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Introduction

Contemporary management control and reporting both face challenges. Consequently, a new and more sophisticated scientific approach is needed. From one point of view, interdisciplinary studies and theories are necessary. From another point of view, empirical research and practical issues call for a more specific and specialized approach. This complexity is reflected by the content of this book, which covers topics that emerge from present world's complexity. Therefore, the authors focus on ever-important issues (such as the strategic approach and its support by management control and reporting, survival of companies), and more modern issues (e.g. cultural aspects, measurement and reporting adjusted to branches, spheres and organizations and specific issues of management control and reporting).

The strategic approach to managerial control and financial statements and their role for company's survival is presented in papers by J. Dyczkowska (who addresses the question whether annual reports communicate strategic issues and focuses her study on reporting practices of high-tech companies), A. Bieńkowska, Z. Kral, A. Zabłocka-Kluczka (who explain the role of responsibility centers in strategic controlling), P. Kroflin (who explores the value-based management and management reporting examining impacts of value reporting on investment decisions and company value perception) and A. Reizinger-Ducsai (who discusses bankruptcy prediction and financial statements). The problems of management control and reporting and their adjustment to specific conditions and organizations are undertaken by T. Dyczkowski (who introduces his NGO performance model), Z. Kes and K. Nowosielski (who present the case study of the process of cost assignment in a local railway company providing passenger transportation services), S. Łęgowik-Świącik, M. Stępień, S. Kowalska and M. Łęgowik-Małolepsza (who analyse the efficiency of the heat market enterprise management process in terms of the concept of the cost of capital), and M. Pietrzak and P. Pietrzak (who discuss the problem of performance measurement in the public higher education). The cultural aspect of managerial control and reporting is explored in papers written by M. Nowak (who presents cultural determinants of accounting, performance management and costs problems showing the issue from Polish perspective using G. Hofstede and GLOBE cultural dimensions) and P. Bednarek, R. Brühl and M. Hanzlick (who provide a literature overview of planning and cross-cultural research). The specific problems and concepts of managerial control and reporting are investigated by M. Ciołek (who discusses the lean thinking and overhead costs), E. Nowak (who analyses the role of costs control role in controlling company operation), Ü. Pärl, R. Koyte,

S. Näsi (who examine middle managers' mediating role in MCS implementation), R.L. Sichel (who discusses the relevance of intellectual property for management control), J. Paranko and P. Huhtala (who analyse the productivity measurement at the factory level).

Marta Nowak

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PRODUCTIVITY MEASUREMENT AT THE FACTORY LEVEL

POMIAR PRODUKTYWNOŚCI NA POZIOMIE WYDZIAŁU PRODUKCYJNEGO

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JEL Classification: L25, M11, M54

Summary: The objective of this study was to develop a new partial productivity measurement method for the case company. The scope of this study was limited to factory-level productivity measurement. Material costs and value of inventory were excluded from the measurement. Labor productivity and capital productivity are the focus of the new method. The case company uses a make-to-order production approach, and it belongs to the mechanical engineering sector, as so many other companies in Finland do. The developed model includes two main components: ROA and the capacity model. Gold's model and the American Productivity and Quality Center model (APQC model) have had the greatest influence on the structure of the presented model. The model has been tested with data covering the last four years. Strictly interpreted, the final result describes the impact of the combined effect of productivity changes and input price changes. The company representatives argued that it is crucial for them to know whether the efficiency of operations will increase, at least in such a way that it will at least cover inflation. Realized productivity development was a pleasant surprise for the steering group. The fear that the intake of total assets would have decreased productivity proved to be wrong. The level of productivity changed nearly every month. One of the main driving forces behind the change is capacity.

Keywords: net capacity, productivity, profitability, ROA, and price recovery.

