in the production of the product are listed (see e.g. Brimson 1991, p. 203 or Turney 1991, pp. 132-133). The costs which can be assigned to certain product k, can be presented as a hierarchy of cost terms (figure 5.6.).

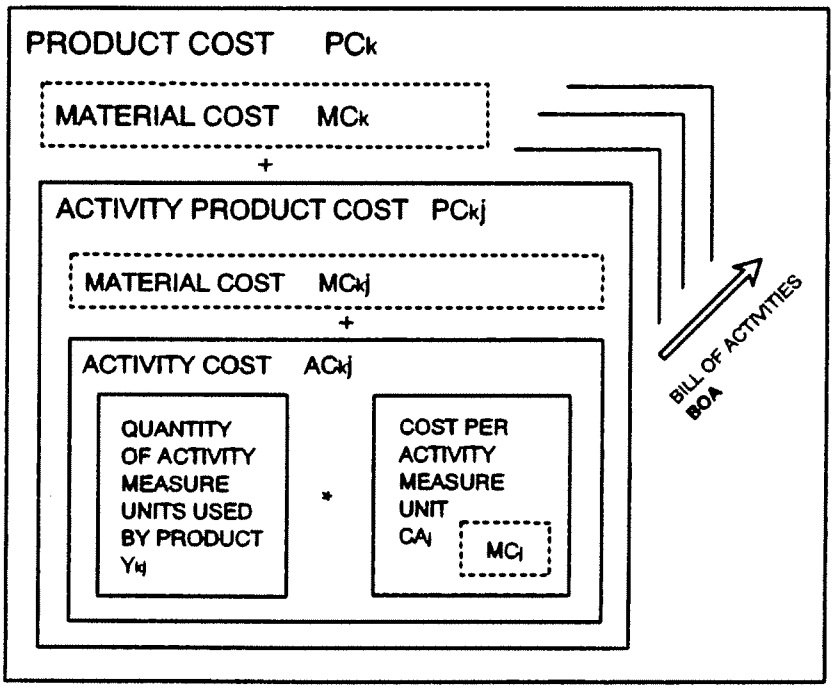

Figure 5.6. The hierarchy of cost terms.

The product cost of product k is the sum over the cost of the usage of all the activities listed in the bill of activities. The cost of material is also included in it. The material cost can be handled either separately, in addition to activity product cost (as MC_k) or activity cost (as MC_{kj}), or together with the other resources of the activity (as MC_j), and so as a part of the total cost of activity.

The way how the material costs are handled is individual and may depend on the significance of the materials. It is possible to define for example that MC_k is the original raw material of product k in the beginning of a production line. MC_{kj} is the unique additional material which is used for product k in activity j. For example screws, nuts or metal plates can be of this kind. MC_j is an additional material which is used for all the products in activity j. All material which is added to all products almost the same way, like for example paints in some cases, can be handled like this.

The cost of unique additional material (MC_{kj}) can be included in the cost of raw material (MC_k) when the physical output of the activity is heterogeneous. If the activity output is homogeneous, the cost of unique additional material in an activity can be handled as cost of material resources of the activity (MC_j). Then these costs are included in the cost per activity measure unit.

The output of an activity can be continually of the same kind. Then the amount of output can be described and measured by the quantity of outputs. For example the output can be expressed by the amount of similar holes produced by a punching machine. However, there can be different amounts of holes in different products. The measuring unit is one hole. Then the physical output of the activity is **homogeneous**.

Usually the output of an activity varies over different products. A machine tool makes different operations for different products. In the painting line there can be several products which need different painting operations. A drilling machine drills holes with different diameters. There are many examples like this. Then the physical output of the activity is **heterogeneous**.

The difference of physical output affects the calculations made by this model. The costs of a product depend on the amount of the activity measure units produced in the activities used by the product. When the physical output of an activity is homogeneous, all the products use one or more of the physical outputs of this activity. The change of productivity does not cause any

change to the amount that one product uses of this activity. If the physical output is heterogeneous, the amount of output can be measured for example by machine time. It is possible that the amount that one product uses of this activity, changes. For example the manufacturing time of one product in an activity can decrease from nine minutes to seven minutes. This presupposes a different way to calculate the economical effects of productivity change than in connection with homogeneous output.

5.3.3. Cost per activity measure unit

One essential element in this model is the cost per activity measure unit in an activity. The effect of productivity change can be connected to profitability with the cost per activity measure unit, and the amount of these activity measure units that one unit of a product uses in this activity. The cost per activity measure unit in activity j in a certain period of time is obtained when the total costs of the activity are divided by the volume of activity measured by activity measure units (equation 5.2.).

$$CA_j = \frac{TC_j}{V_j} \qquad (5.2.)$$

where:
CA_j = cost per activity measure unit in activity j
TC_j = total cost of activity j
V_j = volume of activity j measured by activity measure units

The total costs of an activity are composed of two parts. They are the costs of the resources used in this activity, and the costs which are assigned from other activities to this activity. In theory we can consider the effects of productivity change separately with both of these groups of costs. This idea is based on the fact that productivity improvement actions in an activity can affect only the costs of resources used in this activity. For example, if the output stays constant and the requirement for resources decreases, the cost portion of the activity's own resources to one unit of product decreases, but the cost portion of assigned costs stays constant. If the output increases,

both of these will change. This kind of separate consideration is argued from the activity point of view. This separation of total costs of an activity is very problematic from the modelling point of view, especially when the physical output of the activity is heterogeneous. In this connection the amount that one unit of a product uses in this activity may change.

However, the objective of this study is to examine the effects on the profitability of a firm. From the firm's point of view this separate consideration is not meaningful, because the effect of these assigned costs at firm level do not change due to productivity change in an activity. The change of divisor and dividend in the calculations nullify each other. That is the reason why a separation of the total costs of an activity is not done in this study. These costs are assumed to be minor in the activities and they are handled in the calculations as one resource of activity. When the costs assigned from other activities are very large in relation to the total costs of the activity this must be taken into consideration with the definition of the input in productivity measurement.

The cost per activity measure unit in an activity in a certain period of time can be presented from two points of view. From the production of outputs (or capacity) point of view it can be made as in equation 5.3. Here the volume is presented on the basis of the amount of activity measure units produced. It is possible to use the realized output, standard output or capacity in representing the volume. From the use of activity output point of view it can be presented as in equation 5.4. Here the volume is expressed on the basis of the amount of activity measure units that one product uses in the activity, and the total amount of the product produced in this activity. A sum is taken over all the products k (k= 1...p) produced in this activity. There can be realized values or some average values (standards) representing this usage of activities.

$$CA_j = \frac{\sum_{i=1}^{n} (I_{ij} \cdot PR_i)}{V_j} \qquad (5.3.)$$

$$CA_j = \frac{\sum_{i=1}^{n} (I_{ij} \cdot PR_i)}{\sum_{k=1}^{p} (Y_{kj} \cdot L_k)} \qquad (5.4.)$$

where:
I_{ij} = amount of input factor i in activity j in a period
L_k = production quantity or amount of product k in a period
PR_i = price of input factor i
Y_{kj} = amount of activity measure units that one unit of product k uses in activity j

The cost per activity measure unit can be presented in reversed form as made in equation 5.5. There the use of activity output point of view is used.

$$\frac{1}{CA_j} = \frac{\sum_{k=1}^{p} (Y_{kj} \quad L_k)}{\sum_{i\ 1}^{n} (I_{ij} \quad PR_i)} \qquad (5.5.)$$

This inverted version has a clear structural inverse uniformity with the way productivity (PD) is defined. In the dividend, there is the amount of activity measure units needed for all the products produced in this activity. This is the output of the activity. In the divisor there is the quantity of all resources used in this activity multiplied with the prices of those inputs. This is the input of the activity expressed in monetary value. Usually the monetary value is the only possible way to express the input, because there are many different resources with different measuring units. Equation 5.6. clarifies the structural inverse uniformity between the cost per activity measure unit and productivity.

$$\frac{1}{CA_j} = \frac{Output\ quantity}{(Input\ quantity \cdot Input\ price)} = PD_j \qquad (5.6.)$$

where:
PD_j = productivity in activity j

The difference between the cost per activity measure unit and productivity is the treatment of the prices. In cost accounting, the real prices of resources or standard prices are often used. These prices change over time. In productivity measurement, and especially in the measurement of productivity change, the effects of price fluctuation should be eliminated from the calculations. It is possible to utilize this structural inverse uniformity between the cost per activity measure unit and productivity when analyzing the effects of productivity change in an activity on the profitability of a firm.

5.3.4. Activity product cost of one product

The activity product cost of product k in activity j (PC_{kj}) means the costs which are assignable from activity j to one unit of product k. This can be defined as follows:

$$PC_{kj} = AC_{kj} + MC_{kj} = Y_{kj} \cdot CA_j + MC_{kj} \qquad (5.7.)$$

where:
PC_{kj} = activity product cost of product k in activity j
AC_{kj} = activity cost of product k in activity j
MC_{kj} = material cost of product k in activity j

If the structural inverse uniformity between the cost per activity measure unit and productivity (5.6.) is utilized, it is possible to combine first equations 5.4. and 5.7., and then this wit equation 5.6. This is done in equations 5.8. and 5.9.

$$PC_{kj} = Y_{kj} \cdot \frac{\sum_{i=1}^{n} (I_{ij} \cdot PR_i)}{\sum_{k=1}^{p} (Y_{kj} \cdot L_k)} + MC_{kj} \qquad (5.8.)$$

$$PC_{kj} = \frac{Y_{kj}}{PD_j} + MC_{kj} \qquad (5.9.)$$

This connection between the activity product cost of product k in activity j and productivity in activity j is theoretical. The practical problems in measurement have not been taken into consideration. In the form presented, the output in productivity should be measured by the same unit as the usage of activity. This is not always possible or even meaningful. Later in this study the change between two periods is under consideration. Then the essential question in productivity measurement is the change expressed by percents, not the measures used. However, the productivity measures used in this connection should always express the total productivity of activity, not any partial productivity, such as labor or capital productivity. The relationship between the changes of total and partial productivities is considered in chapter 5.3.8.

The change of the activity product cost of product k in activity j (ΔPC_{kj}) means the difference of this cost between the calculation periods P1 and P2.

$$\Delta PC_{kj} = PC_{kj2} - PC_{kj1} \qquad (5.10.)$$

Below, it is considered how the change of productivity affects the change of the activity product cost of product k in activity j. Productivity in activity j in period P1 is PD_{j1}. Productivity increases $(100 \cdot g)$ percent between the periods P1 and P2 and it is $(1+g) \cdot PD_{j1}$ in period P2. When equations 5.9. and 5.10. are combined, it is possible to see the effect of productivity change. The cost

of unique additional material (MC_{kj}) can be handled in connection with the raw material or the resources of the activity as mentioned in chapter 5.3.2. (see also e.g. Juuti 1993, p. 25). When the physical output of activity j is homogeneous, the effect of productivity change on the change of the activity product cost of product k in activity j can be presented as follows (equations 5.11. and 5.12.):

$$\Delta PC_{kj} = \frac{Y_{kj}}{(1+g)\cdot PD_{j1}} - \frac{Y_{kj}}{PD_{j1}} \qquad (5.11.)$$

$$\Delta PC_{kj} = -\frac{g}{1+g}\cdot\frac{Y_{kj}}{PD_{j1}} = -\frac{g}{1+g}\cdot PC_{kj1} \qquad (5.12.)$$

When the physical output of activity j is heterogeneous, the quantity or amount of activity measure units that one unit of product k uses in activity j (Y_{kj}) may change. For example the set up time or machine time of one product may decrease. We can define that the amount of activity measure units that one unit of product k uses in activity j is Y_{kj1} in period P1. This changes $(100\cdot h_k)$ percent between the periods P1 and P2 and is $(1+h_k)\cdot Y_{kj1}$ in period P2. Normally h_k is negative when productivity increases. Now we can state that the change of activity product cost of product k in activity j is:

$$\Delta PC_{kj} = \frac{Y_{kj2}}{(1+g)\cdot PD_{j1}} - \frac{Y_{kj1}}{PD_{j1}} \qquad (5.13.)$$

$$\Delta PC_{kj} = \frac{(1+h_k)\cdot Y_{kj1}}{(1+g)\cdot PD_{j1}} - \frac{Y_{kj1}}{PD_{j1}} \qquad (5.14.)$$

$$\Delta PC_{kj} = \frac{h_k - g}{1+g}\cdot\frac{Y_{kj1}}{PD_{j1}} = \frac{h_k - g}{1+g}\cdot PC_{kj1} \qquad (5.15.)$$

The relationship between h_k and g may vary depending on the productivity improvement actions. The increase of productivity (g) describes the change of total productivity in the activity. The change of usage (h_k) concerns only one product produced in this activity. When the usage of all products changes in a similar way it is included in the change of productivity. However, often the improvement actions do not affect all products equally. There can be changes in fastening or manufacturing operations with one or a few of the products produced in the activity. Sometimes h_k can be different for every product produced in activity j. This change of usage should be taken into account in the calculations when the change of productivity does not include it.

In equations 5.12. and 5.15. it is presented how the change in productivity affects the change of the activity product cost of product k in activity j. This is stated both in the case of homogeneous and heterogeneous physical output. In the following, it is analyzed how the change of productivity affects forward to the chain of influences.

