PRODUCTIVITY
Theory and Measurement in Business

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This paper is based on the book [19] with the same name in Finnish

1 Introduction

The purpose of this paper is to operationalize the concept of productivity in business. Operationalization comprises the following five steps: *1) Phenomenon description*. The phenomenon of productivity is described as part of economic activity. *2) Concept formation*. Productivity is defined as a concept in close relation to such concepts as profitability, economic growth, efficiency, surplus value, quality, performance, partial productivity, need, etc. *3) Modelling*. A model of productivity measurement is presented, based on the most accurate business data. A time series construction for the development of productivity, profitability and production income distribution is suggested. Interpretations of the partial productivity measurement are given. *4) Horizontal comparison*. The production function-based models for business are compared by identifying their features and evaluating the differences. *5) Vertical comparison*. Productivity models of a business and a nation are compared by identifying their features and evaluating the differences.

As a result, operationalization of the concept of productivity is presented based on the most accurate business information. A quantitative model is demonstrated. Differences in productivity measurement models are made transparent and evaluated based on the production theory.

2 Productivity as part of economic activity

It is most advisable to examine any phenomenon whatsoever only after defining the entity the phenomenon under review forms part of. Then it will be possible to analyse the phenomenon as part of such an entity. Hence, productivity cannot be examined as a phenomenon independently but it is necessary to identify the entity it belongs to. Such an entity is defined as economic activity. It goes without saying that productivity is a critical success factor of economy in one way or another. To define the way is the object of this study. The next step is to describe the model of economic activity and the concepts involved in it.

2.1 Model of Economic Activity

The primary purpose underlying any economic activity is *the satisfaction of human needs*. Welfare can be understood as an adequate degree of needs satisfaction. Need is either a physical or a mental state in which the lack of something necessary, desired or hoped for is experienced consciously or unconsciously. A need initiates a target-oriented activity towards meeting the need.

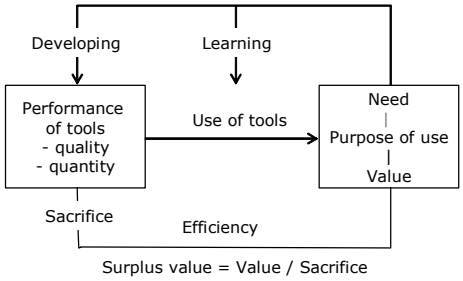


Figure 1. Model of economic activity

Needs are met by means of *tools*. Tools provide some value for their user. Man creates various material and immaterial tools for his use, and tools provide him with some value, need satisfaction. The purpose of use is an idea of how the need is met by means of a given tool. The purpose of use is an idea derived from the qualities of the need and from the characteristics of the tool or it is a more specified plan for the use of the tool and for the value it will produce. Need satisfaction is a result of the value the tool provides, and the degree of need satisfaction varies all according to the success of the tool in its purpose of use.

A basic feature of economic behaviour is the interest to satisfy the needs to the maximum at minimal sacrifice. Here we speak about striving for efficiency which is typical of economic activity. *Efficiency*, in general terms, speaks about the relation between producing *a value* and *sacrifices* made in doing so. Hence, efficiency is at issue when the required sacrifices are being balanced against the value produced. Efficiency is a general concept related to economic activity, and it needs to be given a precise name and a formula case by case. Productivity and profitability are typically such specified concepts of efficiency. The basic idea of efficiency of the tools is that the value they produce is larger than the sacrifices made to provide and use them. The difference or relation between produced value and made sacrifice is *the surplus value*.

The ability of a tool to perform its task is its performance. Performance is a common expression which needs to be further defined in order to understand it exactly. More often than not, performance refers to a tool keeping up with its basic task. The tools' performance depends on their

quality and quantity. Improving the performance takes place by developing their quality and increasing their quantity as well as by evolving the use process. The tools' *quality* means their characteristics. Both quality and quantity are usually developed on the basis of the latest know how and experience, and the work is carried out by means of investment and development projects. The use process of tools evolves over the time through learning.

Based on the distribution of work, economic activity can be identified with *production* and *consumption*. Production is a process of combining various immaterial and material inputs of production so as to produce tools for consumption. The way of combining the inputs of production in the process of making output is called *technology*. Technology can be depicted mathematically by *the production function* which describes the function between input and output. The production function is the measure of production performance.

2.2 Economic Growth and Productivity

By help of the production function, it is possible to describe simply the mechanism of economic growth. Economic growth is a production increase achieved by an economic community. It is usually expressed as an annual growth percentage depicting (real) growth of the national product. Economic growth is created by two factors so that it is appropriate to talk about the components of growth. These components are an increase in production input and an increase in productivity.

