Productivity Measurement

CONCEPTS

Volume I

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EUROPEAN PRODUCTIVITY AGENCY

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I

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EUROPEAN PRODUCTIVITY AGENCY

ORGANISATION FOR EUROPEAN ECONOMIC CO-OPERATION

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The Organisation for European Economic Co-operation comprises the following Member countries : Austria, Belgium, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxemburg, the Netherlands, Norway, Portugal, Sweden, Switzerland, Turkey and the United Kingdom. The Organisation came into being with the signing of the Convention for European Economic Co-operation on 16th April 1948, when Member Governments pledged themselves " to combine their economic strength, to join together to make the fullest collective use of their individual capacities and potentialities, to increase their production, develop and modernise their industrial and agricultural equipment, expand their commerce, reduce progressively barriers to trade among themselves, promote full employment and restore or maintain the stability of their economies and general confidence in their national currencies ". Representatives of each of the Member countries meet daily at OEEC's headquarters, the Château de la Muette, Paris, to discuss their economic problems and work out common solutions. The United States and Canada, although not members of the Organisation, participate in its work.

The European Productivity Agency, which is responsible for the publication of the present report, was set up as a new branch of the OEEC in May, 1953. Its task is to stimulate productivity, and thereby raise European standards of living, by influencing not only Governments but also industrial, agricultural and research organisations, private and collective enterprises and public services. One of its primary aims is to convince management and workers alike of the benefits of productivity and to enlist their co-operation.

The greatest part of this document has been circulated within the O.E.E.C. under the symbol PRA/PS(52)2

Published August 1955

This volume, the first of a projected series on "Productivity Measurement", is dedicated to the memory of

Dr. LASZLO ROSTAS

who died on Friday, 1st October 1954.

This volume has been prepared by

Mr. G. DEURINCK

on the basis of contributions by experts.

Dr. LASZLO ROSTAS

Study of Industrial Productivity

Dr. Laszlo Rostas, an assistant director of research in economics in the University of Cambridge, and formerly an official of the Board of Trade, died on Friday at his home at Cambridge after a prolonged illness. He was 45.

He was born in Budapest in 1909, and graduated in law and economics at Budapest University, where he was one of the best known pupils of the late Professor Navratil. His name first came into prominence in Hungary when at the age of 23 he won the first prize in an award offered by the Hungarian Academy of Sciences for an original treatise on the causes of industrial fluctuations. He came to England in 1939 at the invitation of the National Institute of Economic and Social Research in order to assist in investigations connected with trade cycle research. It was decided that he should collaborate with Professor and Mrs. Hicks in an inquiry on the problems of war taxation, which resulted in the publication in 1941, under their combined authorship, of the "Taxation of War Wealth".

After that he collaborated with Professor Findlay Shirras in the preparation of their well-known work "The Burden of British Taxation", which appeared in 1942. He was then invited by the National Institute to conduct an empirical inquiry into the relationship of costs and prices, and the level of profit margins. His famous paper on the comparative productivity of British, American and German industries, published in the April 1943 issue of the Economic Journal was an offshoot of this. (The full results of that inquiry were published in two volumes in 1944 and 1945).

There were many who refused to accept his startling conclusions about the extent of the superiority of American industrial productivity. Indeed, a presidential address to the Royal Statistical Society by Dr. E.C. Snow was exclusively devoted to an attempt at refutation. This was by no means the only hostile criticism directed at his article. There emerged, however, from these controversies a widespread view in favour of the general validity of his conclusions; and in the outcome the controversy had the wholly beneficial result of arousing serious public concern in problems of industrial efficiency. Indeed, the establishment of an Anglo-American Productivity Council and the many inquiries conducted by that body can be traced back to the interest aroused by his original article.

He was appointed to the Board of Trade Statistics Division in 1946 where he instituted for official use a series of measures of changes in productivity in a wide range of British industries. These were developed and refined as time went on. He also worked with imagination and resourcefulness to clarify some of the difficulties with which the United Kingdom was faced at the end of the war to achieve a balance of payments and to improve the export trade. During this time he was first appointed British representative on the productivity studies sub-committee of the Organisation for European Economic Co-operation in Paris, where he was largely responsible for the shaping of a programme of international co-operation in those fields of economic studies of closest concern to the efficiency of the industries of western Europe. On his resignation from the Board of Trade in 1951 to take up his appointment in Cambridge he was appointed part-time productivity adviser to the Board, and in this capacity continued his work in Paris, playing a leading part in framing the programme of economic studies launched last year under the Conditional Aid Programme.