5.3.5. Product cost of one product

The product cost of one individual product k (PC_k) is the sum of all the costs that can be assigned from the activities to this product according to the bill of activities. This includes also the material cost of this product and it can be stated as follows:

$$PC_k = \sum_{j=1}^{m} PC_{kj} + MC_k \qquad (5.16.)$$

where:
PC_k = product cost of product k
MC_k = material cost of product k

This can also be presented so that the costs which can be assigned from one activity to the product are separated from the costs of the other activities. The costs of the other activities than j are denoted with DC_k. Now the product cost of product k can be presented as in equation 5.17.

$$PC_k = PC_{kj} + DC_k + MC_k \qquad (5.17.)$$

where:
DC_k = all activity product costs of product k excluding the cost from activity j

The change of the product cost of one individual product k is an essential element when analyzing the change of the profit of one product and through it the change of the profit of the firm. The change of product cost can be defined on the basis of the change of activity product cost of product k in activity j when there are no other simultaneous changes in production.

5.3.6. Profit of one product

The profitability of a product is its ability to produce profit. Usually the term profit is not in use in connection with products. In general the terms margin or contribution margin are used. These mean by and large the same as profit. The matter in question is the subtraction of product costs (cost) from product price (income). The term contribution margin is usually connected to different calculations in cost accounting fundamentals (see e.g. Uusi-Rauva 1989, p. 75-77 or Horngen & Foster & Datar 1994, p. 73-74). Because there are many different calculations and margins in the terminology (e.g. how to handle variable costs and so on), in this study the term profit of product is used to avoid confusion. The profit of one product k (PF_k) is the subtraction of product cost from product price (PR_k)[8].

$$PF_k = PR_k - PC_k \qquad (5.18.)$$

where:
PF_k = profit of product k
PR_k = price of product k

[8] In this study it is assumed that every product k has only one selling price. When the improvement actions on the activity level are under examination, it is not possible to consider to whom each unit of product is aimed to be sold.

The separation between the cost of one activity and the costs of other activities (equation 5.17.) can be joined to this general determination as follows:

$$PF_k = PR_k - PC_{kj} - DC_k - MC_k \qquad (5.19.)$$

The essential element from the point of view of this study is the change of the profit of the product. There are two ways to determine this, depending on the nature of the physical output of the activity. When the physical output of the activity is homogeneous, the material cost is handled as a part of the resources. The change of the profit of the product under the assumption of ceteris paribus can be determined as in equation 5.20.

$$\Delta PF_k = PC_{kj1} - PC_{kj2} = -\Delta PC_{kj} \qquad (5.20.)$$

In the case of heterogeneous physical output, the cost of unique additional material is a part of the cost of raw material ($MC_{kj} \subset MC_k$). Now (ceteris paribus) the change of material cost at product level (ΔMC_k) is the same as the change at activity level in connection with this product (ΔMC_{kj}). So the change of the profit of the product can be stated as follows:

$$\Delta PF_k = PC_{kj1} - PC_{kj2} + M_{kj1} - M_{kj2} = -\Delta PC_{kj} - \Delta M_{kj} \qquad (5.21.)$$

Equation 5.21. takes into account that there can be changes in the amount of the additional material that one certain product uses in an activity. This change regarding only one product is possible even though the activity takes part in the manufacturing of several products.

5.3.7. Profit of a firm

Next, the effect of changes at product and activity level on the profitability of the whole firm are considered. The absolute level of profit or profitability is not meaningful in this study. The change in the amount of profit and profitability

caused by a change of productivity in one activity is essential. If the total costs of a firm are assigned well enough[9] to activities, it is possible to state that the profit of a firm is a sum of the profits of all products as follows[10]:

$$PF = \sum_{k=1}^{p} (PF_k \cdot L_k) - NC \qquad (5.22.)$$

where:
PF = profit of a firm in a period
NC = sum of the costs which are not assigned to any activity

The profit of a firm here means the profit that the firm earns from the manufacturing and selling of the products. The other incomes, e.g. interest incomes, are not taken into consideration. The profit of a firm is always calculated for a period of time. The change of profit is the difference between the profits of two periods which are equal in length (here P1 and P2). Under the assumption ceteris paribus the sum of the costs which are not assigned to any activity (NC) stays constant and so the change is nil when the productivity changes in one activity. In addition to this, it is important to notice that the change of productivity includes the change of the production quantity of product k. Now the change of profit can be stated as in equation 5.23.

$$\Delta PF = PF_2 - PF_1 = \sum_{k=1}^{p} (\Delta PF_k \cdot L_{k1}) \qquad (5.23.)$$

When trying to find, on the basis of the preceding equations, the solution for calculating the effect of productivity change in an activity on the profitability of a firm, two possible solutions can be found, depending on the nature of the physical output. In case of a homogeneous output it is possible to combine equations 5.12., 5.21. and 5.23. Now the change of the profit of a firm can be determined as follows:

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[9] Not all costs are traceable directly to activities. In theory these nontraceable costs are recommended to be allocated to the organization's primary activities (e.g. Brimson 1991, p. 142). However, in practice there might be some costs which are not, due to some individual reason, allocated to any activity.

[10] According to Pihlanto & Lukka (1993, p. 268), also Martti Saario has stated this idea in 1945.

$$\Delta PF = \sum_{k=1}^{p} [\frac{g}{1+g} \cdot PC_{kjl} \cdot L_{kl}] \qquad (5.24.)$$

Correspondingly, equations 5.15., 5.22. and 5.23. can be combined when the physical output of the activity is heterogeneous. In this case the change of the profit of a firm can be defined as follows:

$$\Delta PF = \sum_{k=1}^{p} [(-\frac{h-g}{1+g} \cdot PC_{kjl} - \Delta M_{kj}) \cdot L_{kl}] \qquad (5.25.)$$

In equations 5.24. and 5.25. it is presented how to calculate the effect of the change of total productivity in an activity on the profitability of a firm. It is possible to use this model in calculations within the limits made in the connection of the construction of this model. It is suitable for a change of productivity which emerges without any large structural changes in the activity under examination. If the change of productivity is intended to be achieved by a structural change like investment or divestment, it is difficult to use this model. This is due to the possible radical changes in the nature and level of output and inputs.

5.3.8. Relationship between partial and total productivity

The relationship between the change of productivity in an activity and the change of the profit of a firm presented in equations 5.24. and 5.25. considers productivity as total productivity. The change of total productivity is difficult to measure in practice. The measures of partial productivity are more often utilized and easier to use. To make this model more useful as a tool for analysis at firm level, it is necessary to examine the effects of change in one partial productivity on the change of total productivity.

The relationship between total productivity and partial productivities is reversed (see equation 2.5.). It can be presented as follows:

$$\frac{1}{PD_T} = \frac{1}{PD_L} + \frac{1}{PD_C} + \frac{1}{PD_M} + \frac{1}{PD_E} + \frac{1}{PD_X} \qquad (5.26.)$$

When examining the effect of the change of one partial productivity (input Z) it is possible to present this relationship in simpler way.

$$\frac{1}{PD_T} = \frac{1}{PD_Z} + \frac{1}{PD_X} \qquad (5.27.)$$

where:
PD_T = total productivity
PD_Z = input Z productivity
PD_X = other inputs productivity

Next, it is considered how the change of the productivity of input Z (ceteris paribus) affects the change of total productivity. Productivities in period P1 are marked PD_{T1}, PD_{Z1} and PD_{X1}. Productivity of input Z increases $(100 \cdot z)$ percent between the periods P1 and P2, and it is $(1+z) \cdot PD_{Z1}$ in period P2. The increase of PD_{Z1} causes an increase in total productivity. The amount of this increase in total productivity can be marked as $(100 \cdot g)$ percent between the periods P1 and P2. So total productivity is $(1+g) \cdot PD_{T1}$ in period P2. According to the assumption of ceteris paribus[11], the productivities of other inputs (PD_{X1}) do not change between these two periods. In practice a change in one partial productivity may be nullified by a change of another partial productivity (e.g. labor v. capital). According to equation 5.27 the situation in period P2 can be presented as follows:

$$\frac{1}{(1+g) \cdot PD_{T1}} = \frac{1}{(1+z) \cdot PD_{Z1}} + \frac{1}{PD_{X1}} \qquad (5.28.)$$

where:
g = change of total productivity, (100 · g) percent
z = change of productivity of input Z, (100 · z) percent

[11] The assumption of ceteris paribus may cause a marginal error to the value of g, when we are analyzing the total effect of changes of several partial productivities.

According to equation 2.1., productivity is the relationship between output and input. In equation 5.29., the productivities are presented as the ratio of output to input.

$$\frac{1}{(1+g)\cdot\frac{O_1}{I_{T1}}} = \frac{1}{(1+z)\cdot\frac{O_1}{I_{Z1}}} + \frac{1}{\frac{O_1}{I_{X1}}} \qquad (5.29.)$$

where:

O_1 = amount of output in period P1
I_{T1} = amount of total input in period P1
I_{Z1} = amount of input Z in period P1
I_{X1} = amount of input X in period P1

From equation 5.29. we can solve the amount of the increase of total productivity in percents (100·g) when the productivity of input Z increases (100·z) percent between the periods P1 and P2. The solution is presented in its entirety in appendix 1. g can be stated as in equation 5.30.

$$g = \frac{1}{(\frac{1}{z}+1)\cdot\frac{I_{T1}}{I_{Z1}} - 1} \qquad (5.30.)$$

This general formulation of the relationship between the change of one partial productivity and the change of total productivity (equation 5.30) can be used in analyzing the effects of the change of one certain partial productivity (e.g. labor or capital) in an activity on the profit of a firm (equations 5.24 and 5.25.).

5.3.9. Output, capacity and volume of an activity

The output, capacity, and volume of an activity are near to each other. The output of an activity is the amount or quantity of outputs (products, services etc.) produced by that activity in a period. Output can be presented in many ways. One possibility is to use the physical output from the use of activity

point of view as in equation 5.4. Another alternative is e.g. the realized output in a period.

Capacity describes the maximum reasonable output rate which can be achieved with the current product specifications, product mix, work force, plant and equipment. At activity level it is the highest amount of production that can be achieved with normal resources on use. Theoretical capacity (also called maximum or ideal capacity) means the situation where the production runs all the time. When the weekends, holidays, changeover times and similar items are deducted from theoretical capacity, we can get the practical capacity (e.g. Paranko 1994, p. 336 or Cooper & Kaplan 1991, p. 166). The capacity, both theoretical and practical, is usually larger than the output. However, sometimes when the overtime work is used, the output can be larger than practical capacity. Using the symbols of this study, capacity can be described from the use of activity output (equation 5.31) point of view as follows:

$$C_j = \sum_{k=1}^{p} (Y_{kj} \cdot L_k) + EC_j \qquad (5.31.)$$

where:
EC_j = excess or free capacity in activity j in a period

In calculations the volume is usually equivalent to output. It can also be the standard of output in a period. Defining the volume of an activity is a very important phase in calculating the cost per activity measure unit and the effects of productivity change. The volume in a period can be a realized output, standard, or some average value. In some cases even capacity can be a measure of volume. In this study volume is understood to be more stable than the realized output in a period.

One apparent problem is the handling of the costs of free capacity. In many companies the capacity of the majority of activities is higher than the volume of production (see e.g. Paranko 1994, p. 337-339). There is usually much excess or free capacity in the activities. Also the capacities of activities in

production are different. The reason can be for example the size of machines, or the size of different investments. However, in theory the total cost of the activity should be assigned to the products. From this, it follows that when we are using the realized output as measure of volume, the activity product cost of one product varies over time depending e.g. on demand or the ability to sell. This makes it impossible to analyze the effects of productivity improvement actions.

In the literature there is some advise on how to handle the cost of free capacity. For example Paranko (1994, p. 349) sees that if the cost of free capacity is important, and it can be measured, the modified normal costing method would be useful in counting the product costs for a pricing decision. Lumijärvi (1993, p. 35) sees[12] that the cost of free capacity should be separated in internal accounting in order to avoid wrong conclusions.

In equations 5.3. and 5.4. the volume is expressed generally without consideration about the utilization of capacity. It is assumed that all costs of capacity are assigned to cost objects using the cost per activity measure unit. In 5.3. the standard quantity of production or practical capacity can be used as volume. In 5.4. the volume can be the standard quantity or the realized quantity of production. The selection of the way to handle the cost of free capacity must be done individually every time when measuring the effects of productivity improvement. It depends for example on the measurability and importance of these costs.

In the precalculation of this study the costs of free capacity were included in the product cost by using the standards of the quantity of production and the usage of the activity. In the postcalculation both the standard and the realized numbers were used, because the aim was to analyze the difference between the excepted and the realized situation.

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[12] Lumijärvi (1993, p. 35) also says that free capacity can be explained positively, it is a possibility, a potential for sale.

5.4. Structure of the theoretical framework

The following is a short summary of the structure of the framework developed in this study. This *framework* is a systematical way with two stages for analyzing the effects of productivity improvement actions in an activity on the profitability of a firm. In the first stage of the framework, the objects for deeper analysis and possible productivity improvement actions are chosen. In the second stage, it is analyzed how much a certain productivity change in an activity affects the profitability of a firm. The structure of the framework can be described for example as in figure 5.7.