Streszczenie: Celem badania było opracowanie nowej metody pomiaru produktywności cząstkowej w przykładowym przedsiębiorstwie. Zakres badania został ograniczony do pomiaru produktywności na poziomie wydziału produkcyjnego. Z pomiaru wyłączono koszty materiałów oraz wartość zapasów. Nowa metoda pomiarowa skupia się na produktywności pracy i kapitału. Badane przedsiębiorstwo, jak wiele innych w Finlandii, należy do sektora budowy maszyn i realizuje produkcję na zamówienie. Opracowany model zawiera dwie główne składowe: ROA oraz wydajność. Najistotniejszy wpływ na strukturę prezentowanego modelu miały modele Golda oraz Amerykańskiego Centrum Produktywności i Jakości (APQC). Model został przetestowany z wykorzystaniem danych obejmujących cztery ostatnie lata. Ściśle ujmując, ostateczny rezultat opisuje łączny wpływ zmian w produktywności i zmian cen czynników produkcji. Kierownictwo przedsiębiorstwa stwierdziło, że istotne znaczenie miało dla niego stwierdzenie czy sprawność operacyjna wzrośnie w stopniu przynajmniej równoważącym stopę inflacji. Osiągnięty wzrost produktywności okazał się przyjemną niespodzianką dla zarządzających. Obawa, że wzrost wartości aktywów ogółem obniży produktywność okazała się być nieuzasadniona. Poziom produktywności zmieniał się praktycznie co miesiąc. Jednym z głównych czynników zmiany była wydajność.

Słowa kluczowe: wydajność netto, produktywność, rentowność, ROA, zrównoważenie ceny.

It is better to be approximately
right than the completely wrong.

Authors' motto

1. Introduction

The objective of this study was to develop a new and appropriate partial productivity measurement method, which could be used in the case company. The scope of this study was limited to factory-level productivity measurement. Material costs and value of inventory were excluded from the measurement.

The case company uses the factory profit as its main indicator of productivity at the factory level. However, the factory manager complained that the present way of measuring productivity does not sufficiently correlate with real productivity. Nevertheless, the ratio of profit to number of employees is a crucial part of a rewarding system. The factory manager asked our researcher to develop a more valid productivity measurement system. He also asked us to keep it as simple as possible.

Research cooperation with a company specializing in mechanical engineering started about two years ago, with a project that focused on a more accurate costing system of finished goods. Our researcher was at the company every second week. For the rest of the time he worked at the university. An interventionist research method was used [Jönsson, Lukka 2005]. A strong interventionist method was utilized because a high level of participation was involved in the project: the interventionist researcher was part of a joint team. Our researcher also had open access to the company's ERP system. The company wanted to continue the research cooperation, and a new project began about 18 months later, concentrating on productivity measurement. The model's development was carried out in close cooperation with the case company's development engineer for the production systems. In addition, the steering group for the project participated in the model elaboration process by commenting on the research team's work. The productivity measurement model development project was carried out by applying a constructive research method. The previous interventionist research provided a good starting point for this project.

Initial data included the following monthly reports:

1. Volume report for each part divided into assembling parts and in-house manufactured parts.
2. Factory cost report

- personnel costs,
- depreciation,
- other costs.

3. Factory hour report.

The most important factors in other costs are machine maintenance services, different types of machine tools, and leasing payments. The factory hour report consists of hours done on the assembly line and the manufacturing department.

2. The key elements of the model

2.1. ROA

ROA was selected to use as a main productivity ratio in this paper. ROA, which is closely related to return on investment (ROI), return on equity (ROE), and return on capital employed (ROCE), is globally very commonly used as a firm-level profitability ratio.

These ratios describe the interest rate earned on capital employed. The basic formula is as follows:

$$ROA = \frac{Profit}{Capital\ employed}$$

In the various ratios, profit and capital definitions differ from each other. In this paper, profit is measured by earnings before interest and taxes (EBIT), and capital employed is measured by total assets. A more detailed formula may be expressed as follows:

$$ROA = \frac{EBIT}{Total\ assets}$$

ROA can also be expressed by multiplying two ratios – EBIT-% and assets turnover ratio – as follows:

$$ROA = EBIT[\%] \times Assets\ turnover\ ratio$$

where,

$$EBIT[\%] = \frac{EBIT}{Net\ sales} \times 100\% \qquad Assets\ turnover\ ratio = \frac{Net\ sales}{Total\ assets}$$

2.2. Capacity model

Net capacity is defined in the capacity model. The net capacity is that part of a company's capacity that creates net sales. The bigger the net capacity, the bigger the net sales will be. The capacity model is illustrated in Figure 1.