Although he spent only 16 years in the United Kingdom, he produced not only a remarkable number of publications of a high academic standard but considerably advanced the understanding of vitally important issues concerning the British economy. His practical wisdom made him a most valuable member of the many official committees, both inter-departmental and international, on which he served. His loss will be felt deeply by his many colleagues and friends who learnt to appreciate his rare qualities of kindness and humanity and his firm adherence to principles upheld with an almost self-effacing modesty.

He is survived by his widow and three children.

Mr. S. A. Dakin writes:

The farewells to Rostas cannot be said without a word of affectionate recognition from someone who knew him in the Civil Service. My recollections are of an intense enthusiasm and belief in the importance to the country of the studies in which he was an acknowledged master; of a mind always fertile in ideas and penetrating in analysis; of an insistence, sometimes impatient but always friendly; of validity of method and rigorous honesty of thought.

In his last illness his courageous refusal to let go of his intellectual interests was inspiring: up to the last he wanted to be kept in touch with what was happening in the work to which he had given so much, and we found his comments and suggestions as constructive and valuable as ever. During these last months it could be said of him that, when he knew he was under sentence, he behaved as if he were going to live for ever. His friends in the Civil Service will never forget an inspiring colleague and a well-loved friend.

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CONTENTS

GENERAL INTRODUCTION

1. Since its inception, the Organisation for European Economic Co-operation has paid special attention to developing productivity. A committee on scientific and technical questions was set up to be responsible, inter alia, for studying various aspects of the problems involved in increasing productivity. A specialised working party was convened under the chairmanship of Professor Jean Fourastié, which investigated the general concepts of productivity. This led to the publication by the O.E.E.C. of a paper entitled "Terminology of Productivity" which was a preliminary attempt at definition. This working party also initiated a number of European seminars at which various techniques of productivity measurement in industry (textiles, steel, boots, and shoes, coal, etc.) were compared. It advocated that missions should be sent to the United States to study the work done by the Bureau of Labor Statistics of the United States Department of Labor.

2. As early as 1952 it was agreed to review some of the concepts dealt with in the above publication with a view to producing in the light of past experience a more accurate work on productivity concepts and productivity measurement in the various countries of Europe, both at industrial and national level. Member countries were asked to assist in the collection of the basic information which was discussed by the working party on two occasions. At these discussions, it soon became clear that it was going to be difficult, if not impossible, to produce a composite study. The concepts of the various authors differed considerably, and any attempt to make too rigid a synthesis ran the risk of vitiating the basic argument. It was therefore decided that some of the studies should be published in the form of essays and that the terms employed should be sufficiently standardised to avoid undue confusion to the reader.

3. This volume which deals with concepts of productivity measurement, was compiled from the standpoint mentioned. A second volume will deal with the various methods used to measure productivity at the level of the firm and will state some of results obtained. A third volume will deal with the problem of national statistical series at the national level and give the results obtained in this field in Member countries. Volume I contains five studies by Dr. Fürst, Dr. Rostas, Dr. Ruist, Dr. Siegel and Dr. Walstedt, together with a note on terminology compiled by the Productivity Measurement Committee of the French National Committee for Productivity

(Comité national de la productivité) under the chairmanship of Professor Jean Fourastié. The first annex includes three short notes by Mr. Harten, Mr. Prévot, Mr. Rémery and Mr. Carrié, while the second annex contains three numerical examples clearly illustrating the concepts referred to in various parts of the work. These illustrations were worked out by the Productivity Measurement Committee referred to above.

4. The intention of this introduction is to establish a link between the various concepts used in the above studies, and it is hoped thus to give the reader a clearer idea of the points on which the above studies agree or diverge. The essays are very typical of the tendencies that emerged in the course of the Working Party's discussions. Their diversity is proof of the very wide range covered by the concept of productivity.

Meaning and scope of productivity measurement

5. Each of the main essays is an attempt to define the meaning of productivity. The most usual definition which emerges from these essays is that put forward in the French note, i.e. "Productivity is the measure of economy of means". This is the idea which must be kept in view. The concept of productivity is sometimes considered as synonymous with efficiency, but the French note clearly establishes the distinction between productivity and efficiency. Efficiency is "aptitude, capacity; in a word, the quality of the entity whose productivity is under review"(1).* On the other hand the concept of productivity introduces the idea of relationship between product and factors(2). Whatever differences there may be in terminology, it may therefore be said that all the authors agree on matters of substances.