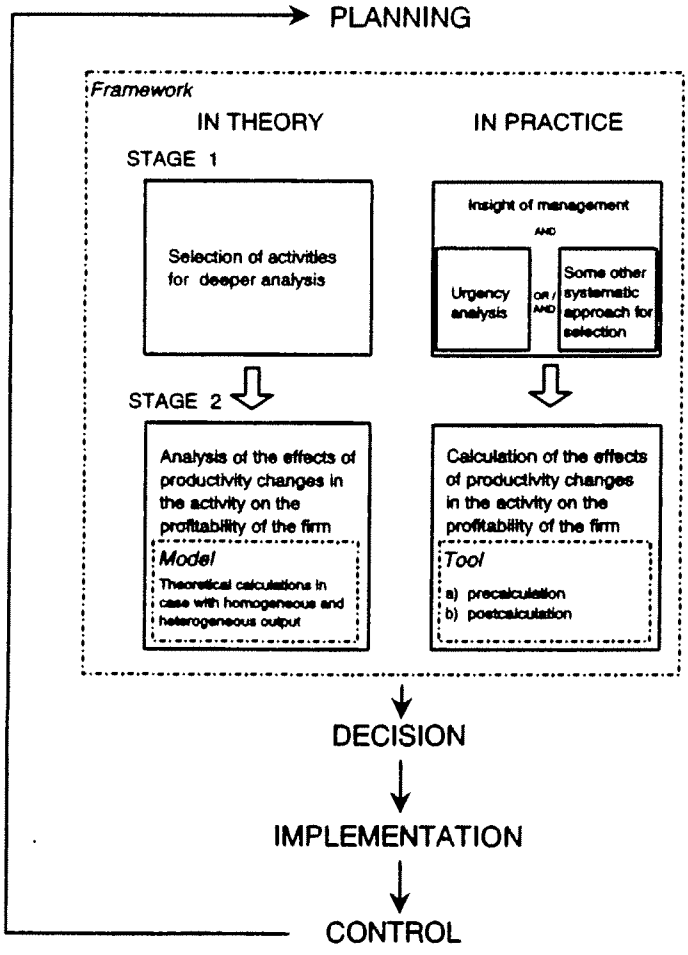

Figure 5.7. The structure of the framework in theory and in practice.

It includes the components and both the theoretical and the practical aspect of the framework. This framework is presented here as a supporting part to the general chain of decision making. It is mostly connected to the planning phase. However, the postcalculation can be also seen as a part of control, which is a basis for planning anew. The framework produces additional information to support the management's decision making, when they are allocating resources to the improvement of productivity in production. In practice the relationship between the selection and analysis of improvement objects and the general chain of decision making is not so systematic as presented here.

The **first stage** of the framework is considered with the selection of activities for deeper analysis and through it to the objects of improvement actions. There are many ways and methods for selecting the improvement objects. For the purposes of practical selection a simple weighted evaluation technique, called Urgency Analysis is presented. This method is based on the worthiness, possibility, and necessity of improvement actions in each activity.

In Urgency Analysis the activities are classified into three urgency categories. To category A are placed the activities with which the improvement actions are the most urgent. These activities are selected to the second stage of the framework. To the second urgency category (B) come those activities which require improvement actions rather soon, for example within a year. The rest of the activities should be placed in urgency category C. The improvement of these activities according to present information is not relevant very soon. However, it is important to understand that the situation may change and there must always be readiness for analyzing the need for improvement actions again. Urgency Analysis can be composed of four main phases. In the first main phase the production process is divided into activities. In the second main phase the activities are classified to four categories in all three dimensions. The urgency point for each activity is calculated in the third main phase. In the last main phase the activities are classified to three urgency categories (A,B,C) on the basis of the urgency points.

In the second stage of the framework it is analyzed how much the change in productivity in an activity affects the profitability of a firm. This analysis concerns the activities with which the improvement affairs are the most urgent. For the purposes of this stage a theoretical calculation *model* is developed, with which it is possible to analyze the effects of productivity (total and partial) improvement in monetary values. On the basis of this theoretical model the *tool* for analysis at firm level is made with Microsoft Excel. The model and the tool are suitable both for preliminary calculations (precalculation) and actual cost calculations (postcalculation) under the limitations placed in developing the model.

This calculation model is based on the effects of changes in physical process. Under the assumption of ceteris paribus it is possible to calculate how the change in physical process affects the result of monetary process. In figure 5.8., it is presented how these changes are connected to each other. The broken line shows the effects which are analyzed at the first level of the framework. The solid line describes the effects which are considered in the calculations at the second stage of the framework. The effects of the changes in the prices (PR_k and PR_l) are left out of the analysis. The dotted line is the "border" between the monetary and physical processes of a firm.

When this framework is in use it must always be confirmed that the productivity improvement actions do not cause any suboptimization at the expense of the benefits of the whole firm. For example a decrease in quality in one activity may lead to better productivity measured by the ratio of output quantity to input quantity. However, this might cause additional costs in the other activities, and decrease the profit of the firm. It is not enough that one activity or production line is more productive than earlier. The effects must be evaluated and the benefits must be earned at firm level.

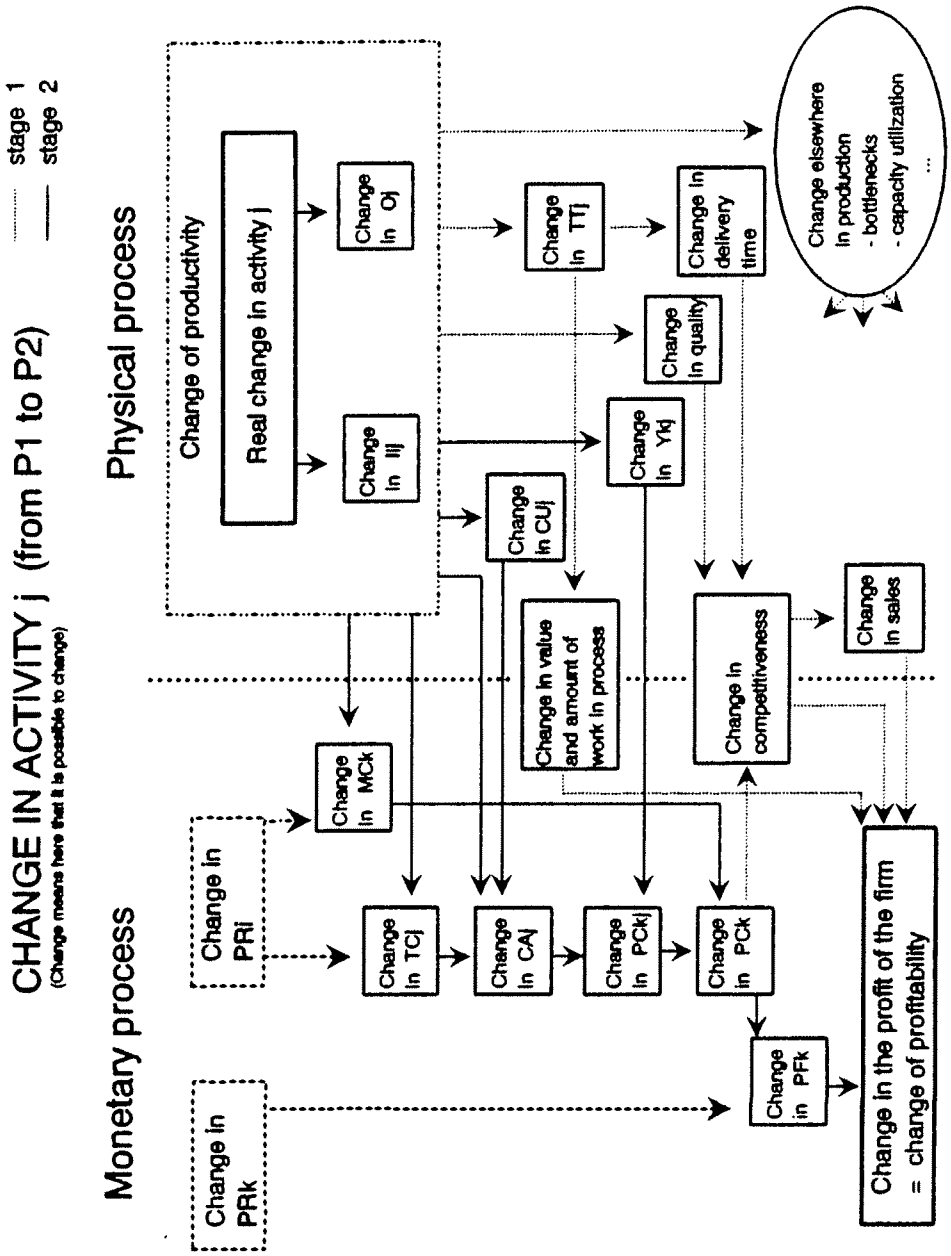

Figure 5.8. The changes in a firm which are analyzed in the framework.

5.5. Summary

The main objective of this study was to develop a method by which it is possible to analyze the effects of productivity change in one activity on the profitability of a firm. In this chapter, the theoretical framework which strives to meet this objective is presented. This framework has been built on the basis of TFPM and ABC.

In chapter 5.1., the background of the framework is discussed generally. It is argued that is it better to do the analysis in two stages. The first stage which concerns the selection of activities for deeper analysis and through it to objects of improvement actions, is presented in chapter 5.2. In chapter 5.3. the theoretical foundations for stage two are presented. It is explained how it is possible to calculate the effects of the change of total and partial productivities in an activity on the profitability of a firm. After that (chapter 5.4.) the whole structure of the framework is introduced.

6. EMPIRICAL TEST OF THE FRAMEWORK

In chapter 5 there is presented the theoretical framework for analyzing the effects of productivity change in an activity on the profitability of a firm. The framework contains a selection of activities for deeper analysis and a theoretical model for calculations about the economical effects of productivity improvement. On the basis of this model, a tool has been made for analyzing the usefulness of these calculations in practice. This tool was made with Microsoft Excel. The results of the empirical test of this framework are presented in this chapter.

6.1. Case firm; A firm manufacturing metal products

The case firm (later called the Firm) is the parent company of one medium size Finnish group (later called the Group) which operates in metal industry. This study concentrates on the production of the Firm. The production of the main products is carried out in one profit center (later called the Profit center). This Profit center has e.g. its own sales and export functions. Some of the subsidiaries of the Firm are under the control of this Profit center. The testing of the framework, Urgency Analysis and the calculations were made with the data of Profit center. The results of the calculations can be converted easily to the Firm level. The question in the matter is only the selection of the point of comparison. It can be either the firm or profit center level as easily. The production of the Profit center takes place mainly in one place, only one small individual manufacturing unit (case D) is located elsewhere. There are sales and service units in several regions in the country. The Group has subsidiaries in Finland and in Europe.

The turnover of the Group has been about 200 million marks and in the Profit center it has been about 110 million marks in recent years. The amount of personnel in the Profit center has been on the average 150. The duality of the Finnish economy - low domestic demand and improved competitiveness in

export industry - has also been reflected in the Group and the Profit center. In spite of the depression in economy the sales have increased in recent years. The foreign sales of the Group have grown over 120 % between 1990 and 1993. The Profit center has also been successful in its operations in recent years and the capacity utilization has been satisfactory.

The products of the Profit center can be divided into three main categories on the basis of size. The categories include several groups of products. The production is divided into two production lines, one production line for the small products and the other for the large products. In addition there is an isolated manufacturing unit for the largest products. The total amount of different products is about 2000. The production is mainly job-order manufacturing. Only some of the smallest products are produced to stock. The products are composed of metal and electrical components.

There are 29 activities in the production. In this study these activities are marked with the numbers 1 to 29. 28 of these activities are located in the two production lines. Activity number 29 is the isolated manufacturing unit. Ten of these activities (5,6,7,11,12,13,15,17,19 and 20) are based upon one large machine tool. Six of these (9,16,18,21,22 and 27) are also manufacturing activities but they do not depend on one machine tool. There are eight activities (2,3,8,10,14,23,24 and 28) which are focused on the finishing of the products. Painting and inspection of products are examples of these activities. The rest of the activities (1,4,25 and 26) are for composition.

In production there have been development and improvement actions continually. Behind this development there has rarely been any systematic search, evaluation or selection of improvement objects. For example a large order or the consequences of another action can be a starter of development. Investment calculations are made only in connection with larger projects. Small improvement actions are made without any calculation of economical effects. The insight of the management has had great significance in the decisions concerning the improvement of production.

6.1.1. Current management accounting system

At the end of the 1980s the costing system was traditional. The costing was based on variable-cost calculation and the cost information was used mostly in the pricing of products, the valuation of inventory and occasionally to help product design. There was a great number of cost pools in the Firm but only one in the production. The listing of accounts was very complex.

The situation was perceived as very problematic. The complexity of costing was a general problem. The control of production was very rough in spite of the fact that production was the biggest source of the costs. There was no possibility to postcalculation (actual cost calculation), and the checking on the correctness of time standards and the prices of hours was impossible. At the same time there was internal and external pressure for change. The competition was tight, the costs increased and there were some development projects in the Firm.

Because of these problems the development of a costing system was started. The objects of this development were for example improving the control of production, reducing the listing of accounts and performing different calculations for different purposes. In production one aim was observing the costs of the individual machines. The basis for this development was to put in practice the idea of the value chain presented by Porter. There was an objective to divide the Firm into primary and support activities, and clear up the costs of these activities.

Today the development of costing is still going on. The listing of accounts is reduced and the amount of cost pools is about one third of what it was. The costs of machines and cells are available more accurately than earlier, almost sufficiently. The costing system corresponds very nearly to the ideas of ABC, and the costs of activities in production can be defined rather satisfactorily. In product costing the full costing price is available for the own products and also the specialities can be priced. Although the situation is better than earlier,

there is plenty of need for additional information. The decisions and selections in the production improvement require more specific information for example about the costs and other effects of alternative development projects, manufacturing methods and so on.

Next, it is empirically tested how the framework described in chapter 5 operates in a firm. First, in chapter 6.2. the use of Urgency Analysis in the production function of the Profit center is presented. It is shown that Urgency Analysis is a capable tool in selecting the objects for a deeper analysis of the effects of productivity improvement. In chapter 6.3. the operativity of the theoretical calculation model is tested. The economical effects of productivity (both total and partial) increase are calculated in four case activities using the tool constructed with Microsoft Excel. After that the problems and restrictive elements perceived during this empirical test are analyzed.

6.2. Selecting the improvement objects

The first stage of the framework is concerned with the selection of activities for deeper analysis and through it to the objects of improvement actions. There are many possible ways for selecting the improvement objects. Here the improvement objects are selected by using the Urgency Analysis.