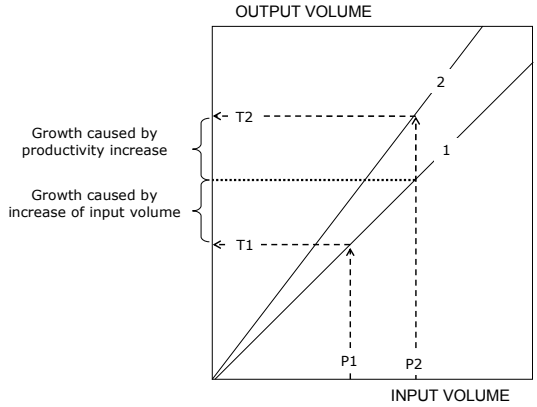


Figure 2. Components of economic growth

The above figure presents the economic growth process. By way of illustration, the proportions shown in the figure are exaggerated. Reviewing the process in subsequent years, one and two, it becomes evident that production has increased from Value T1 to Value T2. Measured in absolute terms, economic growth is T2 – T1, while proportionally speaking, it is (T2 – T1)/T1. At the same time, an increase from Value P1 to Value P2 was measured in the use of production input. Now, both years can be described by a graph of production functions, each function being named after the respective number of the year, i.e., one and two. Two components are distinguishable in the output increase: the growth caused by an increase in production input and the growth caused by an increase in productivity. The growth caused by an increased input is determined by moving along the production function for a respective input increase, i.e. from Value P1 to Value P2. Characteristic of the growth effected by an input increase is that the relation between output and input remains unchanged. An increase in output means a shift of the production function simultaneously with a change in the output/input relation. In other words, the output growth corresponding to a shift of the production function is generated by the increase in productivity.

Accordingly, an increase in productivity is characterized by a shift of the production function and a consequent change to the output/input relation. The formula of total productivity is normally written as follows:

$$Total\ productivity = \frac{Output\ quantity}{Input\ quantity}$$

According to this formula, changes in input and output have to be measured inclusive of both quantitative and qualitative changes [8]. In practice, quantitative and qualitative changes take place when relative quantities and relative prices of different input and output factors alter. In order to accentuate qualitative changes in output and input, the formula of total productivity shall be written as follows:

$$Total\ productivity = \frac{Output\ quality\ and\ quantity}{Input\ quality\ and\ quantity}$$

Davis [4] has deliberated productivity as a phenomenon in business, measurement of productivity, distribution of productivity gains, and how to measure such gains. He refers to an article (1947, Journal of Accountancy, Feb. p. 94) suggesting that the measurement of productivity in business shall be developed so that it "will indicate increases or decreases in the productivity of the company and also the distribution of the 'fruits of production' among all parties at interest".

Davis regards the measurement of productivity gains distribution as an important part of the productivity phenomenon, and he deliberates the problems related to measuring it at great length. According to Davis, the price system is a mechanism through which productivity gains are distributed, and besides the business enterprise, receiving parties may consist of its customers, staff and the suppliers of production inputs. In this paper, the concept of "distribution of the fruits of production" by Davis is simply referred to as *production income distribution* or shorter still as *distribution*.

3 PRODUCTIVITY MEASUREMENT MODEL

First, we describe the main processes of business, and after that, we study in great detail the most interesting processes from the point of view of productivity and the solutions to measure such processes. Productivity as the focus of interest, we must first identify its connection with profitability and only then identify the processes generating productivity and profitability.

3.1 Main processes of a company

Business operations can be divided into sub-processes in different ways; yet, the following five are identified as main processes, each with a logic, objectives, theory and key figures of its own. It is important to examine each of them individually, yet, as a part of the whole, in order to be able to measure and understand them. The main processes of a company are as follows:

- real process
- income distribution process
- business process
- monetary process
- market value process

Productivity is created in the real process, productivity gains are distributed in the income distribution process, and these two processes constitute the business process. The business process and its sub-processes, the real process and income distribution process occur simultaneously, and only the business process is identifiable and measurable by the traditional accounting practices. The real process and income distribution process can be identified and measured by extra calculation, and this is why they need to be analysed separately in order to understand the logic of income formation in business.

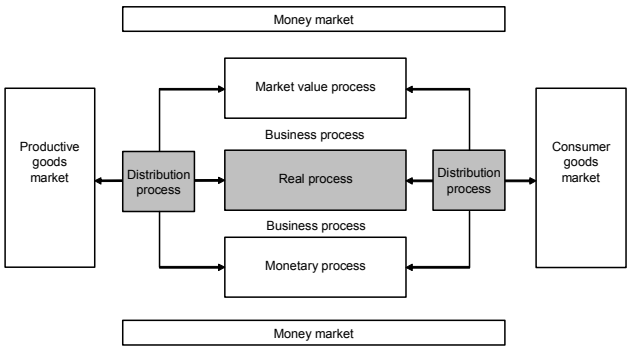


Figure 3. Main processes of a company

Real process generates the production output, and it can be described by means of the production function. It refers to a series of events in production in which production inputs of different quality and quantity are combined into products of different quality and quantity. Products can be physical goods, immaterial services and most often combinations of both. The characteristics created into the product by the manufacturer imply surplus value to the consumer, and on the basis of the price this value is shared by the consumer and the producer in the marketplace. This is the mechanism through which surplus value originates to the consumer and the producer likewise. Surplus value to the producer is a result of the real process, and measured proportionally it means productivity.