6. The problem becomes complicated and divergencies appear when the efficiency of a manufacturing process has to be accurately expressed in figures, i.e. when productivity has to be measured. Dr. Rostas(3) and Dr. Siegel(4) show clearly the problems involved in measuring the factors of production. One of the first difficulties, a technical one, is the definition and heterogeneous nature of the factors and the procedure to be adopted for combining them in one form or another: either in terms of money or in working hours. Another difficulty is how to interpret this kind of calculation. On the other hand, in Dr. Walstedt's view(5), the only significant measurements are those which introduce all factors. This question will be dealt with in greater detail later: note the ambiguity of measurements which introduce all factors.

7. Instead of taking all factors into consideration, it is possible to work out relationships which do not introduce more than one factor. This is the procedure proposed by Dr. Fürst(6) and Dr. Rostas(7) among others. The difficulty now is to determine the meaning of a relationship of this kind. This difficulty appears very clearly in Dr. Fürst's note (8). It is obvious that the

* See references following General Introduction, page 19.

relationship between production and one of the factors does not express either the efficiency or the productivity of this individual factor; production trends also depend on other factors. Consequently the relation between production and one factor is not causal. In this connection it must be realised that expressions like "labour productivity", "productivity of capital", etc., are equivocal. They seem to suggest that a causal relationship exists whereas, in reality, the relationship involved is much more complex. The authors devote considerable space to the study of the measurement of production factors on the one hand and production itself on the other, a point which will be referred to again later.

8. From the conceptual point of view the salient feature in these studies is what is said about the significance of labour productivity. According to Dr. Rostas (9) and Dr. Siegel (10) labour productivity is the more appropriate concept and has a more general significance; labour productivity may be said to provide a general idea of the economy and efficiency with which human labour is used. Dr. Ruist (11) also considers that the relationship between production and the number of hours worked is of particular significance. These authors explain very clearly the reasons why this is so. It is because the worker holds a central place in the economic system in the sense that he is both Producer and Consumer. It being possible to consume only what is produced, it is interesting in this connection to assess the level of average production per worker. As previously stated, this does not imply that there is a direct causal relationship between the effort made by the worker and labour productivity; (and both Dr. Rostas (12) and Dr. Siegel (13) emphasise this point). Labour productivity reflects this first aspect just as much as the considerably more general aspect of the scale and accessibility of natural resources as well as the general economy in the means used in the production process.

9. Labour productivity is therefore of fundamental importance from the general economic standpoint. Expansion of modern economic systems is based on an expansion in purchasing power, the main source of which lies in an increase in the total earnings of labour. Obviously the latter cannot increase unless the labour resources available to any particular economic system are more efficiently used as a whole, i.e. unless labour productivity is improved. Economic expansion must therefore be accompanied by higher labour productivity, a fact which would appear to justify the claim that the latter is of vital importance.

10. Nevertheless, it must be clearly realised that trends in labour productivity do not in themselves provide any indication as to the causes of any particular change in productivity. Dr. Ruist (14) and Dr. Walstedt (15) make it quite clear for example, that measurement of labour productivity does not provide manufacturers with information which is sufficiently accurate to be of practical use. For the manufacturer, it is only one indication among many, and its importance varies

according to the structure of production costs. Dr. Walstedt (16) specifies that high labour productivity is not a manufacturer's chief objective. What interests him is to ascertain whether new methods are likely to bring down costs, and not whether they will improve labour productivity.

11. Thus any kind of measure intended to improve labour productivity depends, in its application, on the cost of the other production factors. According to Dr. Walstedt (17) an "index of industrial efficiency" should therefore be worked out to take account of all production factors. Dr. Ruist (18) also considers that the measurement of labour productivity should also be supplemented by methods which introduce the other factors in different combinations, which could be dealt with later.

12. Emphasis must, however, be laid on the particular importance of improving labour productivity in modern economic systems taking into account the cost of factors other than labour. A feature of expansion is the continual increase in the purchasing power of labour. This means a continuous increase in the cost of labour as compared with the other production factors, and this increase calls for the replacement of the "labour" factor by these other factors, which ultimately implies higher productivity of labour. This replacement takes place in accordance with rules which arise out of the attempts to make production processes profitable. Finally, it should be noted that in the case of economic systems which have achieved full employment, the only way to expand is to improve labour productivity. As already stated, assessment of increased labour productivity is therefore fundamental. In a way, it is the measurement of the degree of expansion achieved, allowing for the conditions under which the economic system as a whole is operating.