The CAM-I capacity model has many features similar to those of the proposed model. The total capacity is divided into idle, nonproductive, and productive capacity. Idle capacity includes holidays and so on. Nonproductive capacity includes standby, waste, setups, and maintenance. Productive capacity is used to change the product or provide the service [Klammer 1996].

The starting point in the capacity model is to determine how many hours an employee is actually at the workplace. The same subcategories for working time and absences as those used by the Confederation of Finnish Industries for its yearly working time surveys have been used in this study [Elinkeinoelämän Keskusliitto 2013].

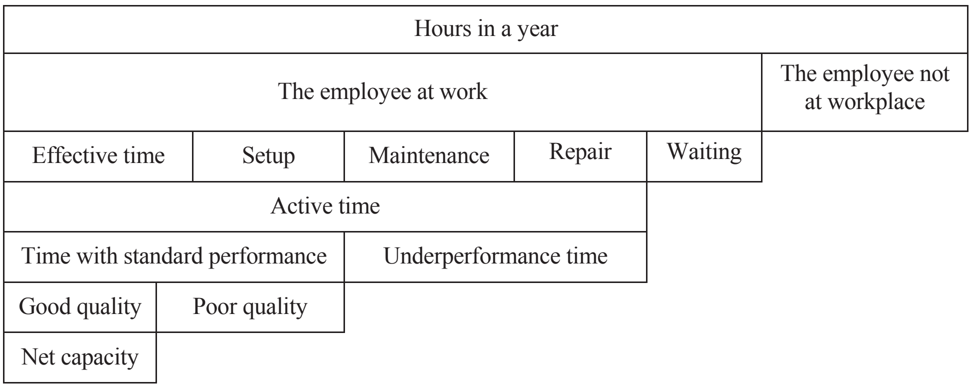

Figure 1. Capacity model

Source: own study.

An average blue-collar worker in 2012 was at his/her workplace for 1,543h [Elinkeinoelämän Keskusliitto 2013]. A more detailed example of the capacity model is shown in Appendix 1. The main reasons for an employee not being at work are annual holidays (35%) and sick leaves (19%). The shortening of weekly working hours (18%) and public holidays (15%) are also significant. Layoffs and industrial disputes accounted for only 3%.

Among OECD countries, Finland has the 13th fewest annual hours actually worked (1,672 h). For example, the Netherlands (1,381 h), Germany (1,397 h), and Norway (1,420) have even fewer hours than Finland [ILO 2008]. The International Labor Organization's (ILO) recommendation is to use hours actually worked as the basis for international comparisons. Hours actually worked includes time spent on productive activities, down time, and resting time. It excludes annual leave, public holidays, sick leave, parental leave, and other leaves for personal or family reasons [OECD 2012]. The main difference between the capacity model's hours at work (1,543 h) and the OECD data (1,672 h) lies with the OECD data, which subtracts only public holidays, shortening of weekly working hours, and annual holidays.

The annual hours actually worked has reduced to 1,672 h/year over approximately 50 years. In 1960, this value was more than 2,100 h. The main reason for this development is the shortening of weekly working hours. In the 1960s, the five-hour workday on Saturdays was stopped. In the 1980s, working hours were decreased by 100h. Furthermore, mainly in the 1970s and 1980s, annual holidays increased by 40h [Kaseva 2012].

The time for which an employee is at work is normally well known in companies. For example, absences from work hours occurring because of illness and occupational injury are reported separately.