Income distribution process of the production refers to a series of events in which the unit prices of constant-quality products and inputs alter causing a change in income distribution among those participating in the exchange. The magnitude of the change in income distribution is directly proportionate to the change in prices of the output and inputs and to their quantities. Productivity gains are distributed, for example, to customers as lower product prices or to staff as higher pay.

Business process consists of the real process and the income distribution process. A result and a criterion of success of the business process is profitability. The profitability of business is the share of the real process result the producer has been able to keep to himself in the income distribution process. Factors describing the business process are the components of profitability, i.e., returns and costs. They differ from the factors of the real process in that the components of profitability are given at nominal prices whereas in the real process the factors are at fixed prices.

Monetary process refers to events related to financing the business.

Market value process refers to a series of events in which investors determine the market value of the company in the investment markets.

3.2 Surplus value as a measure of business profitability

The scale of success run by a going concern is manifold, and there are no criteria that might be universally applicable to success. Nevertheless, there is one criterion by which we can generalise the rate of success in business. This criterion is the ability to produce surplus value. As a criterion of profitability, surplus value refers to the difference between returns and costs, taking into consideration the costs of equity in addition to the costs included in the profit and loss statement as usual. Surplus value indicates that the output has more value than the sacrifice made for it, in other words, the output value is higher than the value (production costs) of the used inputs. If the surplus value is positive, the owner's profit expectation has been surpassed.

TABLE 1. PROFITABILITY OF BUSINESS MEASURED BY SURPLUS VALUE

	Period 1			Period 2		
	Quantity	Price	Value	Quantity	Price	Value
Product 1	210.00	7.20	1512	247.25	7.10	1755
Product 2	200.00	7.00	1400	195.03	7.15	1394
Output			2912			3150
Labour	100.00	7.50	750	115.00	7.70	886
Materials	80.00	8.60	688	79.20	8.50	673
Energy	400.00	1.50	600	428.00	1.55	663
Capital	160.00	3.80	608	164.80	3.90	643
Input			2646			2865
Surplus value (abs.)			266.00			285.12
Surplus value (rel.)			*1.101*			*1.100*

Table 1 presents a surplus value calculation. This basic example is a simplified profit and loss statement used for illustration and modelling. Even as reduced, it comprises all phenomena of a real measuring situation and most importantly the change in the output-input mix between two periods. Hence, the basic example works as an illustrative "scale model" of production without any features of a real measuring situation being lost. In practice, there may be hundreds of products and inputs but the logic of measuring does not differ from that presented in the basic example.

Both the absolute and relative surplus values have been calculated in the example. The absolute value is the difference of the output and input values and the relative value is their relation, respectively. The surplus value calculation in the example is at a nominal price, calculated at the market price of each period.

3.3 Production model

The next step is to describe a *production model* [15]-[19] by help of which it is possible to calculate the results of the real process, income distribution process and business process. The starting point is a profitability calculation using surplus value as a criterion of profitability. The surplus value calculation is the only valid measure for understanding the connection between profitability and productivity or understanding the connection between real process and business process. A valid measurement of total productivity necessitates considering all production inputs, and the surplus value calculation is the only calculation to conform to the requirement.

The process of calculating is best understood by applying the clause of Ceteris paribus, i.e. "all other things being the same," stating that at a time only the impact of one changing factor be introduced to the phenomenon being examined. Therefore, the calculation can be presented as a process advancing step by step. First, the impacts of the income distribution process are calculated, and then, the impacts of the real process on the profitability of the business.

The first step of the calculation is to separate the impacts of the real process and the income distribution process, respectively, from the change in profitability (285.12 – 266.00 = 19.12). This takes place by simply creating one auxiliary column (4) in which a surplus value calculation is compiled using the quantities of Period 1 and the prices of Period 2. In the resulting profitability calculation, Columns 3 and 4 depict the impact of a change in income distribution process on the profitability and in Columns 4 and 7 the impact of a change in real process on the profitability.

3.4 Calculation of the income distribution process

The key figures of income distribution can now be calculated from the surplus value calculations in Columns 3 and 4. The difference of 39.00 (unfavourable) between the surplus values indicates the impact on profitability in terms of money. Indexes depicting the change in income distribution can now be calculated by the formulas presented both for output (1.003) and input (1.018), and as their ratio for the whole business

$$1.003/1.018=0.985.$$

It follows that the change in income distribution means a development in which the quality of output or input stays the same while the unit price changes. A change of price does not involve recompensing for the change in quality. In the short term, price changes do not follow a certain trend, yet, in the long term, the trend is transparent. Consumers benefit from lowering product prices and their buying power increases thanks to better compensation for selling their work input to production. Production income distribution is the mechanism by means of which productivity gains of the production are distributed to interested parties, and it can be measured by means of price changes.