13. The concept of productivity is applicable in its widest sense to a very wide range of situations. It provides an answer to many questions, the diversity of which is emphasised by Dr. Rostas (19). General studies are designed to throw some light on the development of the economic system as a whole; they reveal differences in the level of productivity between one sector and another and show the trend of these divergencies. Studies at firm level attempt to determine the inter-dependence of the factors contributing to productivity. In the individual firm, a distinction is made between general measurements and those designed to ascertain the optimum conditions for some particular operation. Examples of these various types of measurement are given in Volumes II and III of the present work.

Measurement of production

14. The various authors dwell at length on the problems involved in the measurement of production. Dr. Rostas (20) distinguishes between monetary measurement and what is known as "physical" measurement. He specifies (21) the difficulty of interpretation involved in monetary measurement. Costs and prices are affected by a series of factors (e.g.

allocation of resources and forms of competition on the market) among which productive efficiency plays a fairly important part. The fundamental difficulty in measurements of this kind is to eliminate the causes which have absolutely no relation to the phenomenon under review. It is, of course, possible to establish a large number of combinations in measurements of this type: but these may fail to yield any useful information. The points made by Dr. Rostas on the limitations of measurements by value are fundamental. Dr. Fürst and Dr. Ruist consider the possibilities presented by a number of methods of measuring the national product. Dr. Fürst (22) considers the problem involved in the measurement of the "net value added" and the various methods which have to be used when making this computation. Dr. Ruist (23) studies the significance of the relationship between the net national product and the total man hours worked to achieve it. Both authors attempt to determine the whole of the value added in the various productive processes.

15. Dr. Rostas (24) gives a complete list of measurements designed to express volume of production. Dr. Siegel (25) analyses the significance of what are called "physical" measurements and that of the series of index figures obtained by weighting systems based either on a fixed price or some other system. The distinction between "volume" and "value" in production is also dealt with in Dr. Fürst's note (26).

16. This question of weighting is extremely important. Questions relating to allocation of resources must be distinguished from the use made of particular resources in any given industry or firm. It is obvious that both these factors arise in computing the overall productivity of an economic system and different weightings must be given to the results achieved under the particular circumstances obtaining. The mobility of resources determines the overall productivity of the economic system no less than the improved productivity of each firm. It is possible to imagine an increase in the productivity of the economic system as a whole accompanied by a drop in the productivity of each firm taken separately. This reveals the importance of the problem involved in the weighting of partial productivity indices (27). Dr. Ruist (28) is also led to deal with this question although in another form, in his chapter on the connection between wages and productivity. Amongst other things, he shows the part played by the migration of labour from less productive to more productive activities. This paragraph reveals the effect of the mobility of resources on the level of wages. As will be seen later, this problem of index weighting admits of a large number of solutions in view of the possibilities which arise when production indices are combined with the indices of production factors to establish a productivity index.

17. Dr. Siegel devotes his attention to solving the problem raised by the discontinuity of indices caused by change of quality (29), the appearance of new articles or the disappearance of articles of long standing (30).

18. Dr. Siegel (31) also outlines a new method of measuring production known as the sub-product approach. In this method a product is considered as the result of a series of successive Operations. The data are supposed to refer to each individual, special Process.

Measurement of factors

19. The first thing to be done is to consider the problems entailed in the measurement of factors considered individually. In this way labour, capital or power, etc. can be taken into consideration. These various measurements are complementary and their importance varies according to the infrequency of the factor considered (32) or the extent to which it occurs in the process under analysis.

20. As already stated, the measurement of labour productivity is a very special undertaking. Work measurement is certainly the one involving least difficulty. It raises a few problems which are mentioned by Dr. Rostas (33) and Dr. Fürst (34). For example, it must be important to know whether it is a question of direct labour only or of all services including administration, or whether sub-contracted work is taken into account. These problems can easily be solved and the above authors, together with Mr. Rémery and Mr. Carrié (35), indicate a number of solutions.

21. The measurement of capital raises so many difficulties (36) that it can be said that, in practice, no valid data are available on the subject. In any event, such calculations remain very unreliable owing to uncertainty as to the real depreciation rates of equipment and the degree of use to which the equipment is put. It is easy to measure the quantity of power, raw materials or fuel used, but comparisons of this kind are of more limited value. They are mainly useful in the study of productivity at factory level. More specific details on this subject will be found in Volume II.