In a process industry, capacity is relatively straightforward. Unfortunately, in discrete manufacturing, capacity is usually guessed. Production capacity in a discrete factory depends on the bottlenecks within the plant, which, in turn, depend on the product mix. A capacity analysis quickly becomes incredibly complex [O'Guin 1991]. Capacity can be measured in units of output. When the product mix is diverse, it is difficult to find a common unit of output measure that makes sense. As a substitute, capacity can be expressed in terms of input measures. If capacity is a measure of input, it may be expressed as the number of hours of resources available over a specific period, such as a shift, day, week, month, or year. Using hours as a unit of capacity causes some additional problems. An hour is a measurement of time, but it does not actually describe an ability to do something. Time passes regardless of whether we can get anything done or not. To solve this problem, the time available should be divided into effective and ineffective categories. This is done in the lower part of the capacity model.

Hours at work are divided into productive and non-productive time. Non-productive time includes waiting, coffee breaks, loss of performance, loss of quality, maintenance, repairs, and set-up. Productive time is the same as net capacity. Working time does not reflect the quality, intensity, or efficiency of work. The level of detail with which the elements of non-productive periods are known varies greatly between different companies. Coffee breaks, maintenance, repairs, and set-up are among the best known elements in traditional factory work. Loss of quality is well known only in some business areas. In our culture, there is no tradition of reporting waiting times or loss of performance. In fact, we behave as though these do not even exist, even though it is commonly known that they are present in relatively large amounts.

Effective time in the capacity model includes maintenance, repairs, and set-up. These actions are a natural part of work from the employee's perspective. However, they are not included in the net capacity as the customer is assumed to be unwilling to pay for them.

Loss of performance reflects the efficiency of work. If the efficiency is not at the targeted level, it indicates that some loss of performance has occurred. In the capacity model, it is assumed that capacity losses in quality, maintenance, repairs, and set-up will no longer include efficiency losses. The efficiency loss will only be in one place (loss of performance).

3. Description of the model

3.1. Modification of initial data ROA

Before the actual calculation of productivity can be done, some modification of the initial data is needed. This modification includes the following phases: cost allocation, total volume calculation, part pricing, and calculation of total assets.

Costs are allocated by the rate of actual hours on an annual level (see Figure 2). The procedure ensures that costs and acts are matched in the same time span.

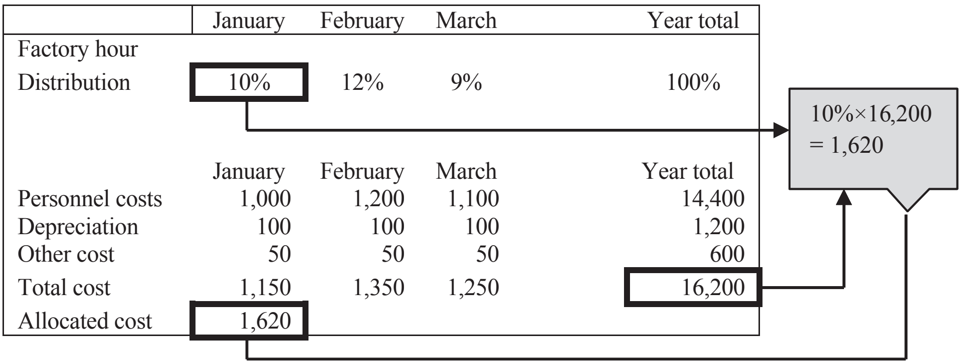

Figure 2. Cost allocation

Source: own study.

In-house manufactured parts are made equivalent with the assembling parts by calculating the following:

- a parts-per-hour rate for both groups,
- a rate describing for how many assembling parts one in-house part corresponds (the equivalent ratio) (see Figure 3).

By using the equivalent ratio, the volume of the parts is turned into a total volume, which expresses the total volume of parts as assembling parts. The ratio is updated every month. At this point, the manufacturing hour report only represents the attendance hours of the personnel. In the future, the capacity model is intended to provide more comprehensive explanations for the changes in productivity.