TABLE 2. PRODUCTION MODEL

		Period 1			$Q_1 \times P_2$	Period 2		
		1	2	3	4	5	6	7
		Quantity	Price	Value		Quantity	Price	Value
a	Product 1	210.00	7.20	1512.00	1491.00	247.25	7.10	1755.48
b	Product 2	200.00	7.00	1400.00	1430.00	195.03	7.15	1394.46
c	Output			2912.00	2921.00			3149.94
d	Labour	100.00	7.50	750.00	770.00	115.00	7.70	885.50
e	Materials	80.00	8.60	688.00	680.00	79.20	8.50	673.20
f	Energy	400.00	1.50	600.00	620.00	428.00	1.55	663.40
g	Capital	160.00	3.80	608.00	624.00	164.80	3.90	642.72
h	Input			2646.00	2694.00			2864.82
i	Surplus value (abs.)			266.00	227.00			285.12
j	*Surplus value (rel.)*			*1.101*				*1.100*
k	Change of distribution (abs.); i4-i3				-39.00			
l	Distribution index of output; c4/c3				1.003			
m	Distribution index of input; h4/h3				1.018			
n	Distribution index; l4/m4				0.985			
	Distribution process							
p	Productivity; c4/h4, c7/h7				1.084			1.100
q	Productivity index; p7/p4							1.014
r	Change of productivity (abs.); (q7-1)×c4							41.12
s	Volume index of output; c7/c4							1.078
t	Volume index of input; h7/h4							1.063
u	Change of input volume (abs); (t7-1)×(i4+r7)							17.00
	Real process							
v	Change of profitability; j7/j3							0.999
x	Change of returns; c7/c3							1.082
z	Change of costs; h7/h3							1.083
	Business process							

3.5 Calculation of the real process

Columns 4 and 7 depict the change in performance in the real process. Surplus values have been calculated at a fixed price, in this case, at prices of Period 2. Fixed-price calculation is a method in which the quantities of the items of different qualities can be measured and added up. This concept is called the volume which is a measure of absolute value. The time series depicting its change is called the volume index.

The surplus value of the real process is called the real surplus value as distinct from the nominal price surplus value of profitability. All changes in the surplus value of the real process are changes of performance. Productivity is the surplus value of the real process proportionally measured. Now it is possible to calculate productivity (1.084 and 1.100) for Periods 1 and 2 using the formula of productivity output per input, and as their ratio we get the productivity index depicting the change in productivity.

$$1.100/1.084=1.014.$$

As a result, we can calculate the monetary quantity equivalent to the change in productivity, and in this case it is favourable 41.12.

3.6 Illustration of the real and income distribution processes

Measurement results can be illustrated by models and graphic presentations. The following figure illustrates the connections between the processes by means of indexes describing the change [12], [18], [19]. A presentation by means of an index is illustrative because the magnitudes of the changes are commensurate. Figures are from the above calculation example of the production model.

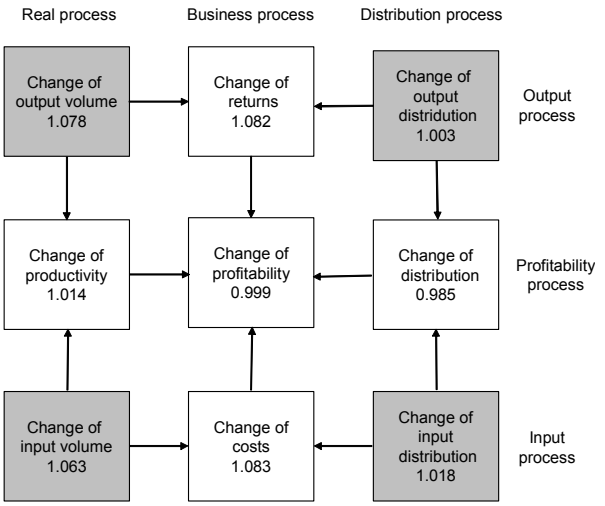


Figure 4. Variables of business performance

The nine most central key figures depicting changes in business performance can be presented as shown in Figure 4. Vertical lines depict the key figures of the real process, business process and income distribution process. Key figures in the business process are a result of the real process and the income distribution process. Horizontal lines show the changes in input and output processes and their impact on profitability. The logic behind the figure is simple. Squares in the corners refer to initial calculation data. Profitability figures are obtained by dividing the output figures by the input figures in each process. After this, the business process figures are obtained by multiplying the figures of the real and income distribution processes.

3.7 Depicting the development by time series

Development in the real process, income distribution process and business process can be illustrated by means of the time series. The principle of a time series is to describe, for example, the profitability of business annually by means of a relative surplus value and also to explain how profitability was produced as a consequence of productivity development and income distribution. A time series can be composed using the chain indexes as seen in the following.

Now the intention is to draw up the time series for the ten periods in order to express the annual profitability of business by help of productivity and income distribution development. With the time series it is possible to prove that productivity of the real process is the distributable result of production, and profitability is the share remaining in the company after income distribution between the company and the interested parties participating in the exchange.