22. It has already been seen that, in its widest sense, productivity may be defined as "the measure of economy of means". The search for some relationship between production and the factors as a whole is therefore of definite value. In working out this relationship it is assumed that the various factors will be expressed in one and the same unit.

23. A preliminary method would be to weight the quantities of the factors used by their unit value. This method is used by firms to work out their production costs. The French note defines the measurement derived from it as "the total productivity of the factors" (37). Price fluctuations can easily be eliminated by basing comparison on constant prices. The various methods used in working out heterogeneous production indices are also employed in computing the weighted averages of the

factors (Laspeyres' index, Paasche's index, etc.). At this stage it is worth recalling the points (38) previously made in connection with the meaning of labour productivity. A comparison between production and quantity of work does not provide the manufacturer with enough data to guide him in his search for higher efficiency. Dr. Walstedt (39) and Dr. Ruist (40) particularly emphasised this point. "The aim of the firm" they say "is not to improve productivity of labour but to lower production costs". It is not however enough to consider merely the overall cost of production, as Dr. Rostas points out (41); a change in the ratio cost/labour, for example, reveals nothing as to the cause of the fluctuation. Labour productivity may be responsible but so may be the hourly rate of pay. The two authors just quoted are aiming at expressing what Dr. Walstedt (42) calls "an index of industrial efficiency" and Dr. Ruist (43) "an index of technical efficiency". This index is obtained by comparing total costs at constant prices incurred in the production of one and the same article under different conditions (time or place).

24. Manufacturers are constantly obliged to make comparisons of this kind which are tantamount to comparing production costs at constant unit prices. These comparisons present one serious disadvantage. Once the addition has been completed it is difficult to deduce from the results which factors should be replaced to obtain the greatest reduction in the total cost. It is therefore necessary to revert to the primary elements in the cost of production and the productivity of each separate factor, to ascertain how far and in what direction factors can be profitably replaced. The theoretical and mathematical arguments of Dr. Walstedt (44) and Dr. Ruist (45) will therefore be read with interest, together with the numerical examples attached as an annex (46) as these tests clearly demonstrate the difficulty in working out overall productivity. When interpreting these calculations in terms of value, the reservations previously mentioned regarding the inevitable distortions of every price system, e.g. owing to imperfect competition, must also be taken into account (47).

25. Another method of solving the problem is to ascertain the total amount of work incorporated in a particular article. This can be done by multiplying the quantities of each factor used by the quantity of labour (direct, indirect or total) employed in making the factor, and so on for each factor produced. These measurements give an expression of what was called "total labour productivity" in the French note (48). In any given sector of production, calculations of this type approximate to those derived from the "input-output" tables of Léontieff-Evans and resemble the subproduct approach referred to above (49). It has also been suggested that the expression of the quantity of each factor consumed in terms of value should be divided by the average hourly wage. The consumption of each of these factors is thus expressed in hours of work or "salary price" as defined in the French note (50). Needless to say, these complications involve considerable technical difficulty, for example, when

capital which is already partly amortised has to be expressed in terms of hours of work. Here, as before, it may be wondered what the significance of this measurement is. The indices or figures obtained are as Dr. Rostas says (51) difficult to interpret, as the effects of the various factors are cumulative. However, this author - following Dr. Siegel - estimates that in its broadest sense the concept of "incorporated labour" still has a certain value, precisely because of the central position which the worker occupies in the economic system. It should in passing be noted that analyses of this kind were made in the United States during 1934-39 to determine the effect on the level of employment of programmes to absorb unemployment. In any event, it may be concluded that, as in the previous case, these interesting computations are only applicable provided that the primary data on which they have been based, is available simultaneously. In this connection the note by Mr. Rémery and Mr. Carrié (52) on the relationship between the ideas of "labour productivity" and "integrated labour" will be found of interest.

26. Another example of the application of the method of salary prices is provided by Mr. Harten's note (53). By dividing each element in production costs by the average hourly wage, a structure of production costs in terms of salary prices is obtained which can provide interesting comparisons, particularly on an international basis.