In the production function of the Profit center there are 29 different activities, which are specified in the costing system. These activities can be considered on the basis of how significant the phase of production made in a specific activity is for the Profit center. Five activities can be mentioned as vital conditions for the Profit center. For the rest of the activities, it is possible to buy the operations from a subcontractor. The urgency points of the activities were calculated with the help of some employees at the Profit center. There was a questionnaire (Appendix 2) in use for making this task easier and more systematic. The results are presented in table 6.1.

Activity 1	10.0	Activity 16	6.9
Activity 2	7.5 (r)	Activity 17	7.2
Activity 3	4.0	Activity 18	7.3
Activity 4	4.5	Activity 19	4.0
Activity 5	4.0	Activity 20	4.0
Activity 6	3.0	Activity 21	4.5
Activity 7	3.0	Activity 22	3.0
Activity 8	3.0	Activity 23	3.0
Activity 9	6.0	Activity 24	6.3
Activity 10	4.0	Activity 25	4.5
Activity 11	5.0	Activity 26	8.3
Activity 12	3.0	Activity 27	3.0
Activity 13	6.0	Activity 28	11.0
Activity 14	6.3	Activity 29	11.5
Activity 15	3.0 (e)		

Table 6.1. Urgency points of the activities in the production of the Profit center.

According to the principles of Urgency Analysis the size of category A could be approximately three activities (10 %). There were three clear cases for this category. Activities 1, 28 and 29 got much higher urgency points than the others. Activity 26 got also a clearly higher urgency point than the others but also clearly lower than the three mentioned above. Activity 26 has, however, some interesting details and it was also taken to category A. These four activities were selected as objects of deeper analysis of the effects of productivity improvement on the profitability of the firm. In the following, some details of these four activities are given.

Activity 1 is the composition line for the category of the large products (see chapter 6.3.1.). It is possible to increase the sales and production of these products. It is not very easy to utilize the resources of this activity somewhere else in the production. The weight of each dimension is equal ($a = b = c = 1$). The worth (W) of improvement actions was valued as 3. So, it is possible to get a rather large increase in the income. The possibility (P) to improve was valued also as 3, which means that there is rather large potential for improvement actions. The necessity (N) for improvement actions was obvious. This was valued as 4. The urgency point for activity 1 was 10.

Activity 26 is the composition line for the category of the small products (see chapter 6.3.2.). The products made in this line are bulk products. They are, however, an important and even essential part of product assortment. It is possible to increase the production of the present products in this activity. It is possible to utilize the resources somewhere else in the production. The possibility of improvement is an important factor in evaluating this activity. The weight of it was 1.5. There is assumed to exist rather large potential for improvement actions. It was valued as 3. The weight of worth and necessity were both 0.75. The worth was valued as 2 which means that it is possible to earn some savings or increase in incomes with this activity. It was deemed rather necessary to improve this activity. The necessity was valued as 3. The urgency point for activity 26 was 8.3.

Activity 28 is the painting for the category of the small products (see 6.3.3.). This activity is a bottleneck in the production of the small products. The weight of necessity was valued as 2 and the weights of the two other dimensions were both 0.5. The necessity was valued as 4. There was urgent need for improvement actions. There was also high potential for improvement. There are several ways of developing this activity. New paints or a new kiln are possible. It is also possible to unite the painting of the small products and the painting of the large products. The possibility was also valued as 4. The worth of improvement was valued as 2, which means that it is possible to get some savings or increase in incomes. The urgency point for this activity was 11. Increase of production in this activity is possible, but the resources are not movable.

Activity 29 is an isolated manufacturing unit (see chapter 6.3.4.). This activity produces the largest products of the Profit center. These are the systems which utilize to some extent the products of the main production function. The prerequisites for improvement are good. It is possible to increase the production with the present products. The capital is moveable but the human resources are not. The necessity was assumed to be the most important dimension. It was weighted as 2.5. The weights of the two other dimensions

were both 0.25. Because of some changes in the production mix there was a very urgent need for improvement. The necessity was valued as 4. The possibility and worth were valued as 3. There was a possibility to get rather large savings or increase in incomes and rather large potential for improvement. The urgency point for this isolated manufacturing unit was 11.5.

About 20 % of the activities were put to category B. In production, this means six activities. Activities 2,14,16,17,18 and 24 had urgency points between 6.3 to 7.3. According to present information, these are the activities which will require improvement actions, possibly within a year or two. Activity 2 has been renovated (r) in 1994. The rest of the activities, which had urgency points 6 or lower, stay in category C. Activity 15 was eliminated (e) from production in 1994.

Urgency Analysis is an easy way of gathering and systematizing the available information about the activities. Urgency Analysis does not create any new information, it only systematizes the information the management has. According to this information it is possible to put the activities in order as possible improvement objects. The insight of the management has a great significance in Urgency Analysis. The values calculated are based on the information mainly got from the controller and partly from the supervisor of production.

6.3. The effect of productivity change on profitability

To use the calculation model in practice the tool is constructed with Microsoft Excel. This tool is composed of two parts. First there is a spreadsheet made for precalculation. The precalculation part is presented in figure 6.1. There is original state information about the activity and the period in general and information about the costs and outputs of activity. There is also a part for forecasting information containing the change of productivity and the effects of this change on the profitability of the firm. The white cells are for input

information and the shaded cells are for output information, or they are empty cells.

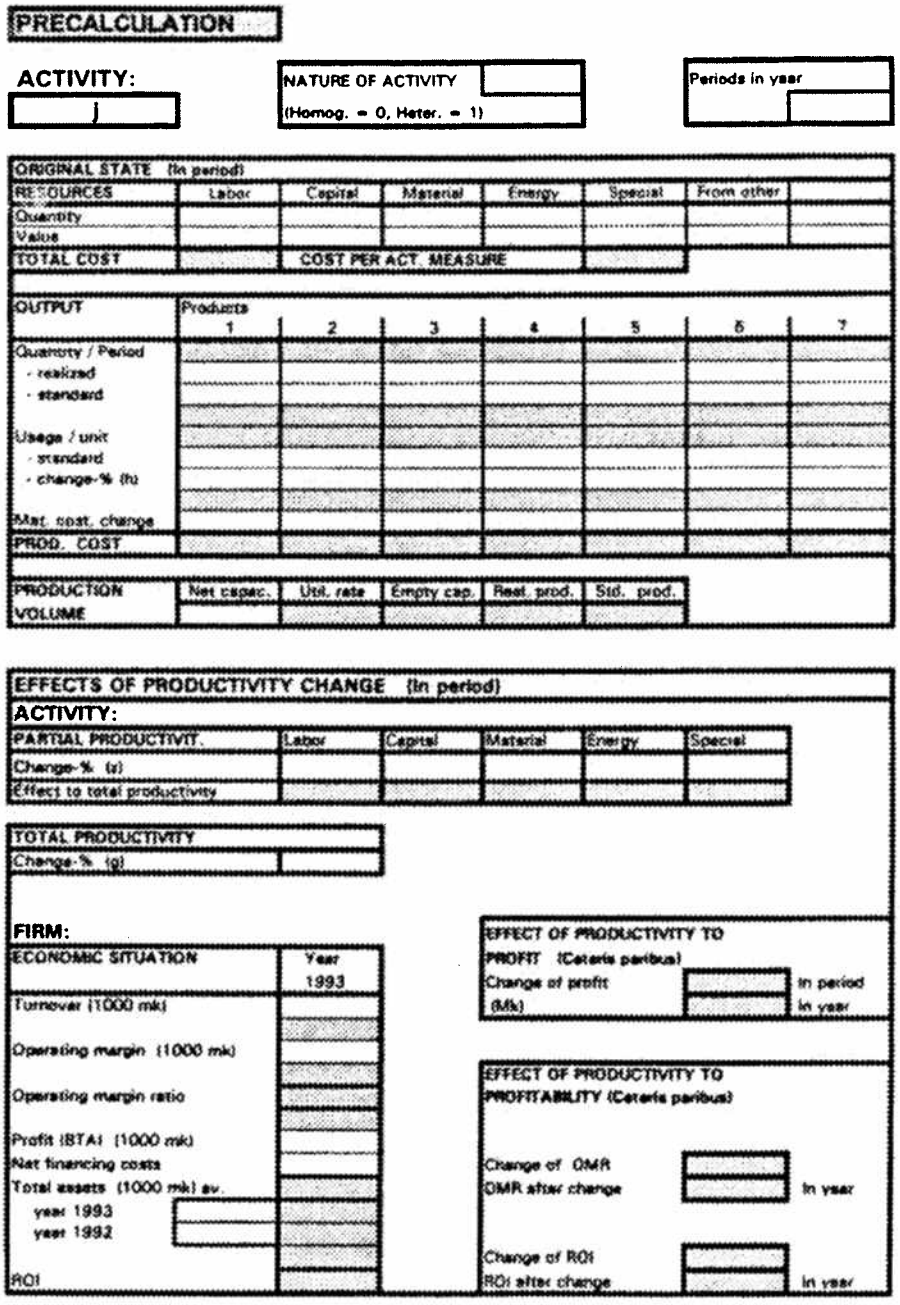

Figure 6.1. The tool for precalculation.

In the general information, there is the name and nature of activity and the number of calculation periods in a year. The nature means that the output of the activity is either homogeneous or heterogeneous. The number of periods in a year is needed with the calculation of key ratios of profitability. In the original state there is information about the costs of resources used in the activity. There is also information about the output. Every product and product group made in the activity is considered. The number of products or groups can be larger than the seven shown in the figure. There is both the realized and the standard amount of production in a period. Standard amount is used in the calculations and the realized production quantity of the last period is for the evaluation. There is as input information the amount of activity measure units that one unit of product uses in the activity (Y_{kj}) and the forecasted change of this amount in percents (h_k). The forecasted change in material costs for the product is also asked. In addition, there is information about the capacity and the production level, partly as input and partly as output information.

The lower part of the tool contains information about desirable productivity increase in percents (g or z) and the effects of it. It is possible to consider the increase of total productivity or the increase of one or several partial productivities. There is basic information about the economic situation of the firm. The effects are expressed as monetary values in a period and in a year. In addition, the effects of productivity change on the key economic ratios of firm are presented. These are the operating margin ratio (OMR) and the return on investment (ROI). These key ratios are selected for two reasons, theoretical and practical. The theoretical reason is that it is possible to utilize the change of profit calculated by the model in the calculation of these ratios. The practical reason is that the accounting information available makes it possible to calculate these ratios to describe the profitability of the Profit center.

The second part of the tool is the spreadsheet made for postcalculation. That is presented in figure 6.2. The original state (in period P1) is presented as in the precalculation. The calculation here is based on the standards.

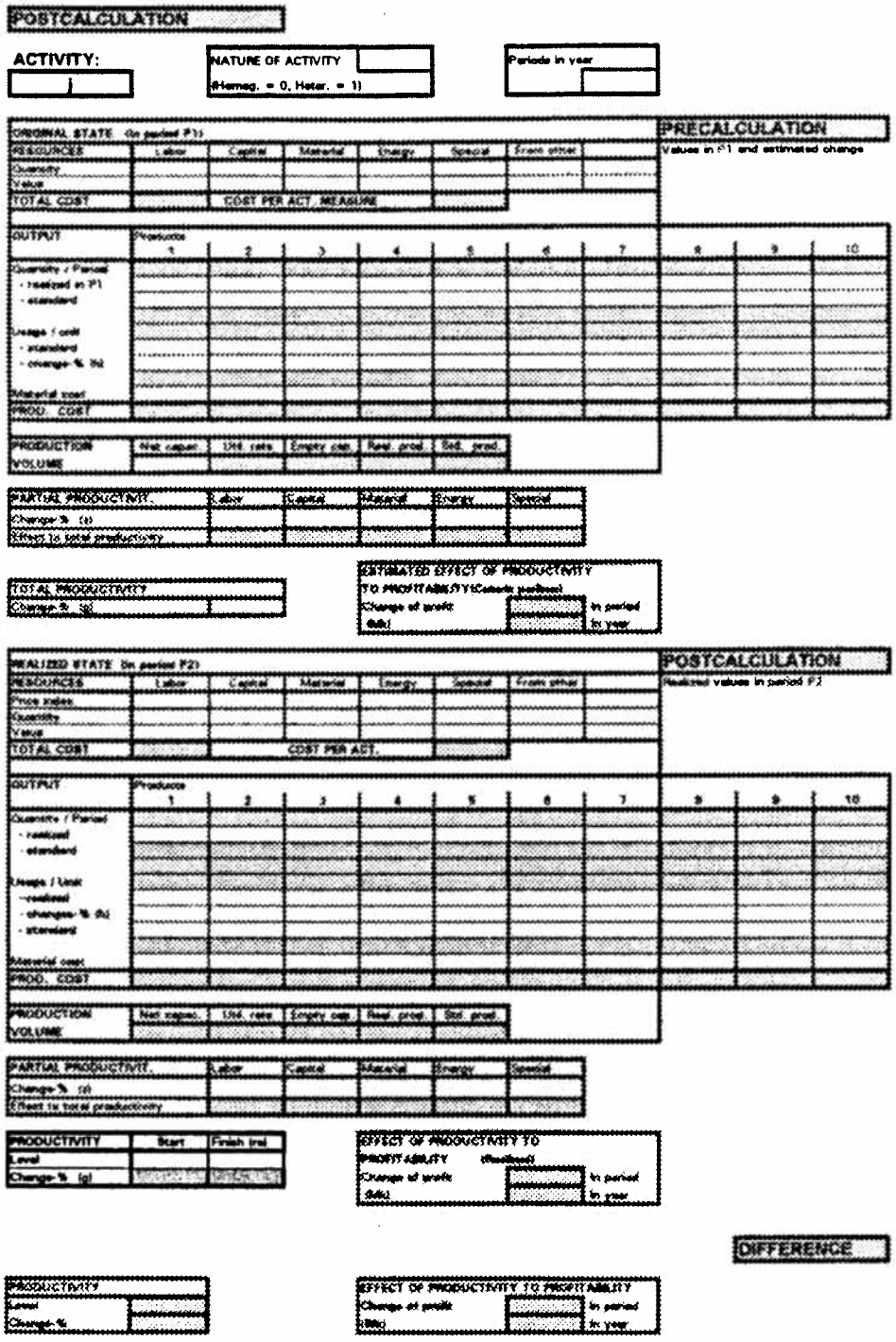

Figure 6.2. The tool for postcalculation.