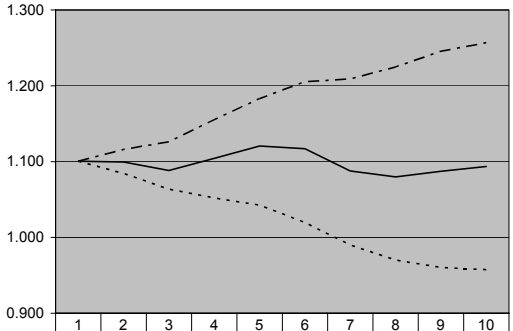
TABLE 3. PRODUCTIVITY AND INCOME DISTRIBUTION INDEXES

	1	2	3	4	5	6	7	8	9	10
Chain index of distribution	**1.101**	1.084	1.064	1.052	1.042	1.020	0.990	0.970	0.960	0.958
Annual index of distribution		**0.985**	0.981	0.989	0.991	0.978	0.971	0.980	0.990	0.997
Chain index of productivity	**1.101**	1.116	1.126	1.155	1.183	1.206	1.209	1.225	1.246	1.257
Annual index of productivity		**1.014**	1.009	1.026	1.024	1.019	1.003	1.013	1.017	1.009
Surplus value of business (rel.)	**1.101**	**1.100**	1.088	1.104	1.121	1.117	1.088	1.080	1.087	1.094

Figures in bold are from the calculation example. They can describe the entire logic of the table. A common starting point for the time series is the profitability of the first period, being 1.101 measured by the surplus value. The profitability of business is presented as an annual relative surplus value. A change in profitability between two periods can be presented using the profitability and income distribution index. For example, the development between Periods 1 and 2 can be expressed as

$$1.101 \times 1.014 \times 0.985 = 1.100.$$

In a market economy the prevailing competition sees to it that the productivity rise achieved in production will be distributed to interested parties sooner or later. This phenomenon can be illustrated by drawing up a chain index of the development of productivity and income distribution. The chain index is drawn up by multiplying the index of previous development by the index of annual change. In other words, productivity is given its first numeral value (1.116) by multiplying the common starting point (1.101) by the annual productivity index (1.014). This is the procedure for dealing with every period, and the formula explaining profitability by means of productivity and income distribution indexes holds to every period.



	1	2	3	4	5	6	7	8	9	10
Productivity	1.101	1.116	1.126	1.155	1.183	1.206	1.209	1.225	1.246	1.257
Surplus value	1.101	1.100	1.088	1.104	1.121	1.117	1.088	1.080	1.087	1.094
Distribution	1.101	1.084	1.064	1.052	1.042	1.020	0.990	0.970	0.960	0.958

Figure 5. Profitability as a function of productivity and income distribution development

The above graph shows how profitability depends on the development of productivity and income distribution. Productivity figures are fictional but in practice they are perfectly feasible indicating an annual growth of 1.5 per cent on average. Growth potentials in productivity vary greatly by industry, and as a whole, they are directly proportionate to the technical development in the branch. Fast-developing

industries attain stronger growth in productivity. This is a traditional way of thinking. Today we understand that human and social capitals together with competition have a significant impact on productivity growth. In any case, productivity grows in small steps. By the accurate measurement of productivity, it is possible to appreciate these small changes and create an organisation culture where continuous improvement is a common value.

3.8 Measuring and interpreting partial productivity

Measurement of partial productivity refers to the measurement solutions which do not meet the requirements of total productivity measurement, yet, being practicable as indicators of total productivity. In practice, measurement in business means measures of partial productivity. In that case, the objects of measurement are components of total productivity, and interpreted correctly, these components are indicative of productivity development. The term of partial productivity illustrates well the fact that total productivity is only measured partially – or approximately. In a way, measurements are defective but, by understanding the logic of total productivity, it is possible to interpret correctly the results of partial productivity and to benefit from them in practical situations. Typical solutions of partial productivity are:

1. Single-factor productivity
2. Value-added productivity
3. Unit cost accounting
4. Efficiency ratios
5. Managerial control ratio system

Single-factor productivity refers to the measurement of productivity that is a ratio of output and one input factor. A most well-known measure of single-factor productivity is the measure of output per work input, describing work productivity. Sometimes it is practical to employ the value added as output. Productivity measured in this way is called *Value-added productivity*. Also, productivity can be examined in cost accounting using *Unit costs*. Then it is mostly a question of exploiting data from standard cost accounting for productivity measurements. *Efficiency ratios*, which tell something about the ratio between the value produced and the sacrifices made for it, are available in large numbers. *Managerial control ratio* systems are composed of single measures which are interpreted in parallel with other measures related to the subject. Ratios may be related to any success factor of the area of responsibility, such as profitability, quality, position on the market, etc. Ratios may be combined to form one whole using simple rules, hence, creating a key figure system.