Mathematical relationship between various types of measurements

27. Mr. Prévot's note (54) gives an example of possible combinations of the index of production and indices of consumption for the factors of production, the employment index being that most frequently used. As will be seen, a large number of combinations result from the choice of the basic period for establishing these indices. The above note gives an idea of the multiplicity of solutions possible. Dr. Ruist (55) proceeding from a different standpoint, also shows that labour productivity can be calculated in a large number of ways. He establishes a series of mathematical ratios between measurements relating to different levels (the economic system as a whole, industrial sectors or products). Dr. Walstedt (56) establishes the relationships which exist between what he calls "the index of industrial efficiency", the ratio of production costs, the ratio of amounts of labour and the ratio of salary costs. Finally, Dr. Siegel makes a detailed analysis of the conditions under which useful and significant indexes of productivity can be obtained by dividing production indices by the indices of one or more production factors (Siegel, 32 to 38).

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28. These mathematical arguments, although comparatively simple, indicate the very wide range of solutions open to statisticians engaged in studying the measurement of productivity.

When the differences created by the various concepts already discussed are also taken into account, it will be found that there are a great number of possible solutions both from the purely mathematical as well as from the conceptual point of view. Productivity measurement can in fact be made in an extremely varied number of ways. There is no single hard and fast measurement. Each type of problem requires a special solution and the most suitable method of measurement depends on the aim pursued (57).

29. The individual character of the various types of productivity measurements cannot be over-emphasised. The problem of measurement has been approached from very different standpoints by the authors who have contributed to this work. The reader will undoubtedly be struck by the variety of viewpoints and solutions put forward. One of the most serious errors to make with regard to this subject is excessive over-simplification, as Dr. Siegel points out. There is no master formula applicable to all cases and all situations. One of the purposes of this work is to illustrate this point.

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The following references relate to paragraphs in the documents quoted :

(1) French note	24	(30) Siegel	26 to 29
(2) Siegel	4	(31) Siegel	30-33
(3) Rostas	20	(32) Rostas	19
(4) Siegel	5-6	(33) Rostas	21
(5) Walstedt	2	(34) Fürst	30 to 32
(6) Fürst	3	(35) Rémery and Carrié	8 to 14
(7) Rostas	4	(36) Easterfield	37 to 42
(8) Fürst	3-4	(37) French note	10
(9) Rostas	6	(38) Introduction	
(10) Siegel	7 to 10	(39) Walstedt	2
(11) Ruist	4	(40) Ruist	4
(12) Rostas	9	(41) Rostas	14
(13) Siegel	10	(42) Walstedt	12
(14) Ruist	4	(43) Ruist	28
(15) Walstedt	7	(44) Walstedt	16-17
(16) Walstedt	2	(45) Ruist	38
(17) Walstedt	8	(46) Annex II	
(18) Ruist	4	(47) Introduction	
(19) Rostas	1	(48) French note	13
(20) Rostas	11	(49) Siegel	31
(21) Rostas	12	(50) French note	14
(22) Fürst	16	(51) Rostas	20
(23) Ruist	8	(52) Rémery and Carrié	Note I
(24) Rostas	22-23	(53) Harten	Note 3
(25) Siegel	19 to 23	(54) Annex I	
(26) Fürst	22-23	(55) Ruist	35-38
(27) Rostas	5 and 24	(56) Walstedt	13 to 18
(28) Ruist	22	(57) Siegel	13 to 15
(29) Siegel	24-25		

I

THE CONCEPT OF PRODUCTIVITY AND ITS COROLLARIES

by a working party of the French National Committee for Productivity

PRODUCTIVITY

1. This word, which has recently come into current use, has taken on a more precise meaning in the course of time. According to the Larousse etymological dictionary, the term appeared for the first time in an article by Quesnay, Head of the School of Physiocrats, in 1766. For a long time its meaning remained somewhat vague. Littré (1883) gives the definition "faculty to produce", which is still to be found in Larousse (1946-49 edition).

By the beginning of the 20th century, however, economists already attached a more precise meaning to the word "productivity" - the relationship (measurable) between product and factors. The new meaning has now been regarded as a faculty or aptitude, but as a result or effect; i.e. the relationship between the result and the means employed; between product and factors.

2. In its widest sense, it may be said that productivity is the measurement of the economic soundness of the means. It is higher as the means used to achieve a given end are more limited. From a more technical standpoint, productivity may be defined as "production per factor unit". This concise definition may, however, be understood in two different ways, according as production is considered in relation to one factor, or all factors of production.