The forecasting is made on the basis of the information on period P1. In the realized state (P2) the calculations are based on realized values. The number of products or product groups can be larger than the ten shown in the figure. The essential part of the postcalculation is the difference between the forecasted and the realized situation, and the evaluation of the causes behind this difference. In the realized state there is also the price index as input information for every group of resources. This might be one affecting factor explaining the differences. In the following, the use of this tool in analyzing the effects of increase in productivity at different levels is presented, concerning the activities classified to urgency category A.

6.3.1. Case A; Composition line II

Composition line II is the activity number 1 in Urgency Analysis. This activity differs from composition line I mainly in the size of products composed. These products are important for the Profit center because they represent the area of competitive advantage. The products are mainly individual units and the manufacturing of these always entails learning and practice. They are also very expensive, which means that the construction of a prototype is impossible. This also means that it is difficult to define a standard time for manufacturing and there are no standards for the quantity of production.

In composition line II there were two men working in one shift in the year 1993. Today there are three men. The same staff carries out the tests of the products. The total costs of this activity were about 560 000 mk in 1993. The share of the labor costs was 57 %. The share of the material costs was only 2 %. The value of capital in use is nil in the accounting, because the age of the capital. The rest of total costs were from other sources. The costs from other sources included for example the proportion of this activity in the salaries of supervision, the cost of space and some nontraceable costs of maintenance.

The effects of productivity change (ΔPDj) at different levels were calculated for this activity. In table 6.2. the results of the calculations are presented. The calculations were based on the accounting numbers from the year 1993. The effects of both the change of total productivity and the changes of two partial productivities are presented. These are labor and material productivities which represent the direct resources of the painting activity. The effects of partial productivities are calculated separately under the assumption of ceteris paribus. This means that in the calculation, no other changes than the change in one partial productivity have been taken into consideration. The effects of change in total productivity on four different levels of increase are presented; 5 %, 10 %, 15 % and 20 %. The effects of change in partial productivities are presented on two possible levels of increase; 10 % and 20 %. These levels of increase are chosen only for clarifying the distinction between the different levels of increase in productivity. The steps between the levels are large enough to be clear and small enough to achieve. The situation without change is also presented.

ΔPDj (%)	Change of profit (mk)	OMR (%)	ROI (%)
0	0	15.30	16.89
Total			
5	26 609	15.33	16.93
10	50 798	15.35	16.96
15	72 885	15.37	16 99
20	93 131	15.39	17.02
Labor			
10	28 764	15.33	16.93
20	52 733	15.35	16.97
Material			
10	853	15.31	16.89
20	1 564	15.31	16.89

Table 6.2. The effects of productivity increase in composition line II.

From the table we can see that if total productivity in this activity increases e.g. 15 %, the change of profit in the Profit center is 72 885 mk. This change in profit raises the operating margin ratio of the Profit center from 15.30 % to 15.37 % and the return on investment from 16.89 % to 16.99 %. We can also see for example that if labor productivity in this composition line II increases 20 %, the change of profit in a year at the Profit center level is 52 733 mk. This change in profit raises the operating margin ratio of the Profit center from 15.30 % to 15.35 % and the return on investment from 16.89% to 16.97 %.

The possible benefits from minor productivity improvements are rather low. However, in this activity there is a good possibility for improving productivity remarkably. If the proportion of learning and practice in manufacturing could be decreased, the productivity might increase very much. If labor productivity in this composition line II doubles, the change of profit in the Profit center can be 158 200 mk. If labor productivity is trebled, the change of profit in the Profit center can be 210 933 mk. Then the operating margin ratio of the Profit center raises from 15.30 % to 15.50 % and the return on investment from 16.89 % to 17.19 %.

6.3.2. Case B; Composition line I

Composition line I is the activity number 26. There is mainly job-order production in this activity while the production of the parts operates according to the make-to-stock principle. Composition takes place in the line where the products move on. One person composes the whole product. There are three employees working in the line. In fact there are two separate "composition lines" in this activity. There is another smaller cell beside the main line. Some of the products are composed there. The reason for the existence of two lines is the personal relationships between the employees. The capacity of this composition line is not a bottleneck. The painting activity just behind this is the one which limits the production in this composition line.

There are no standard quantities for the production of different product groups. The range of variation in annual total quantity of production of small products is about 200. The year 1993 was rather normal and so the standard quantities of different product groups were the same as the realized quantities. The products are composed here in small batches. The average usage of the activity for all the product groups is smaller than the standard usage. Because of this the utilization rate of this activity shows 120 %, even though this is not a bottleneck in production. So the standard for usage is too high.

The total costs of composition line I were about 700 000 mk. The share of the labor costs was 45 % and the share of the capital costs was 7 %. The value of capital costs included the calculated depreciations and the interests of the line and the storage unit. The costs from other sources included the proportion of this activity in the salaries of supervision, the cost of space and other costs like these. The share of these was 44 %. The rest of the costs were from the material and energy.

The results of the calculations on the effects of productivity change in this activity are presented in table 6.3. The calculation is based on the accounting numbers from the year 1993. From the table we can see that if total productivity in this activity increases e.g. 15 %, the change of profit in a year in the Profit center is 91 138 mk. This change in profit raises the operating margin ratio of the Profit center from 15.30 % to 15.39 % and the return on investment from 16.89 % to 17.02 %.

We can also see for example that if labor productivity in this activity increases 20 %, the change of profit in a year at the Profit center level is 52 733 mk. This change in profit raises the operating margin ratio of the Profit center from 15.30 % to 15.35 % and the return on investment from 16.89 % to 16.97%. The effects are higher than in composition line II. That is obvious because the total costs of this activity are also higher than in composition line II.

ΔPDj (%)	Change of profit (mk)	OMR (%)	ROI (%)
0	0	15.30	16.89
Total			
5	33 272	15.34	16.94
10	63 520	15.36	16.98
15	91 138	15.39	17.02
20	116 454	15.41	17.05
Labor			
10	28 764	15.33	16.93
20	52 733	15.35	16.97
Capital			
10	4 405	15.31	16.90
20	8 076	15.31	16.90
Material			
10	1 382	15.31	16.89
20	2 533	15.31	16.90
Energy			
10	909	15.31	16.89
20	1 667	15.31	16.89

Table 6.3. The effects of productivity increase in composition line I.

In this activity there are some possibilities to improve productivity. The problem is, however, the bottleneck in painting, which does not allow any larger increase of production without first solving the problem of drying capacity.

6.3.3. Case C; Painting

The painting activity (number 28) is placed in production just behind composition line I (activity 26). All the products are not painted and some parts of products are purchased painted. This phase of production is not a vital condition for the Profit center. There is one person working in painting. The capital in use has no value at all. The kiln is very old (over 14 years) and

there is no value for that in accounting. The costs from other sources include the proportion of painting in the salaries of supervision, cost of space and other costs like these. The standard quantity of output is here the same as the realized output. The usage of the activity includes only the time for painting, not the drying time.

The total costs of this activity were about 320 000 mk. The share of the labor costs was 26 % and the share of the material costs was 30 %. The rest are the costs from energy, supervision, space and other sources. The effects of productivity change (ΔPDj) at different levels were calculated for the painting activity. The calculation was based on the accounting numbers from the year 1993. The results are presented in table 6.4. In appendix 3 there is an example of use of the tool in precalculation. It describes the effects of a 10% increase in material productivity in the painting activity.

ΔPDj (%)	Change of profit (mk)	OMR (%)	ROI (%)
0	0	15.30	16.89
Total			
5	15 255	15.32	16.91
10	29 123	15.33	16.93
15	41 785	15.34	16.95
20	53 392	15.35	16.97
Material			
10	8 636	15.31	16.90
20	15 833	15.32	16.91
Labor			
10	7 618	15.31	16.90
20	13 967	15.32	16.91
Energy			
10	636	15.31	16.89
20	1 167	15.31	16.89

Table 6.4. The effects of productivity increase in painting activity.

From the table we can see that if total productivity in the painting activity increases e.g. 15 %, the change of profit in a year at the Profit center level (and also at firm level) is 41 785 mk. This change in profit raises the operating margin ratio of the Profit center from 15.30 % to 15.34 % and the return on investment from 16.89 % to 16.95 %. We can also see for example that if labor productivity in the painting activity increases 20 %, the change of profit in a year at the Profit center level is 13 967 mk. This change in profit raises the operating margin ratio of the Profit center from 15.30 % to 15.32 % and the return on investment from 16.89 % to 16.91 %.

The effects of productivity improvement in the painting on the economic key ratios are not very significant. The main reason is that the painting activity is a very small and "cheap" activity. However, if there are many improvement objects like this in the production, the sum of the effects can be remarkable.

The problem in painting is the capacity of the kiln. The operating time per day is 24 hours. The capacity of labor presented in working hours is 1530 hours per year. This is the standard of one man in one shift used in the Profit center. The capacity of labor is marked in the calculations as the measure of the capacity of this activity. From appendix 3 we can see that the total production of the year 1993 used only 68 % of this capacity. Because of the kiln the man has to use some of his capacity in other activities (this has been taken into account in the value of the labor resource). The increase of labor productivity does not have any effect if there is no way to increase the efficiency of the kiln. The only ways to speed up the drying process are either using different types of paints or making an investment for a larger kiln. There has not been any searching for new paints. Some plans about joining this painting activity to another painting activity has been made.

6.3.4. Case D; Isolated manufacturing unit

Activity 29 is an isolated manufacturing unit. This activity produces solely the largest products (systems) of the Profit center. The products of the main production function are used here as components. In 1993 there were four employees in production and one supervisor. This is a rather large activity and its costs are quite clear because of the isolated situation.

The total costs of this activity were about 1 600 000 mk. The costs of capital was the largest component of the total costs. The share of it was 59 %. The value of capital included the calculated depreciations. There were also the calculated interests of the fixed and current assets. The share of the labor costs was 21 % and the share of the material costs was 13 %. The rest of the total costs were the fixed costs of the activity

In this activity, changes in the usage of activity (h_k) for a few groups of products are assumed. It is assumed that production time will decrease 50 % with one and 10 % with two groups of products. In the calculations here it is assumed that the increase of productivity does not include those individual changes in the usage of the activity. This means that the results include both the effects of changes in usage and the effects of change in productivity.

Table 6.5. presents the results of the calculations for the effects of productivity change in this isolated manufacturing unit. The calculation was based on the accounting numbers from the year 1993. From the table we can see that if total productivity in this activity increases e.g. 15 %, the change of profit in a year in the Profit center is 312 646 mk. This change in profit raises the operating margin ratio of the Profit center from 15.30 % to 15.59% and the return on investment from 16.89 % to 17.33 %. We can also see for example that if labor productivity in this activity increases 20 %, the change of profit in a year at the Profit center level is 172 931 mk. This change in profit raises the operating margin ratio of the Profit center from 15.30 % to 15.46 % and the return on investment from 16.89 % to 17.13 %. These

results include both the effects of changes in usage and the effects of change in productivity. In appendix 4 there is an example of the use of the tool in precalculation. It describes the effects of a 20 % increase in labor productivity in this activity.

ΔPDj (%)	Change of profit (mk)	OMR (%)	ROI (%)
0	0	15.30	16.89
Total			
5	191 873	15.48	17.16
10	255 005	15.54	17.25
15	312 646	15.59	17.33
20	365 484	15.64	17.40
Labor			
10	149 975	15.44	17.10
20	172 931	15.46	17.13
Capital			
10	200 617	15.49	17.17
20	265 774	15.55	17.26
Material			
10	139 657	15.43	17.09
20	154 013	15.45	17.11

Table 6.5. The effects of productivity increase in the isolated manufacturing unit.

There has been some ideas of how to handle this unit in the future. Some improvement actions have been started or done in 1994. Some production phases and one service unit have been moved here from other places. Two additional employees have been hired. The construction of new production space has been started. There has also been a change-over in the payroll system.

6.3.5. General comments about the calculations

The results of the calculations show that the effect of productivity change on change of profit depends on the size of activity. It is clear that the possibilities for savings or increase in income are better in a large activity than in a small activity. This has been common knowledge for a long time. The new result is the size of the effect of a specific change in productivity. Figure 6.3. describes the size of the change of profit due to the different levels of increase in total productivity. We can see that the biggest effects are caused by the changes in the isolated manufacturing unit. The total costs of that activity were almost equal with the sum of total costs of the three other activities analyzed.

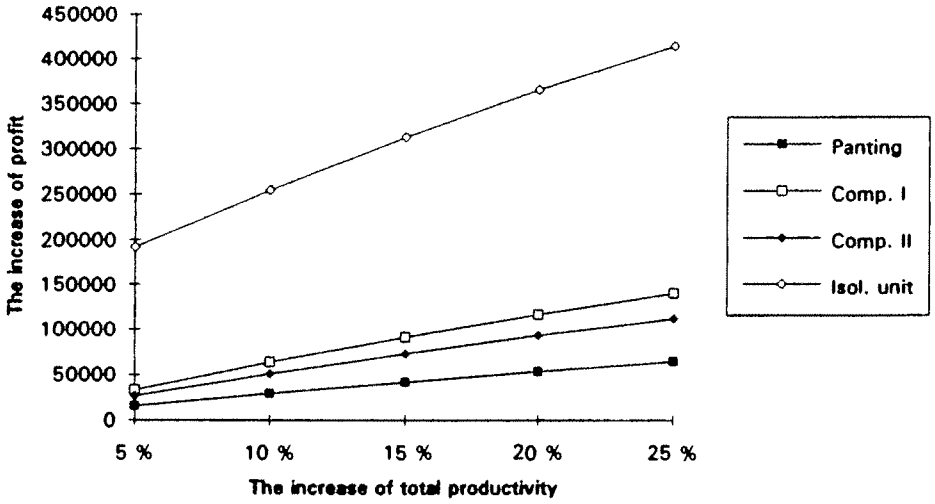

Figure 6.3. The change of profit caused by the increase in total productivity in different levels in the case activities.