In the productivity measurement, the effect of the prices has been intentionally eliminated. In this context, the prices include both sale and purchase prices. The goal was to create a system where the above prices do not affect the productivity of the factory. One crucial weakness of the present value-added-based model is the fact that if a seller has managed to make a trade at a good price, the price of the concerned trade should not have a direct effect on the productivity of the factory. Similarly, supplies were restricted outside the productivity measurement.

	January	February	March
Hours of in-house parts	33,600	35,200	28,800
Hours of assembling parts	40,320	38,720	37,440

		Volumes	
	January	February	March
In-house parts	35,000	39,600	27,000
Assembling parts	350,000	360,000	300,000

$$\frac{28,800}{27,000}$$

		Parts/hour	
In-house parts	1.04	1.13	0.94
Assembling parts	8.68	9.30	8.01
The equivalent ratio	8.33	8.26	8.55

$$\frac{8.01}{0.94}$$

Figure 3. The equivalent ratio

Source: own study.

Instead of the actual sale prices, one virtual price is used for all the parts in the calculations. This price is kept constant as long as possible, and hence the effect of the changes in the prices on productivity is eliminated. The reason for using the prices in the model is that productivity is measured with ROA. To calculate this key ratio, we needed EBIT-%.

Price per part is determined in such a way that for the initial time period being viewed (four years), the EBIT-% is 10. The profit goal has been chosen based on the convenience of this number in calculations. Furthermore, it represents the lower limit of the good profitability level in the industry. All items are given an equal value (price) in the model. The total number of active parts in the company is around 50,000. This includes the whole variety from simple screws to devices that form quite complicated machinery. The final product is almost without exception designed for customer-specific needs. One of the basic requirements for the model was to keep it simple. At least for the time being, the parts have not been classified into subgroups, but the calculations are computed as if the company only had one part. The forthcoming experience will show whether more specific classification is needed.

Material costs are not included in the model because they belong to the responsibility of the purchase department, and the manager of the factory did not want them as part of the productivity analysis. For the same reason, the inventories are not included in the total assets.

Only machines and buildings used by the factory are taken into account in the total assets. Their value is calculated backwards using depreciations. Hence, the monthly depreciation can be seen in the monthly cost reports. Furthermore, the distribution of depreciation periods is known. The total assets can be calculated from this data.

3.2. The actual calculation

The actual monthly calculation begins by defining the net sales. The net sales consist of the monthly total volume of products and the fixed price per part. The costs allocated by hours are subtracted from the revenue, and the result is the EBIT. EBIT-% is the ratio of EBIT and net sales. The assets turnover ratio is the ratio of revenue and total assets (see Table 1).

Table 1. ROA calculation

	X/2014	XI/2014	XII/2014	I/2015	II/2015	III/2015	IV/2015
Net sales	2,041,402	1,798,625	1,485,304	1,719,196	1,788,982	1,412,812	1,776,879
Personnel	1,419,101	1,257,463	1,052,509	1,152,838	1,257,768	1,185,378	1,256,629
Depreciation	119,570	105,951	88,682	95,618	104,321	98,317	104,227
Other Expenses	271,451	240,532	201,328	218,731	238,640	224,905	238,424
EBIT	231,280	194,680	142,785	252,009	188,253	95,788	177,600
EBIT [%]	11%	11%	10%	15%	11%	–7%	10%
Total Assets	7,515,040	7,521,040	7,917,360	7,917,360	7,940,400	8,175,360	8,165,520
Assets turnover ratio	3.26	2.87	2.25	2.61	2.70	2.07	2.61
ROA	37%	31%	22%	38%	28%	–14%	26%

Source: own study.