Specific productivity of the various factors

3. If production is considered in relation to a given factor, the specific productivity of the factor concerned is obtained. This is the general concept adopted by the Organisation for European Economic Co-operation (O. E. E. C.) as a result of the work of a research sub-committee under the chairmanship of Professor Jean Fourastié.

4. Thus, paragraph 2 of the "Terminology of Productivity" published by O.E.E.C. in December 1950 reads as follows: "Productivity is the quotient obtained by dividing output by one of the factors of production. In this way it is possible to speak of the productivity of capital, investment, or raw materials, according to whether output is being considered in relation to capital, investment or raw materials, etc." Paragraph 3 states : "The most usual meaning of productivity is the productivity of human labour. When the word productivity is used without further qualification, the productivity of labour is understood." It is clear from this definition that the measurement of specific productivity must take as much account as possible of the relationship between physical quantities.

5. This relationship is expressed either in the direct form mentioned above (production per factor unit), or in the inverse from of specific consumption per unit produced.*

6. Generally speaking :

The direct form is used to measure productivity of fixed factors such as agricultural land (production per hectare), and fixed assets in the shape of plant (production per machine, etc.).
The inverse form (consumption per unit produced) is used to measure the economic use of variable factors such as human labour, raw materials, or power. For instance, the productivity of labour in a factory will be measured by computing the number of man-hours worked per unit produced; similarly, the effective yield of fuel in a thermal power station will be computed in kg. of coal consumed per kWh produced.

7. The advantage of this concept of specific consumption per unit produced is that additive quantities can be obtained. For example, it can be shown that a unit of a given product is obtained by adding together certain consumed quantities of labour power, raw materials, plant, etc. Being calculated from physical quantities, concepts of specific productivity (or specific consumption) have the advantage of being extremely significant and easily understood by those actually engaged on the job (engineers, foremen, workers).

8. The indices thus obtained should, however, be interpreted with discrimination, as the increase in specific productivity of the factors most usually considered (productivity of labour, effective yield of raw material) may in some cases coincide with a rise in production costs, even if the factor costs have not increased. This may occur if the specific productivity of certain

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* It should be noticed that the inverse form, although it is a measure of productivity, is not usually called one.
The consumption of a factor per unit of product diminishes when the productivity of this factor increases. For this reason it is better to reserve the use of the expression "productivity" for the direct form.
See also on this subject the note of Messrs. Rémery and Carrié in Annex I.

other factors less frequently taken into account has unexpectedly fallen; for instance, the substitution of machine for manual work may in some cases cause an increase in the unit cost of the product and, consequently, a drop in the productivity of the total factors, although such a changeover usually increases the specific productivity of human labour to a very marked extent. This may occur if the machine has to stand idle for long, or if the cost of running the plant equals or exceeds the saving on labour per unit produced.

Synthesised concepts of productivity

9. It is therefore of interest to consider, in relation to the specific productivity of each factor, a series of synthesised concepts bringing all the factors into play, and obtained by combining the effect of each. This also leads to the definition of total productivity of factors and total productivity of labour.

Total productivity of factors

10. Total productivity of factors may be defined as the relationship between the volume of production and the total volume of factors included in the production cycle. In practice, total productivity can most conveniently be expressed by an estimate in value,* as production is usually heterogeneous, and the factors of production are always so. Care must then be taken to eliminate the effect of price variation, which means that, in comparative measurement, values of products and factors must be calculated by a constant price method. It follows that the productivity indices obtained (in relation to a given reference basis) depend on the price system used in making the comparison. This relationship between total productivity and the prices used for evaluation has been clearly brought out in several theoretical works.**

11. In short, the increase in total productivity indicates the total actual savings made on the total consumption of production factors. Lower costs may result from either a drop in factor costs, or from turning the factors to better account. The increase in total productivity of the factors thus reflects the lower cost achieved, assuming price fluctuation to be eliminated. However, as stated in the previous paragraph, this estimate is still affected by the price structure chosen as a basis. Total productivity can be linked to the specific productivity of the various factors and represents their weighted average.

Productivity concepts based on total labour: total productivity and labour

12. At the same time, research has been carried out to measure the ratio of productivity to human labour, which is at the root of most evaluation. Any outlay in raw materials, plant or services of any kind can be very nearly expressed as an

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* For this subject see the comments in the Introduction.

** See Annex II.

outlay in human labour (the labour required to produce the materials, plant or services). In this way, by including "visible labour" and "incorporated labour" with the other factors, the concept of productivity of total labour is evolved. This concept inversely expresses the total unit cost of the product in terms of human labour.