Another obvious result is that the effect of the change in partial productivity depends on the resources share of the total costs of the activity. The new result is the size of the effect of a specific change in one partial productivity. Equation 5.30. states this connection.

According to equations 2.5. and 5.30 we can also assume that the economical effect of a certain change in total productivity is equal to the sum of the effects of equal changes in partial productivities of all the resources in the activity. If we calculate this with the tool there is a marginal error due to the assumption of ceteris paribus made in the derivation of equation 5.30. Table 6.6. describes the effects of a 10 % increase in each partial productivity in composition line I. There is also the effect of a 10 % increase in total productivity.

	Change of profit	
	Mk	%
Labor	28 764	46 %
Capital	4 405	7 %
Material	1 382	2 %
Energy	909	1 %
Other	28 060	44 %
Total	63 520	100 %

Table 6.6. The effects of 10 % increase in partial productivities and total productivity in composition line I.

In general, the trend of the results is equal to what was expected. New information is the exact size of the economical effect of a specific change in one partial productivity or in total productivity. What do these results mean? How do the limitations affect the validity and relevance of these results? These questions are considered in chapter 7.

6.4. Perceived problems and restrictive elements

In connection with the empirical test of the framework there emerged some problems and elements which may restrict or cause trouble in the use of the framework. These problems and restrictive elements can be divided into two

categories. First there are the problems which emerged because of theoretical problems and limitations in the framework. The second category comprises the problems which emerged due to the properties of the case firm. In the following, the theoretical and the limitation problems are briefly discussed. After that there is a short review about the problems due to the case firm. The consequences of the limitations and selections made in connection with the construction of the framework are further considered in chapter 7.1.1.

One basic problem from the theoretical point of view was the twofold nature of change in productivity[1]. The calculation model developed here is suitable when the change of productivity emerges without any large structural changes. When the change of productivity in the activity is due to a large structural change like capital investment or divestment there are problems with the reliability of the results in this model. While it is possible to measure or estimate the change of productivity in this situation, the basis for calculations (the level and nature of output and inputs) can be changed too much. There can be large changes in the relations between the resources and the partial productivities of these resources. A model based on the assumption of ceteris paribus may have poor validity in these kinds of situations.

A serious problem due to the limitations in the framework are the bottlenecks inside and outside of production. In this study, the evaluation of the effects of the bottlenecks was made only in the first stage of the framework. A bottleneck can emerge in the production chain before, after or even at the side of the activity under analysis. The effect of the bottleneck can be direct or indirect. Eliminating the bottleneck may require additional resources. It may be impossible to utilize the ability to produce more due to a bottleneck somewhere else in the production. In general, the ability to utilize the increase in production capability due to productivity improvement is important in every activity. The increase of production due to productivity improvement may move a bottleneck from one place to another.

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[1] These are dealt with in chapter 2.1.4.

The effects of bottlenecks can and must be analyzed mostly in the first stage of the framework. This is clear because it obvious that the bottlenecks are often valuable objects for productivity improvement actions. A qualitative analysis of the effects of the bottlenecks in connection of Urgency Analysis is rather easy to do. A quantitative analysis in monetary values at the second stage of the framework in connection with the calculation model is very difficult. Satisfactory handling of bottlenecks may presuppose the simulation of the whole production function.

Some of the partial productivities are too "theoretical" for measuring in practice. For example energy productivity is not a relevant measure in practice. Normally the consumption of energy is measured. In theory consumption can be defined as productivity in reversed form. The same problem emerges also in connection with material productivity. For these reasons the measures in practice are not always ideal for the theory of this model.

The relationship between the increase of productivity (g) in an activity and the change in the quantity or amount of activity measure units that product k uses in that activity (h_k) is difficult to analyze. What amount of the change in usage should be included in the change of productivity and what amount should be considered separately? This question emerged e.g. with the calculations in connection with the isolated manufacturing unit. In the calculations, it is assumed that the increase of productivity does not include the individual changes in the usage of activity (h_k) of the three groups of products.

There were also some problems which emerged due to the properties of the case firm. The bottlenecks are a problem from the theoretical point of view, as mentioned above. They can also be problems characteristic of the firm. One notable bottleneck for the production function of the Profit center was the sales function[2]. The ability to make business as a bottleneck affects the

[2] The sales function can be a bottleneck for the production function in general. However, in this case it emerged quite clearly as a bottleneck depending on the properties of the firm.

possibilities of utilizing the increase of production capacity achieved by productivity improvement. This was a problem especially in those activities which take part in the production of the larger products (e.g. composition line II).

One area of problems was the costs allocation level. This framework and the theoretical calculation model is based on the ideas of ABC. As mentioned earlier, the costing system of the Firm is near to the ideas of ABC and the costs of activities in production can be defined rather satisfactorily. A little variation in the accuracy of the costing system does not affect the framework or the model. In the calculations with the tool the accuracy of the costing system affects directly the reliability of the results. When the results of this analysis are under evaluation, the accuracy of cost information must be kept in mind. The accuracy of the results of calculations cannot usually be better than the accuracy of input information.

The costs from other activities and other departments is one problematic question. There are many ways of handling these. They can be within the calculations, or the other way is to consider only the costs of resources used in the activity (see e.g. Turney & Stratton 1992, p. 49). In this study the costs of the support activities or functions of the Profit center (e.g. sales or purchasing) are excluded from the calculations. In the current costing system these are not allocated to the activities of production. The costs are allocated directly to the products. The costs of the support activities of a production function (e.g. supervision and maintenance) are included in the calculations as a part of the group of the costs from other sources.

The material costs of the products are one area of problems. They can be taken into the costs of the activities as resources. If this is done, the wasting of the raw material affects the measures of productivity of the activity. Another way is to allocate the raw material costs direct to the products. So the costs of activity include only the costs of some additional materials which are used for all the products made in this activity (see also chapter 5.3.2.). In

the current costing system of the Profit center the raw material costs are allocated direct to the products. This is the reason why in the calculations the raw material costs are not included in the costs of activities.

An interesting factor was also the effects of personal relationships between the employees. As mentioned earlier in composition line I these relationships had caused the construction of two separate composition units in one activity. Which are the management's means to prevent and solve the personal problems between the employees? How is it possible to evaluate the benefits and the disadvantages of situations like this? How much is it possible to pay for a good but problematic employee?

Because of the continuous development of production and especially the change-over in the accounting system, there were no suitable data for the testing of postcalculation. The operativity of the model was tested sufficiently with precalculation because the calculations and equations are mostly the same in both parts of the tool. However, the usefulness of the tool for postcalculation stays without evaluation. This part of the framework should be tested as soon as possible.

The costing system of the Profit center corresponds very nearly to the ideas of ABC, and the costs of activities in production can be defined rather satisfactorily. One area where this costing system is not good enough from the productivity analysis point of view is the handling of the value of capital. The value of capital is based on the bookkeeping and there are many machines which do not have any value at all while they are in use. It is difficult to analyze the productivity of capital and even total productivity when there is no value for the largest resource of an activity. There is need to enlarge the management accounting data for example with the replacement prices of the capital. The costs of capital, depreciations and interest expenses are handled well. They are expressed as calculated and thus independent on the accounting data.

The testing of the framework, the Urgency Analysis and the calculations were made with information from the Profit center. The results of the calculations can be converted very easily to the firm level. The question is only how to select the points of comparison for the economic ratios. It can be the firm or profit center level as easily.

6.5. Summary

On the basis of the model presented in chapter 5 a tool was made for analyzing in practice the usefulness of the calculations. This tool was made with Microsoft Excel. The usefulness of this tool was tested with the data of four case activities in one medium size Finnish firm which operates in metal industry. In chapter 6 the results of the empirical testing of this model are presented. It is also presented how these four activities were selected among the 29 activities as the objects of the calculations. In the firms there are many possible ways for selecting the improvement objects. In this study the activities for the calculations and the possible improvement objects were selected by using the Urgency Analysis.

First, (chapter 6.2) the operativity of the Urgency Analysis in selecting the activities for deeper analysis and through it to objects of productivity improvement is tested. With Urgency Analysis, four activities for deeper analysis of the effects of productivity change on the profitability of the firm were selected.

In chapter 6.3. the economical effects of several different productivity change levels in the four case activities are presented. The changes in both total productivity and partial productivities are discussed. It is shown how much a certain change of productivity affects the change of profit in the Profit center. In addition, it is shown how this change of profit reflects on the operating margin ratio and the return on investment ratio of the Profit center.

In the end (chapter 6.4.) there is a short discussion about the perceived problems and restrictive elements within the analysis made in the case firm. There are some problems but the benefits of the new additional information provided by this framework seems to be larger than the disadvantages caused by these problems. It is shown that this framework provides additional information about the economical effects of productivity improvement to support the management decision making.

7. DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

The aim of this chapter is to evaluate this dissertation from different points of view and to show its contribution. First the limitations made and the problems in the framework developed as well as the results of this study are discussed. Then there is a conclusion about how the objectives of this study are achieved. In the end there are made recommendations for future research.

7.1. Discussion

7.1.1. Limitations and problems in this research

In this study the focus is in the change of productivity in an activity and its effects on the profitability of a firm. The effect of one change in one activity in production is considered here. The other functions of a firm, like sales and marketing, are restricted out of the framework. The objectives of this study do not include the question about the means to improve productivity. The means used in practice are always individual and depend on the situation, firm and activity under examination, and the possibilities in use.

With the development and testing of the framework there were some questions which need a closer consideration. These questions can be classified into three groups. First, there are the limitations which are needed when developing the calculation model. These limitations are made to construct a calculation model for use in several cases and to avoid simulating of one firm. The second group consists of the selections made in the connection of the framework development, or calculations made with the tool in the cases. There were some questions which can be solved by two or more alternative ways. The third group consists of the questions which emerged as problematic in the connection of the development, or empirical testing of the

framework. These problems were theoretical or/and empirical. The three groups[1] of questions can be presented as follow:

1) *The limitations*
   in general
   1.1. The framework considers only the production function.

   in the calculation model
   1.2. The assumption of ceteris paribus in analyzing the effect of the change of productivity in activity.
   1.3. The assumption of ceteris paribus in analyzing the effect of change in partial productivity on the total productivity.
   1.4. The changes in quality in the activity due to the changes in productivity are not considered.
   1.5. The calculation model does not consider the structural changes.
   1.6. The calculation model does not consider the effects of bottlenecks.

2) *The selections made in this study*
   2.1. The material costs are assigned straight to the products, not through the activities.
   2.2. The cost of free capacity is included in the calculations by the standard quantities of production in precalculation.
   2.3. The costs from other activities are considered with the costs of resources, not separately.

3) *The theoretical and/or empirical problems*
   3.1. The relationship between g and h_k.
   3.2. The possibility of forecasting the change of productivity (g and z).
   3.3. The limits of productivity increase.

In the following, each one of these questions is discussed. The first limitation is the focusing on the production function (1.1.). The other functions of a firm like sales and marketing are restricted out of the framework. The limitation is made to simplify the problem considered. The calculation model for the support activities must be different, because they do not treat the products directly. In the model the products need to be replaced by the output of these activities. The problem with the other functions is that the increase in output

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[1] Some of the questions presented here can be put in more than one group. For example the handling of bottlenecks is a problem in theory and in practice, and it requires the limitation to be set up. However, these questions are considered here only in the connection of one group.

due to the productivity improvement cannot always be utilized. When the productivity increase is based on a decrease in the usage of resources the calculation model is suitable. The selection of the improvement object is equal in the production and support activities. The widening of the suitability of the framework is one obvious scope for future research.

The main limitation of this framework is the assumption ceteris paribus made in the connection of the theoretical calculation model. It has been made in two connections. First, it has been assumed that there are no other simultaneous changes in production than the one in the activity under examination (1.2.). This has been done because the alternative way would be the simulation of the whole firm and all the possible simultaneous changes happening in production. There are many factors affecting the profitability of a firm. When the aim is to analyze the effect of a certain factor, the other affecting factors must be restricted out of the analysis. A certain simulation model about the economical effects of productivity improvement where all the factors are included, would be perhaps useful only in one firm. The simulation of the production process can be done separately for every firm which are to be analyzed. The aim of this study was not to make a general[2] framework for all the economic levels and firms. However, the aim was to develop a method which would operate for more than one firm. A general model does not perhaps produce any relevant information for management decision making. On the other hand, a very detailed simulation model about the situation of one firm can be without any contribution from the theory point of view. Here, it was intended to make a framework which would have a contribution both in theory and in practice. Secondly, (see chapter 5.3.8. and appendix 1) it has been assumed that change in one partial productivity does not affect the other partial productivities (1.3.). This was also made for simplifying the situation for modelling. The relationships between the resources used, and the relationships between the changes in partial productivities are individual in

[2] More about the generalizability in research can be found e.g. in the paper of Lukka & Kasanen (1993).

every activity and firm. There is no possible way for modelling these in general.