ROA, which represents productivity, is a product of EBIT-% and assets turnover ratio. The changes in productivity are evaluated with five-month moving averages. The average evens the random variations and gives a good picture of the trends of the progress. Moving averages are used to smooth the data in an array to help eliminate noise and identify trends. Its purpose is to detect the start of a trend, follow its progress, as well as to report its reversal. Moving averages do not anticipate the start or the end of a trend. They only confirm it, but only after the actual reversal occurs. A simple moving average weights all the data the same while an exponential moving average places more emphasis on the latest data. The fewer days a moving average contains, the sooner it can detect a trend's reversal. However, the fewer days we use in the moving average's computation, the more false signals we get.

When we want a moving average that will respond to the change rather quickly, then a short period exponential moving average is the best way to go. When we want a moving average that is smoother and slower to respond to changes, then a longer period simple moving average is the best way to go. This would work well when we look at longer time frames, as it could give us an idea of the overall trend. A great disadvantage of moving averages is that they work well only when trends can be found in the phenomenon. When for example prices fluctuate in a particular price range they do not work too well.

The aim of this model is to find out the overall trends in productivity. This is the main reason for the use of five months simple moving average. It has also felt like a good practice for years. Further, Hayes and Clark [1986] used a five-month moving average in their TFP-calculations.

3.3. Findings

The results of the new model (see Figure 4) were a positive surprise for the steering group in this project. They expected that the development had been more negative; in particular, they assumed that the assets turnover ratio had decreased and thus also weakened productivity.

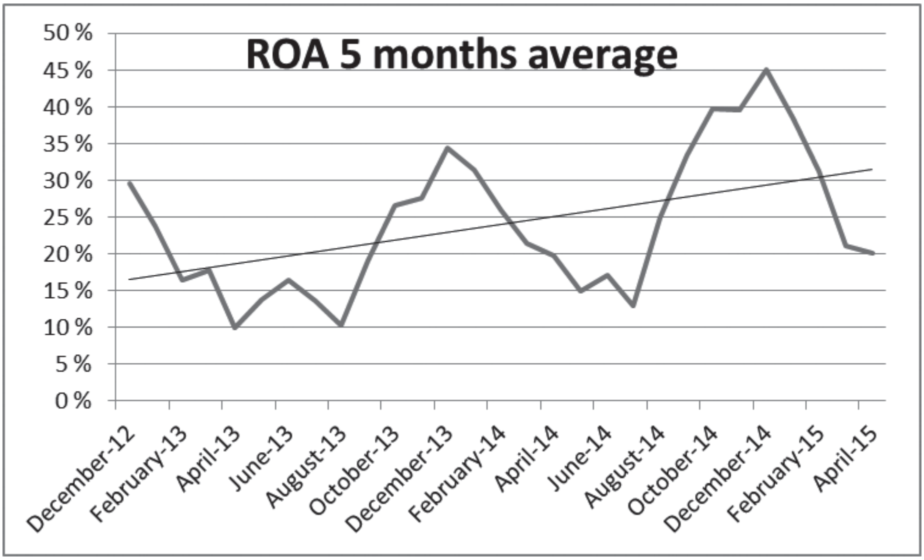

Figure 4. ROA (five-month moving average)

Source: own study.

In the background of the positive development in productivity is increased profit and a higher assets turnover ratio (see Figures 5a-b).

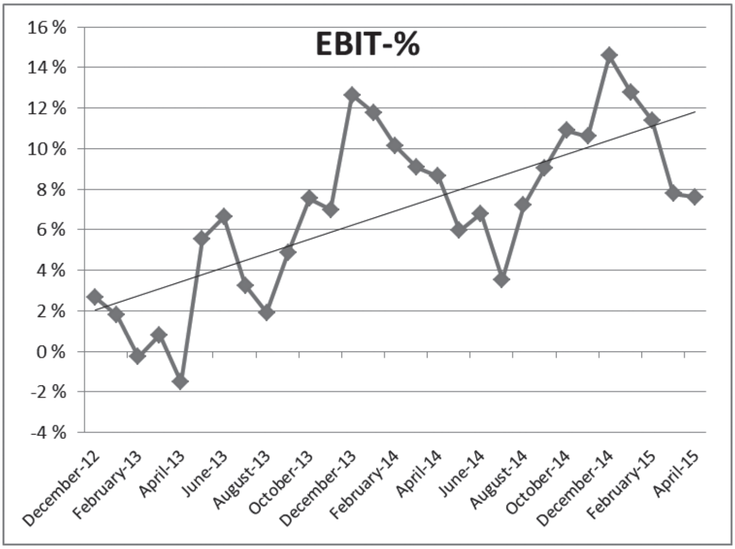

Figure 5a. EBIT [%]

Source: own study.