The measures of partial productivity are physical measures, nominal price value measures and fixed price value measures. These measures differ from one another by the variables they measure and by the variables excluded from measurements. By excluding variables from measurement makes it possible to better focus the measurement on a given variable, yet, this means a more narrow approach. The table below was compiled to compare the basic types of measurement. The first column presents the measure types, the second column the variables being measured, and the third column gives the variables excluded from the measurement.

TABLE 4. COMPARISON OF BASIC MEASURE TYPES

TYPE OF MEASURE	Variables to be measured	Variables excluded
Physical	Quantity	Quality and distribution
Fixed price value	Quantity and quality	Distribution
Nominal price value	Quantity, quality and distribution	None

A physical measure can measure the quantity of a variable with unchanged quality. Using a physical measure provides that the quality of the measurement object has been specified and the quality remains homogeneous. If the presumed unchanged quality is not realised, the measurement gives results which are hard to interpret. In this case, the results are affected by changes in both quantity and quality but in which proportion is unknown. Values of the objects being measured are by no means related to the physical measures, hence, changes in prices do not affect the measurement results. Normally it is not possible to combine physical measures. They are best suited for narrow-focused measurements without any quality or value alterations. Therefore, physical measures are best for measuring the real process, and this is why they are used a lot as tools of operative management. Typical ratios in a real process are capacity, efficiencies, lead times, loads, faults, product and process characteristics, etc.

A fixed-price value measure is used to measure changes in quality and quantity. True to its name, prices are kept fixed for a minimum of two measuring situations. For this reason, it is possible to define the changes in quality and quantity of a most varied and wide range of commodities, keeping apart the changes in income distribution. Fixed-price measures are suited for wide-ranging measurement because it is possible to combine different commodities based on their value. In a fixed-price measurement, a change in quality means that the relative quantities and relative prices of various commodities change. The best known applications of this are the productivity formula and the production function. The production function is always presented with fixed-price ratios, i.e., its variables, productivity and volume, are fixed-price values.

The most common figures in measuring business are the *nominal price figures* because they can describe the profitability of business process. Variables in the nominal price measurement are quality, quantities and distribution (prices). There are no excluded variables. Nominal price measures of value are suited for measuring profitability and its components as well as the value of reserves. Return and costs in the loss and profit statement are typical examples of a nominal price. In short-term reviews with only little

production income distribution taking place, nominal price values are well suited for estimates of fixed price values.

4 Comparison of the productivity measurement models

The principle of comparing productivity measurement models is to identify the characteristics that are present in the models and to understand their differences. This task is alleviated by the fact that such characteristics can unmistakably be identified by their measurement formula. Based on the model comparison, it is possible to identify the models that are suited for measuring productivity. A criterion of this solution is the production theory and the production function. It is essential that the model is able to describe the production function.

The principle of model comparison becomes evident in the following figure. There are two dimensions in the comparison. Horizontal model comparison refers to a comparison between business models. Vertical model comparison refers to a comparison between economic levels of activity or between the levels of business, industry and national economy.

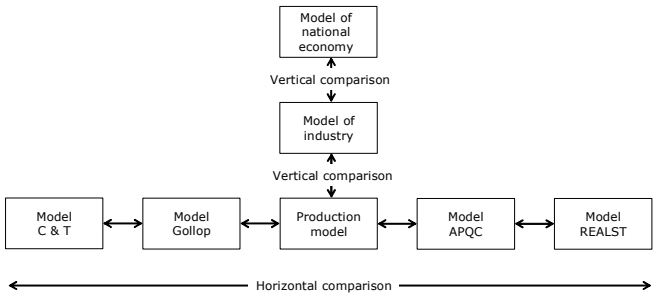


Figure 6. Dimensions of productivity model comparisons

The conclusion of the model comparison is interesting. At all three levels of economy, that is, that of business, industry and national economy, a uniform understanding prevails of the phenomenon of productivity and of how it should be modelled and measured. The comparison reveals some differences that can mainly be seen to result from differences in measuring accuracy. It has been possible to develop the productivity model of business so as to be more accurate than that of national economy for the simple reason that in business the measuring data are much more accurate. As soon as the development efforts related to the national economy model are carried out in practice, the logic of the model would be very close to that of the present business models.

4.1 Business models

There are several different models available for measuring productivity. Comparing the models systematically has proved most problematic. In terms of pure mathematics it has not been possible to establish the different and similar characteristics of them so as to be able to understand each model as such and in relation to another model. This kind of comparison is possible using the production model which is a model with adjustable characteristics. An adjustable model can be set with the characteristics of the model under review after which both differences and similarities are identifiable. A comprehensive comparison of productivity measurement models is presented in another publication [16].

A characteristic of productivity measurement models that surpasses all the others is the ability to describe the production function. If the model can describe the production function, it is applicable to total productivity measurements. On the other hand, if it cannot describe the production function or if it can do so only partly, the model is not suitable for its task. The production models based on the production function form rather a coherent entity in which differences in models are fairly small. The differences play an insignificant role, and the solutions that are optional can be recommended for good reasons. Productivity measurement models can differ in characteristics from another in six ways.