In reality, the presumption of ceteris paribus is not ever realized. Changes in an activity may always affect the other activities in the production and other functions of the firm. A change in a certain partial productivity may often have effects on the other partial productivities. The relationship between labor and capital productivities is the best known example of this. There are also some elements outside of the firm which can affect the firm because of changes made in the activities. The assumption of ceteris paribus simplifies the outlining of the problem and the calculations needed.

Another limitation is that the changes in the quality in the activity due to changes in productivity are not taken into consideration in this model (1.4.). These changes in quality may have positive or negative effect on the incomes and costs of the firm. Positive changes make it possible to achieve larger production or get higher prices from the products. Negative changes may lead to lower product prices or additional costs in the other activities. There are many affecting factors which are nonmeasurable and independent on the decisions made in production. These factors have effects on the profitability of a firm. The changes in quality in the activities due to changes in productivity have obvious effects, but they are too complicated for modelling.

The calculation model developed here is very suitable when the change of productivity emerges without any large structural changes. When the change of productivity in the activity is due to a large structural change like capital investment or divestment, there are problems with the reliability of the results of this model (1.5.). While a change of productivity between periods P1 and P2 can be measured or estimated, the basis for the calculations, the level and nature of output and inputs (resources), can change too much in this situation. The results of period P2 are in practice impossible to be derived and calculated on the basis of the values from period P1. This means that after an investment

or divestment, periods P1 and P2 are not comparable to each other. In these situations the difference between the levels of productivity is perhaps not meaningful to be expressed as direct increase in percents.

The effects of the bottlenecks in production are difficult to take into consideration in the calculation model (1.6.). There are no exact values for the costs of bottlenecks. Sometimes it is difficult to estimate where the next bottleneck is when the one under examination is eliminated. Some estimation can be done on the basis of capacity information, but in practice the situation may be different. In this framework the bottlenecks and their removal are taken into consideration only with Urgency Analysis in the first stage of the framework, not in the calculation model.

The first selection made in this study (2.1.) considers the way how the material costs are handled. In theory there are different ways to do this. The material costs can be handled (see chapter 5.3.2.) either separately, in addition to activity product costs (as MC_k) or activity costs (as MC_{kj}), or together with the other resources of an activity (as MC_j) and thus as part of the total costs of activity. The way to handle material costs is individual and may depend on the significance of the materials. The material costs are assigned in the calculation model straight to the products, not through the activities. One reason behind this selection is that in the cost information system of the case firm the material costs are presented separated from the costs of activities.

The cost of free capacity and its handling is also one emerging question in the connection of this kind of framework (2.2.). In this framework the cost of free capacity is included in the calculation model in connection of precalculation. The standard quantities of production and usage of activity as well as the total costs of the activity when the product cost of one product is calculated are used. Due to the standards, the variance of production quantity and free capacity do not affect the calculations immediately. In postcalculation both

the standard and the realized numbers are used because the aim is to analyze the difference between the excepted and the realized situation.

The total costs of activity are composed of two parts. There are the costs of the resources used in this activity, and the costs which are assigned from the other activities to this activity. In theory we can consider the effects of productivity change separately with both of these groups of costs. This idea is based on the fact that productivity improvement actions in an activity can affect only the costs of resources used in this activity. The separation of the total costs of an activity is very problematic from the modelling point of view. In this study these costs are assumed to be minor in the activities and they are handled in the calculations as one resource of activity (2.3.). When these costs assigned from other activities are very large in relation to total costs of the activity, this must be taken into consideration with the definition of the input in productivity measurement.

The relationship between the increase of productivity (g) in an activity and the change of the quantity or amount of activity measure units that product k uses in that activity (h_k) is difficult to analyze and handle (3.1.). The relationship between h_k and g may vary depending on the productivity improvement actions. Productivity increase (g) describes the change of the total productivity of the whole activity. The change of usage (h_k) concerns only one product. When the usage of all products changes similarly it is included in the change of productivity. However, the improvement actions do not concern all products equally. There can be changes in fastening, or manufacturing operations with one or some of the products produced in the activity. Sometimes h_k can be different for every product which is produced in activity j. What amount of the change of usage should be included in the change of productivity, and what amount should be considered separately? The same problem emerges also in connection with the increase of partial productivities (z). The change of usage (h_k) should be considered separately in the calculations when the change of productivity does not include it.

The estimation or forecasting of the increase of productivity (g and z) is always uncertain (3.2.). In practice we do not have any means for achieving a certain predestined increase in productivity. In precalculation this is a problem in the connection of selecting the means for improving productivity and evaluating the extent of productivity increase achieved by these means. In postcalculation the problem is how to select the measure of the realized increase of productivity. This must be the same as the one used or intended to be used with forecasting the increase of productivity and its effects on profitability.

One theoretical problem with the calculation model is the question of the limits of productivity increase (3.3.). The calculation model developed here contains a linear relationship between the change of productivity and the change of profit (see equations 5.24 and 5.25). In practice the relation can be linear only within some limits. If there are no limits, the increase of productivity should always be profitable. It is known that it is easier to achieve a certain increase in productivity at a low level than at a high level of productivity. The costs of productivity improvement are also wider at the high level of productivity. There must be some point where the costs sacrificed for productivity improvement are higher than the profits gained by the improvement. Perhaps it is possible to find a empirical generalization about the relationship between productivity change and change of profit. This would possibly be of the same kind as the law of diminishing returns (see e.g. Naylor & Vernon 1969, p. 73-76) where the linearity is suitable within certain limits, but not on all the levels of change. This question of the limits of a linear relationship is connected to the nature of the change of productivity. When there are no structural changes, the linear relationship is obvious. The investments and divestments create a disturbance to this linear relationship. The demand and ability to sell restricts the possibility for increasing productivity and the amount of production, and affects also the relationship between productivity and profitability.

A general problem in the connection of productivity improvement is that the savings in costs of products required for profitability increase do not exist if one or both of the following are not realized in the activity under examination:

1) **The increase in the capability to produce caused by productivity improvement should be able to be utilized.**

2) **The decrease in the requirement for resources caused by productivity improvement should be able to be realized.**

7.1.2. The results of the study

Although there were some limitations and a few problems in the construction and testing of this framework, there are also many benefits. As mentioned earlier, there is a real need for a systematic tool for analyzing the activities. Moreover, there is also need for additional and especially more accurate information about the relationship between productivity and profitability, and for tools for managing manufacturing processes on the basis of this information.

The aim of this study was to support the selection of objects for productivity improvement, and to develop a method for analyzing the effects of productivity change in an activity on the profitability of a firm. So the objective was to create a systematic way to manage and control the productivity improvement from the economic point of view. The reason for this is supporting the management in their decision making.

The framework developed here provides a systematic way for selecting the objects (activities) for productivity improvement and analyzing the effects of productivity improvement on the profitability of a firm. One possible tool (Urgency Analysis) for selecting the activities is presented. Urgency Analysis is a multi-criteria evaluation technique. It can be also seen as a modified version of the generally known ABC-analysis. Three dimensions which affect

this classification and the way to stress these dimensions on the basis of the properties of the activity under consideration are presented. It is also presented how to calculate a numerical value for the basis of classification.

The calculation model presented here combines the productivity change in an activity with the profitability of a firm more accurately than earlier models. It is possible to calculate the effect of one certain change of productivity in an activity on the profitability of the firm. The relationship between the change of one partial productivity and the change of total productivity is also dealt with.

When analyzing the usefulness of the calculation model it is necessary to consider **what means this change of profit** received as the result of using the tool? The change of profit describes the potential for the change in the level of profit that can be achieved in a period or in a year by improving the productivity in conditions where the other factors do not affect the situation. It is also possible to say that if the increase of resources is included in the measure of productivity and so taken into consideration within the percentage of productivity increase, the result describes the pure additional profit. If the increase of resources is not included in the increase of productivity, the result describes the amount of money that it is reasonable to sacrifice annually to achieve a certain increase in productivity. The limitations, the selections made and the problems emerged must be taken into consideration when analyzing the reliability of the change of profit.

This is the first time when ABC is utilized as an environment in developing a method for managing productivity improvement. In the literature there are some articles where the utilization of ABC in connection with productivity analysis is described. However, these articles concern the suitability and operativity of the older models or systems in a new accounting environment.

The problem with the models mentioned above and the other older models is that they usually do not operate on relevant levels of actions. Productivity improvement actions are in general made at floor level with machines, cells, activities and human beings. This is the level where productivity should be influenced and measured. Profitability is most meaningful at the level of the whole firm. Another problem with these older models is how to unite the properties of two different processes in a firm. Productivity reflects the performance of the real process of a firm, whereas profitability is the property of the monetary process. In addition to this, the traditional costing systems set their own restrictions to this problem. It has been very difficult or even impossible to analyze closely enough the economical aspects at floor level. The older models are too general to produce any relevant information about the effects of productivity improvement.

In this framework, the changes of productivity (both total and partial) at floor level and the profitability of a firm are connected. The main contribution of this dissertation is to offer a possibility for analyzing the effects of productivity improvement actions where they really happen, in the activities at floor level.

The operativity of the framework was tested with the data of one medium size Finnish metal firm. It is shown that Urgency Analysis is a suitable tool in selecting the objects for the deeper analysis of the effects of productivity improvement. The calculation model was tested in four case activities by using a tool constructed with Microsoft Excel. This model provides additional information about the economical effects of productivity improvement for supporting the management decision making. There are some problems, but the benefits of the new additional information provided by this framework are larger than the disadvantages caused by these problems. This information needs to be used together with other sources of information and keeping in mind the limitations of the framework.

7.2. Conclusions and recommendations for further research

As a conclusion, the results of this study should to be compared to the predefined objectives. The objective was to create a systematic way to manage and control the productivity improvement from the economic point of view. The second level objectives of this study were the evaluation of the functioning of this method and the tool developed in practice. The three objectives of this study are classified on two levels in chapter 1.

The main objective was to ***create a framework for economic management and control of the productivity improvement***. This objective was fulfilled by the framework developed. The framework is a systematical way with two stages for analyzing the effects of productivity improvement actions in an activity on the profitability of a firm. In the first stage of the framework, the objects for the deeper analysis and possible productivity improvement actions are selected. For the purposes of this stage a simple selection method based on the worth, possibility, and necessity of improvement actions in each activity is presented. This method is called Urgency Analysis. On the second stage it is analyzed how much a certain productivity change in an activity affects the profitability of a firm. A theoretical calculation model is presented, with which it is possible to analyze the effects of productivity (both total and partial) improvement in monetary values. On the basis of this theoretical model a tool for analysis at firm level was made. This model is suitable both for precalculation and postcalculation (actual costs) under the limitations placed in developing the model.

The first subordinate objective was to ***evaluate the functioning of the framework in different kinds of environments***. This objective was fulfilled by the empirical test of the framework. This empirical test was made with the data of one Finnish firm in metal industry. Both stages of the framework were tested. Urgency Analysis was found to be a suitable tool in selecting the objects for deeper analysis and through it to objects of improvement actions.

The operativity of the theoretical calculation model was tested by using the tool to analyze four different case activities. Because the study was a decision oriented case study there was no need for wide empirical tests with large samples and statistical methods. The shortcoming of this empirical test was that there was no suitable data for testing the operativity of the post-calculation part of the tool.

The second subordinate objective was to ***evaluate the effects of individual factors in production to the functioning of the framework***. In connection with the analysis of the case activities there emerged several individual factors which affect the framework. Because case study is an interactive process, many of these factors had their own effects on the structure of the framework. There were also some factors which were problematic to be taken into consideration. For example the bottlenecks and especially the bottlenecks outside the production function, such as sales are difficult to handle.

The general aim of this study was to support management decision making by providing additional information about the effects of productivity change in an activity on the profitability of a firm. This was achieved in spite of the fact that the model developed contains some limitations which are unfamiliar in the real world. These limitations were made for to simplify the outlining of the problem and the calculations needed. The main contribution of this study can be given as follows:

* The framework presented here provides a systematic way for selecting the objects (activities) for productivity improvement and for analyzing the effects of productivity improvement on the profitability of a firm.

* The framework offers a possibility to analyze the effects of the productivity improvement actions where they really happen, at floor level.

* The calculation model combines the productivity change in an activity with the profitability of a firm more accurately than earlier models.

* The relationship between the change of one partial productivity and the change of total productivity is presented.

* This is the first time when ABC is utilized as an environment in developing a method for managing productivity improvement.

There are some recommendations for future research. One possible extension is widening the area where the framework operates. The framework developed here is made for use in the production function of a firm. It is possible to utilize it also in the other functions of a firm. The calculation model for the support activities must be different, because they do not treat the products directly. In the model, the products must be replaced by the output of these activities. The problem with the other functions is that the increase in output due to the productivity improvement cannot always be utilized. When the productivity increase is based on the decrease in the usage of resources, the calculation model is suitable. The selection of the improvement object is equal in the production and support activities. The only thing that is needed to be done, is to define the critical factors in Urgency Analysis according to the properties of the other functions. The widening of the suitability of the framework is one obvious scope for future research.

One theoretical problem with the calculation model was the question of the limits of productivity increase. The calculation model developed here contains a linear relationship between the change of productivity and the change of profit. In practice the relation can be linear only within some limits. If there are no limits the increase of productivity should always be profitable. Perhaps it is possible to find a empirical generalization about the relationship between the productivity change and change of profit. This would possibly be some kind of "law" where linearity is suitable within certain limits, but not on all levels of change. This question of the limits of the linear relationship is connected with the nature of the change of productivity. The examining of the limits of this model and the general relationship is also a good scope for future research.

8. SUMMARY

Productivity and profitability are important concepts and measures describing the performance and success of a firm. Common sense tells us that there has to be a relationship between these two. We can usually accept that increase in productivity decreases the costs per unit produced and leads to better profitability. This common knowledge is not, however, enough in the modern business environment. Productivity improvement is one means among others for increasing the profitability of actions. There are many means to increase productivity. The use of these means presupposes operative decisions and these decisions presuppose information about the effects of these means.