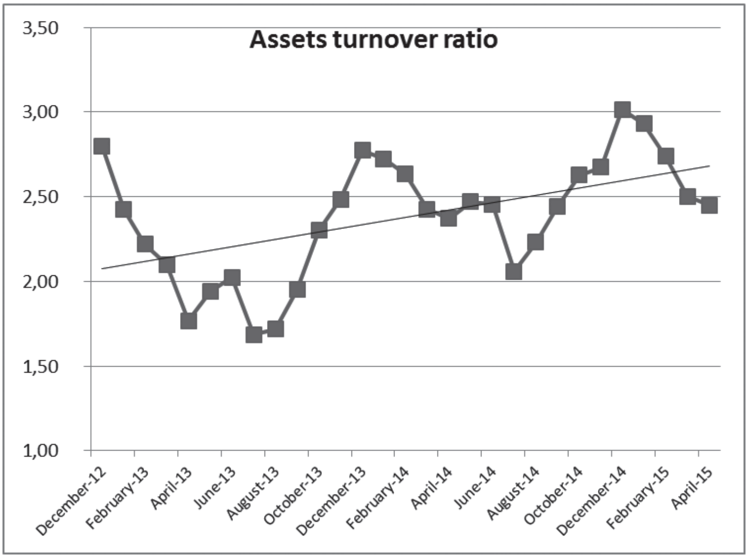

Figure 5b. Assets turnover ratio

Source: own study.

Behind the good development of the two main components (profit and assets turnover ratio) there are increased volumes.

The company has a productivity gainsharing system in use. This is part of the productivity management system, and it is establishing a structure to reward and motivate employees for productivity improvement. A proportion of the gains is paid out to employees in the form of a monthly bonus. This monthly variable component is adjusted according to the results based on the present productivity measurement system. If the bonuses were the same amount as in the past, they would have gone to different time periods with this new system. In that sense, the new model gives a different picture of productivity than the current model. The biggest differences arise with regard to allocating costs differently.

The level of productivity changes nearly every month. One of the main driving forces behind this change is the capacity. Variations in hours worked monthly are high. In particular, the hours worked in July are abnormally low. Summer vacation typically takes place in July in Finland – there is even a saying that Finland is closed during July. Additional low capacity months are December and March. Those months of capacity remains low due to public holidays and shortening of weekly hours appears frequently during these months. The capacity index varies between 76% and 114% (excluding July), which means a 38 percentage point variation in capacity. The capacity model presented in this paper will be used to explain the changes in productivity in more detail in a follow-up project.

Another factor affecting the variations in productivity is the total assets turnover ratio, which is an exceptionally high level. The high level of the ratio can be explained by the fact that inventory is not included there. When the ratio gets as high as 2.5, already small changes in EBIT-% will have a huge influence on ROA.

ROA is one of the most common profitability ratios. In this model, only one virtual price is used for the entire output. The price is needed to measure the output, with the same units as total assets. Actual prices are used in inputs. It would be ideal to measure productivity with physical measures and profitability with financial ones. The end result is a hybrid model that combines both physical measures and financial measures. Strictly interpreted, the final result does not measure productivity. Instead, the outcome describes the impact of the combined effect of productivity changes and input price changes. When we discussed what the model actually measures with the representatives of the company, I received the following response: from the factory point of view, it is crucial that the efficiency of operations rises, at least in such a way that price changes in inputs will be covered. It is important that productivity development will at least cover inflation. If this is the case, there is no need to increase selling prices and the company will be able to compete in the markets. Whether this ratio measures profitability or productivity is a secondary issue for them.