1. First, it is necessary to examine and clarify the *differences in the names* of the concepts. Model developers have given different names to the same concepts, causing a lot of confusion. It goes without saying that differences in names do not affect the logic of modelling. The name differences can be traced in the publication [16].

2. *Model variables* can differ; hence, the basic logic of the model is different. It is a question of the variables to be used for the measurement. The most important characteristic of a model is its ability to describe the production function. This requirement is fulfilled in case the model has the production function variables of productivity and volume. Only the models that meet this criterion are worth a closer comparison.

3. *Calculation order* of the variables can differ. Calculation is based on the principle of Ceteris paribus stating that when calculating the impacts of change in one variable all other variables are hold constant. The order of calculating the variables has some effect on the calculation results, yet, the difference is not significant.

4. *Theoretical framework* of the model can be either cost theory or production theory. In a model based on the production theory, the volume of activity is measured by input volume. In a model based on the cost theory, the volume of activity is measured by output volume.

5. *Accounting technique*, i.e., how measurement results are produced, can differ. In calculation, three techniques apply: ratio accounting, variance accounting and accounting form. Differences in the accounting technique do not imply differences in accounting results but differences in clarity and intelligibility. Variance accounting gives the user most possibilities for an analysis.

6. *Adjustability of the model*. There are two kinds of models, fixed and adjustable. On an adjustable model, characteristics can be changed, and therefore, they can examine the characteristics of other models. A fixed model can not be changed. It holds constant the characteristic that the de-

veloper has created in it.

Based on the variables used in the production measurement model suggested for measuring business, such models can be grouped into three categories as follows:

1. Productivity index models
2. PPPV models
3. PPPR models

In 1955, Davis published a book titled Productivity Accounting [4] in which he presented a productivity index model. Based on Davis' model several versions have been developed, yet, the basic solution is always the same [9], [7], [13], [20]. The only variable in the index model is productivity, which implies that the model can not be used for describing the production function. Therefore, the model is not introduced in more detail here.

PPPV is the abbreviation for the following variables, profitability being expressed as a function of them:

Profitability = f (Productivity, Prices, Volume)

The model is linked to the profit and loss statement so that profitability is expressed as a function of productivity, volume and unit prices. Productivity and volume are the variables of a production function, and using them makes it is possible to describe the real process. A change in unit prices describes a change of production income distribution.

PPPR is the abbreviation for the following function:

Profitability = f (Productivity, Price Recovery)

In this model, the variables of profitability are productivity and price recovery. Only the productivity is a variable of the production function. The model lacks the variable of volume, and for this reason, the model can not describe the production function. The American models of REALST [12], [14] and APQC [2], [5], [10], [14] belong to this category of models but since they do not apply to describing the production function they are not reviewed here more closely.

4.2 Comparative summary of the PPPV models

PPPV models measure profitability as a function of productivity, volume and income distribution (unit prices). Such models are

- Japanese Kurosawa [11]
- French Courbois & Temple [3]
- Finnish Saari [15]-[19] in this paper called the production model
- American Gollop [6]

The following table presents the characteristics of the PPPV models. All four models use the same variables by which a change in profitability is written into formulas to be used for measurement. These variables are income distribution (prices), productivity and volume. A conclusion is that the basic logic of measurement is the same in all models. The method of implementing the measurements varies to a degree, depending on the fact that the models do not produce similar results from the same calculating material.

Even if the production function variables of profitability and volume were in the model, in practice the calculation can also be carried out in compliance with the cost function. This is the case in models C & T as well as Gollop. Calculating methods differ in the use of either output volume or input volume for measuring the volume of activity. The former solution complies with the cost function and the latter with the production function. It is obvious that the calculation produces different results from the same material. A recommendation is to apply calculation in accordance with the production function. According to the definition of the production function used in the production model and that of Kurosawa, productivity means the quantity and quality of output per one unit of input.

The production model is the only model weighting quantity changes with new prices. The order of calculating the changes in the production model is as follows: 1) Prices, 2) Productivity and 3) Volume. The question is how the results of the real process should be valued. The solution is justified by the fact that the real process should be valued by the new prices because new prices are a spur guiding the activity. This choice is followed by the fact that the changes in income distribution are valued on the basis of the quantities of Period 1.