In the literature concerning the productivity of a firm there are many models[1] for analyzing the effects of productivity change on the profitability of a firm. The problem with these models is that in general they do not operate on relevant levels of actions. The productivity improvement actions are in general made at floor level with machines, cells, activities and human beings. Profitability is most meaningful at the level of the whole firm. In addition to this, the traditional costing systems have set their own restrictions to this question. It has been very difficult or even impossible to analyze closely enough the economical aspects of the changes at floor level. New ideas in accounting have only recently brought in elements which make it possible to consider these phenomena where they actually happen.

The aim of this study is to support the selection of objects for productivity improvement, and to develop a method to analyze the effects of productivity change in an activity on the profitability of a firm. Thus the objective is to

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[1] A more efficient use of resources is a widely considered topic in the literature of many areas. For example the investment projects can be considered as projects for productivity improvement and the investment calculations can be described as models. The aim of these projects is often to increase the profitability of a firm. However, these projects may have also other objectives, depending on the nature of the investment. In this connection the investment calculations are not considered as models for analyzing the effects of productivity change on the profitability of a firm. In this connection the focus is on the literature concerning productivity and the models presented there.

create a systematic way to manage and control the productivity improvement from the economic point of view. This also means creating a tool for producing information about the effects of productivity improvement to support the management in their decision making. The second level objective of this study is the evaluation of the functioning of the method and tool developed in practice.

A framework for systemizing the economical management of productivity improvement is developed in this study. This framework is a systematical way with two stages to analyze the effects of productivity improvement actions in an activity on the profitability of a firm. The first stage of the framework concerns the selection of the activities for the deeper analysis and through it to the objects of possible productivity improvement actions. A simple selection method which is based on the worth, possibility and necessity of the improvement actions in each activity is presented. This method is called Urgency Analysis.

In the second stage it is analyzed how much a certain change of productivity in an activity affects the profitability of a firm. A theoretical calculation model with which it is possible to analyze the effects of productivity improvement in monetary values is presented. On the basis of this theoretical model a tool is made with Microsoft Excel for the analysis at firm level.

The aim of this framework is to produce additional information to support the management's decision making when they are allocating resources for the improvement of productivity in production. The usefulness of this framework was empirically tested with the data of the Profit center of one medium size Finnish firm which operates in metal industry.

In the first stage, Urgency Analysis was used in the selection of activities to deeper analysis among the 29 activities of the production function of this Profit center. The activities were classified to three urgency categories. Four

activities were selected to category A and to the objects of deeper analysis in the second stage of the framework.

In the second stage of the framework the usefulness of the tool was tested by calculating how much a certain change of productivity in the activities affects the change of profit in the Profit center. The effects of 5 %, 10 %, 15 % and 20 % increase in total productivity in the activity on the profit of the Profit center were calculated. Also the effects of 10 and 20 percent increase in certain partial productivities in the activity on the profit of the Profit center were calculated. In addition, it is shown how the change of profit reflects on the operating margin ratio and the return on investment ratio of the Profit center.

At the end the limitations and problems in connection with this study are considered. After that the results of this study are discussed and conclusions are made about achieving the objectives. Also some recommendations for future research are made. It is expressed that the framework provides valuable information about the economical effects of productivity improvement for supporting the management in their decision making.

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Appendix 1

The effects of the change of productivity of one input Z (ceteris paribus) on the change of total productivity

The relationship between total productivity and partial productivities is reversed (see equation 2.5.). It can be presented as follows:

$$\frac{1}{PD_T} = \frac{1}{PD_L} + \frac{1}{PD_C} + \frac{1}{PD_M} + \frac{1}{PD_E} + \frac{1}{PD_X}$$

When we are examining the effect of change of one partial productivity it is possible to present this relationship in a more simple way.

$$\frac{1}{PD_T} = \frac{1}{PD_Z} + \frac{1}{PD_X}$$

where:

PD_T = total productivity
PD_Z = input Z productivity
PD_X = other inputs productivity

In the following, the question of how the change of productivity of input Z (ceteris paribus) affects the change of total productivity is considered. Productivities in period P1 are marked PD_{T1}, PD_{Z1} and PD_{X1}. Productivity of input Z increases $(100 \cdot z)$ percent between the periods P1 and P2 and it is $(1+z) \cdot PD_{Z1}$ in period P2. This increase of PD_Z cause an increase in total productivity. The amount of this increase can be marked as $(100 \cdot g)$ percent between the periods P1 and P2. So total productivity is $(1+g) \cdot PD_{T1}$ in period P2. According to the assumption of ceteris paribus the productivity of other inputs (PD_{X1}) does not change between these two periods. According to the previous equation the situation in period P2 can be presented as follows:

$$\frac{1}{(1+g) \cdot PD_{T1}} = \frac{1}{(1+z) \cdot PD_{Z1}} + \frac{1}{PD_{X1}}$$

where:

g = change of total productivity, (100 · g) percent
z = change of productivity of input Z, (100 · z) percent

According to the equation 2.1. the productivity is the relationship between output and input. The productivities can be presented as the ratio of output to input.

$$\frac{1}{(1+g)\cdot\frac{O_1}{I_{T1}}} = \frac{1}{(1+z)\cdot\frac{O_1}{I_{Z1}}} + \frac{1}{\frac{O_1}{I_{X1}}}$$

where:

O_1 = amount of output in period P1
I_{T1} = amount of total input in period P1
I_{Z1} = amount of input Z in period P1
I_{X1} = amount of input X in period P1

Further, it can be presented as follows:

$$\frac{I_{T1}}{(1+g)\cdot O_1} = \frac{I_{Z1}}{(1+z)\cdot O_1} + \frac{I_{X1}}{O_1}$$

When the previous equation is multiplied with $((1+g)\cdot(1+z))$ and O_1 we can get

$$(1+z)\cdot I_{T1} = (1+g)\cdot I_{Z1} + (1+g)\cdot(1+z)\cdot I_{X1}$$

and further

$$I_{T1} + z\cdot I_{T1} = (I_{Z1} + I_{X1}) + g\cdot(I_{Z1} + I_{X1}) + z\cdot I_{X1} + g\cdot z\cdot I_{X1}$$

Because I_{T1} is the sum of I_{Z1} and I_{X1} we can get

$$z\cdot I_{T1} = g\cdot I_{T1} + z\cdot I_{X1} + g\cdot z\cdot I_{X1}$$

If we mark that $I_{X1} = (I_{T1} - I_{Z1})$ we can get

$$(z-g)\cdot I_{T1} = z\cdot(I_{T1} - I_{Z1}) + g\cdot z\cdot(I_{T1} - I_{Z1})$$

Further we can get

$$z\cdot I_{T1} - g\cdot I_{T1} = z\cdot I_{T1} - z\cdot I_{Z1} + g\cdot z\cdot I_{T1} - g\cdot z\, I_{Z1}$$

and in a condensed form

$$-g \cdot I_{T1} = -z \cdot I_{Z1} + g \cdot z \cdot I_{T1} - g \cdot z\, I_{Z1}$$

Now the multiplier of input factors can be put together

$$(z + g \cdot z) \cdot I_{Z1} = (g + g \cdot z) \cdot I_{T1}$$

$$z \cdot (1 + g) \cdot I_{Z1} = g \cdot (1 + z) \cdot I_{T1}$$

$$\frac{z}{(1 + z)} \cdot I_{Z1} = \frac{g}{(1 + g)} \cdot I_{T1}$$

$$\frac{(1 + g)}{g} = \frac{(1 + z)}{z} \cdot \frac{I_{T1}}{I_{Z1}}$$

$$\frac{1}{g} + 1 = (\frac{1}{z} + 1) \cdot \frac{I_{T1}}{I_{Z1}}$$

$$\frac{1}{g} = (\frac{1}{z} + 1) \cdot \frac{I_{T1}}{I_{Z1}} - 1$$

From this equation we can solve the amount of increase of total productivity in percents (100·g) when the productivity of input Z increases (100·z) percent between the periods P1 and P2. The g can be stated as follows:

$$g = \frac{1}{(\frac{1}{z}+1) \cdot \frac{I_{T1}}{I_{Z1}} - 1}$$

Appendix 2

(The original questionnaire is in Finnish)

URGENCY ANALYSIS

_____
(activity)

Conditions

a) Is it possible to increase the production?

1) no 2) yes (_____ %), with present products

3) yes, with new products

b) Is it possible to reduce the use of resources or move them?

1) no 2) yes (_____ %)

Classification

Worthiness (W), weight a _____ , (a + b + c = 3)

4 large savings or increase in incomes are possible
3 rather large savings or increase in incomes are possible
2 some savings or increase in incomes are possible
1 no savings or increase in incomes

Possibility (P), weight b _____

4 high potential for improvement in the present level of production
3 rather large potential for improvement in the present level of production
2 some potential for improvement in the present level of production
1 do not contain any or contain only very little potential for improvement without investments

Necessity (N), weight c _____

4 need for improvement is very urgent
3 rather large necessity for improvement actions
2 some necessity for improvement actions
1 do not need any or need only very little improvement according to the present information

Urgency point

$UP = a \cdot W + b \cdot P + c \cdot N$ = _____

Other (e.g. possible limitations or consequences elsewhere)

_____

_____

_____

_____

PRECALCULATION

Appendix 3

ACTIVITY: Painting

NATURE OF ACTIVITY (Homog. = 0, Heter. = 1)	1

Periode in year	1

ORIGINAL STATE (in period)

RESOURCES	Labor	Capital	Material	Energy	Special	From other	
Quantity	0	0	0	0	0	0	0
Value	83800	0	95000	7000	0	134550	0
TOTAL COST	320350	COST PER ACT. MEASURE			308,12		

OUTPUT	Products A	B	C	D	E	F	7
Quantity / Period							
- realized	797	65	1686	60	328	343	0
- standard	797	65	1688	60	328	343	0
Usage / unit							
- standard	0,36	0,31	0,31	0,28	0,28	0,30	0,00
- change-% (h)	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
Mat. cost, change	0	0	0	0	0	0	0
PROD COST	111,25	95,95	95,95	85,32	90,99	93,28	0,00

PRODUCTION VOLUME	Net capac.	Util. rate	Empty cap.	Real. prod.	Std. prod.
	1530	67,73%	493,6702	1036,33	1036,33

EFFECTS OF PRODUCTIVITY CHANGE (in period)

ACTIVITY:

PARTIAL PRODUCTIVIT.	Labor	Capital	Material	Energy	Special
Change-% (z)	0,00%	0,00%	10,00%	0,00%	0,00%
Effect to total productivity	0,000	0,000	0,028	0,000	0,000

TOTAL PRODUCTIVITY	
Change-% (g)	2,77%

FIRM:

ECONOMIC SITUATION		Year 1993
Turnover (1000 mk)		108954
Operating margin (1000 mk)		16675
Operating margin ratio		15,30%
Profit (BTA) (1000 mk)		5433
Net financing costs		6700
Total assets (1000 mk) av.		71828,5
year 1993	72612	
year 1992	71045	
ROI		16,89%

EFFECT OF PRODUCTIVITY TO PROFIT (Ceteris paribus)

Change of profit	8638	in period
(Mk)	8638	in year

EFFECT OF PRODUCTIVITY TO PROFITABILITY (Ceteris paribus)

Change of OMR	0,01%	
OMR after change	15,31%	in year
Change of ROI	0,01%	
ROI after change	16,90%	in year

PRECALCULATION

Appendix 4

ACTIVITY:

ls. man. unit

NATURE OF ACTIVITY	1
(Homog. = 0, Heter. = 1)	

Periods in year	
	1

ORIGINAL STATE (In period)

RESOURCES	Labor	Capital	Material	Energy	Special	From other	
Quantity	5258	0	0	0	0	0	0
Value	328448	932372	205415	0	114626	0	0
TOTAL COST	1580761	COST PER ACT. MEASURE			307,30		

OUTPUT	Products H	I	J	K	L	M	N
Quantity / Period							
- realized	81	82	66	20	8	23	18
- standard	81	82	65	20	8	23	18
Usage / unit							
- standard	8,00	13,00	15,00	24,00	33,00	65,00	12,00
- change-% (h)	-50,00%	0,00%	0,00%	-10,00%	-10,00%	0,00%	0,00%
Mat. cost, change	0	0	0	0	0	0	0
PROD. COST	2459,42	3934,92	4609,63	7375,25	10140,99	19874,62	3687,62

PRODUCTION VOLUME	Net capac.	Util. rate	Empty cap.	Real. prod.	Std. prod.
	6120	84,05%	976	5144	5144

EFFECTS OF PRODUCTIVITY CHANGE (In period)

ACTIVITY:

PARTIAL PRODUCTIVIT.	Labor	Capital	Material	Energy	Special
Change-% (z)	20,00%	0,00%	0,00%	0,00%	0,00%
Effect to total productivity	0,038	0,000	0,000	0,000	0,000

TOTAL PRODUCTIVITY	
Change-% (g)	3,59%

FIRM:

ECONOMIC SITUATION		Year 1993
Turnover (1000 mk)		108954
Operating margin (1000 mk)		16675
Operating margin ratio		15,30%
Profit (BTA) (1000 mk)		5433
Net financing costs		6700
Total assets (1000 mk) av.		71828,5
year 1993	72612	
year 1992	71045	
ROI		15,89%

EFFECT OF PRODUCTIVITY TO PROFIT (Ceteris paribus)

Change of profit	172931	in period
(Mk)	172931	in year

EFFECT OF PRODUCTIVITY TO PROFITABILITY (Ceteris paribus)

Change of OMR	0,16%	
OMR after change	15,46%	in year
Change of ROI	0,24%	
ROI after change	12,13%	in year