It is good to remember that this model mainly measures the changes in productivity. Although ROA gets very clear and unambiguous values, it is not construed as an absolute value in this case. Over time, learning will take place to interpret the system better. The meter is therefore not suitable for use in comparisons between companies.

4. Conclusion

With an increasing interest in keeping our standard of living high, there is also a growing interest in improving work productivity. The case company is a mechanical engineering company utilizing a make-to-order production approach. This industry plays an important role in Finland. Improving one's own production seems to be an issue for whole industry.

The productivity measurement system developed in this research project is used mainly for performance control purposes. Naturally, it is also used for planning purposes. The new accounting system seems to have the role of a "learning machine" [Burchell et al. 1980]. The management of the case company received further confirmation that the actions taken by the company have been the right ones. The measurement system belongs to a category of managerial control ratios.

The level of productivity fluctuates greatly each month. One of the main driving forces behind the change is capacity. Monthly variations in hours worked are high. The capacity index varies between 76% and 114%, which means a 38 percentage point variation in capacity. The long-term relationship between productivity and financial performance is positive and relatively stable. However, the short-term relationship can be volatile.

The proposed model allows the production function to be viewed more broadly than as a simple cost factor. Instead of concentrating solely on costs, the model also allows users to take income and capital turnover into account. The model has two key elements: the ROA calculation and the capacity model. Inputs are valued by actual prices, but outputs are valued by one virtual price. The greatest scientific contribution of the paper relates to the capacity model. Capacity utilization as a driver of productivity change is well known fact in the literature. The actual amount of capacity has interested researchers less strongly. This study is offering one opportunity to measure the net capacity in labor-intensive sector. The capacity model has also practical relevance. Today developed countries try to find methods to boost competitiveness, employment and productivity. One of the key methods in aimed productivity leap is the extensions of working hours. Instead of working hours, the net capacity defines our real capacity.

The proposed model received a very positive response in the case company. The key choices of the model, as well as the level of analysis, were especially appreciated. The ROA calculation is already part of managers' daily work, and in that sense, the management is already familiar with this concept. The capacity model is easy to understand, and it gives the user sufficient degrees of freedom. The roughness of the model helps keep the parameters within reasonable limits.

ROA is a widely used measure of financial performance. The necessity of converting current price accounts into constant price accounts in order to measure productivity in this model is done by using virtual price for the outputs. However, actual prices are used in the inputs. It would be ideal to be able to measure productivity with physical measures and profitability with financial ones. This model is a hybrid model that combines both physical measures and financial measures. The outcome describes the impact of the combined effect of productivity changes and input price changes.

The model is most suitable in the labor-intensive environments and for analysis taking place at the company level. This model is based on Excel, and the special features of possible new accounting objects should be defined case by case.

The pilot stage also showed some shortcomings of the model. The model treats quality investments like other investments. In the future, they may be given special treatment by re-pricing the outcome. The capacity model will also be used to explain the changes in productivity in more detail in the future.

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Appendix 1. The capacity model

Working hours in a year (365/7*5*8)	2,085.71
(five days per week eight hour per day)	
Overtime	40.00
Absences	
Absences without payment	82.25
Public holidays	88.00
Shortening of weekly working hours	100.00
Annual holiday	200.00
Other absences	111.75
sick-leave (illness)	80.25
sick-leave (injury)	3.75
family holidays	15.75
trade union activities	2.00
travelling time	2.00
education	8.00
Total	582.00
Hours at work place	1,543.71
Waiting time	0.00
Rest breaks	
Coffee break	128.64
Lunch break	
Available for work	1,414.73
Loss of performance	424.42
Loss of quality	59.42
Time losses due to accidents	–
Effective time	930.89
Maintenance	46.54
Repairs	46.54
Set up	93.09
	186.18
Net capacity	744.71