TABLE 5. SUMMARY OF THE PPPV MODEL CHARACTERISTICS

CHOICE	Saari	Kurosawa	Gollop	C & T
Variables used in the model	Distribution Productivity Volume	Distribution Productivity Volume	Distribution Productivity Volume	Distribution Productivity Volume
Theory, alternatives; 1. Production function 2. Cost function	Production function	Production function	Cost function	Cost function
Calculation order of variables	1. Distribution 2. Productivity 3. Volume	1. Volume 2. Productivity 3. Distribution	1. Volume 2. Productivity 3. Distribution	1. Volume 2. Productivity 3. Distribution
Accounting technique, alternatives; 1. Variance accounting 2. Ratio accounting 3. Accounting form	All changes; Variance accounting	All changes; Accounting form	Distribution; Variance acc. Productivity; Ratio acc. Volume; Account. form	All Changes Accounting; form
Adjustability, alternatives; 1. Adjustable 2. Fixed	Adjustable	Fixed	Fixed	Fixed

Models differ from one another significantly in their calculation techniques. Differences in the calculation technique do not cause differences in calculation results but it is rather a question of differences in clarity and intelligibility between the models. From the comparison it is evident that the models of Courbois & Temple and Kurosawa are purely based on calculation formulas. The calculation is based on the aggregates in the loss and profit account. Consequently, it does not suit to analysis. The production model is purely based on variance accounting known from the standard cost accounting. Variance accounting is applied to elementary variables, that is, to quantities and prices of different products and inputs. Variance accounting gives the user most possibilities for analysis. The model of Gollop is a mixed model by its calculation technique. Every variable is calculated using a different calculation technique.

The production model is the only model with alterable characteristics. Hence, it is an adjustable model. A comparison between other models has been feasible by exploiting this particular characteristic of the production model.

4.3 Model of national economy

In order to measure productivity of a nation or an industry, it is necessary to operationalize the same concept of productivity as in business, yet, the object of modelling is substantially wider and the information more aggregate. The calculations of total productivity of a nation or an industry are based on the time series of the SNA, System of National Accounts, formulated and developed for half a century. National accounting is a system based on the recommendations of the UN (SNA 93) to measure total production and total income of a nation and how they are used.

Measurement of productivity is at its most accurate in business because of the availability of all elementary data of the quantities and prices of the inputs and the output in production. The more comprehensive the entity we want to analyse by measurements, the more data need to be aggregated. In productivity measurement, combining and aggregating the data always involves reduced measurement accuracy.

Output measurement

Conceptually speaking, the amount of total production means the same in the national economy and in business but for practical reasons modelling the concept differs, respectively. In national economy, the total production is measured as the sum of value added whereas in business it is measured by the total output value. When the output is calculated by the value added, all purchase inputs and their productivity impacts are excluded from the examination. Consequently, the production function of national economy is written as follows:

$$Output = f(Capital, Labour)$$

In business, production is measured by the gross value of production, and in addition to the producer's own inputs (capital and labour) productivity analysis comprises all purchase inputs such as raw-materials, outsourcing services, supplies, components, etc. Accordingly, it is possible to measure the total productivity in business which implies absolute consideration of all inputs. It is clear that productivity measurement in business gives a more accurate result because it analyses all the inputs used in production.

The productivity measurement based on national accounting has been under development recently. The method is known as KLEMS, and it takes all production inputs into consideration. KLEMS is an abbreviation for K = capital, L = labour, E = energy, M = materials, and S = services. In principle, all inputs are treated the same way. As for the capital input in particular this means that it is measured by capital services, not by the capital stock [1].

Combination or aggregation problem

The problem of aggregating or combining the output and the inputs is purely measurement technical, and it is caused by the fixed grouping of the items. In national accounting, data need to be fed under fixed items resulting in large items of output and input which are not homogeneous as provided in the measurements but include qualitative changes. There is no fixed grouping of items in the business production model, neither for inputs nor for products, but both inputs and products are present in calculations by their own names representing the elementary price and quantity of the calculation material.

Problem of the relative prices

For productivity analyses, the value of total production of the national economy, GNP, is calculated with fixed prices. The fixed price calculation principle means that the prices by which quantities are evaluated are hold fixed or unchanged for a given period. In the calculation complying with national accounting, a fixed price GNP is obtained by applying the so-called basic year prices. Since the basic year is usually changed every 5th year, the evaluation of the output and input quantities remains unchanged for five years. When the new basic-year prices are introduced, relative prices will change in relation to the prices of the previous basic year, which has a certain impact on productivity.

It is clear that old basic-year prices entail inaccuracy in the production measurement. For reasons of market economy, relative values of output and inputs alter while the relative prices of the basic year do not react to these changes in any way. Structural changes like this will be wrongly evaluated. Short life-cycle products will not have any basis of evaluation because they are born and they die in between the two basic years. Obtaining good productivity by elasticity is ignored if old and long-term fixed prices are being used. In business models this problem does not exist because correct prices are available all the time.

4.4 Conclusion of the model comparison

The business production model enables us to have a new point of view into growth research because by help of the production model it is possible to analyse growth at its sources or in the production and in the co-operative networks created by them, such as in the know-how concentrations or clusters. Until now, there has been very little, if any, research into economic growth at the production unit or cluster level despite the fact that there would be reliable initial data available.

The objectives of developing a productivity model for national economy are clear. In conclusion, we can say that in the business productivity model all the intended characteristics are working practices and indispensable principles; measuring the gross value-based output, considering all production inputs, measuring the capital input as a capital service flow, measuring the inputs (and the output) in as homogeneous groups as possible and the relative prices corresponding with the reality.

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