13. It is touched upon under the name of total productivity in paragraph 15 of the O.E.E.C. terminology. Mr. Dayre* took up this concept under the name of total productivity of labour, to distinguish it both from total productivity of factors and productivity (gross or net) of visible labour alone. The author points out the difficulties of direct measurement of total productivity of labour, and shows how wage costs provide, with some reservations, a rough indirect measurement.

14. The wage cost of a commodity may be defined as the "price assessed in wage units" by dividing the monetary price of the commodity by a typical hourly wage taken as unit of value. This standard wage may be, according to the convention adopted, either the unskilled worker's wage, or the weighted average of the wages of various categories of workers, corresponding to the total labour entailed in the production process. It is shown that the wage cost computed on an hourly wage basis varies considerably in inverse ratio to total labour productivity.

15. Without undertaking the full calculation of total productivity of labour, it may in practice be useful, especially in comparison between firms, to work measurements wherein some production factors other than labour - e.g. plant or power - are assessed in labour equivalents.

Expression of productivity in net value

16. Keeping the productivity of labour in view, and considering a given stage of the productive process, the question arises as to whether it is possible to work out a formula taking intc account the combined action of the various factors of production, visible labour and the other related factors. This line of enquiry leads to a new concept, net productivity of labour, which corresponds to added value per labour unit.

17. The calculation of net productivity of labour will be based on an estimate of the "net product" or added value in terms of labour. The net product cannot generally be expressed in physical volume; it will therefore be measured in value, bearing in mind the conditions implied (cf. 10). The net product will thus be defined as the difference between the gross value of the product and the total value of all the other factors entering into the production cycle (including capital servicing charges). It should be noted that these values for products and factors must, if comparison is to be valid, be calculated on a constant price range, not at variable market prices.

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* Jean Dayre - Productivité, Mesure du Progrès (page 43), (réf. Société Auxiliaire de Diffusion des Editions de Productivité)- Paris, 1952.

18. The net productivity of labour is obtained by dividing the net product thus computed by the amount of visible work expended in the production cycle. The resulting expressions will vary accordingly, as the amount of labour (estimated in hours, for example) is computed by simple addition or weighted, according to the job in question, by appropriate coefficients for skill or difficulty of execution.

19. The concept of net productivity of labour is of importance in connection with the study of national productivity. It can be shown that the index, based on a given reference period, of total productivity of the national labour force equals the average, weighted by the amount of work done, of the indices for net productivity of labour in the various branches of the national economy.* The index should, however, be used with caution as its variations, at company or industry level, do not always precisely reflect the trend of the total productivity of factors.

20. The concept of net productivity, put forward above in relation to visible work, may be extended to other factors of production. Thus, the net productivity of plant, power or any other specific factor can be defined in the same way. On these lines, the net productivity of the firm (not of visible labour alone) may be regarded as expressing the combined action of the two internal factors, labour and capital. In this conception, the net product of the firm is the difference between gross product and total external factors (excluding capital). The net product is considered in relation to the complex unit formed by associating labour with capital.

Summary of the various concepts

21. The various concepts of production can then be represented by the following formulae :

Specific productivity of labour	=	Production (6) / Visible labour (2)
Specific productivity of any other given factor	=	Production (6) / Amount of the factor (4)
Total productivity of factors	=	Production (6) / Total factors (5) (visible labour + other factors)
Total productivity of labour	=	Production (6) / Total labour (3) (visible labour + incorporated labour)
Net productivity of labour	=	Net product (6 - 4) (Production - External factors) / Visible labour (2)

* Jean Dayre - op. cit. Chapter VII, page 61.

22. The terms of these various fractions are assessed in physical units if possible but, otherwise, in value for certain special calculations. The comparative estimates in value must be made by using a constant price method for products as well as for factors; furthermore, it must be remembered that the constant price method, whatever it may be, will exert an influence on the resulting figures which cannot be eliminated.

Productivity and Cost

23. Whatever specific definition is adopted, the numerical expression of productivity is in inverse ratio to the cost of production (taking cost of production to mean the unit cost of the commodity based on the factors considered). The specific productivity of a given factor is in inverse ratio to the cost per unit of product expressed in terms of the factor concerned. The total productivity of labour is in inverse ratio to the cost per unit of product expressed in terms of total labour (visible and incorporated). The total productivity of factors varies in inverse ratio to factor cost, prices remaining constant.

EFFICIENCY

24. This word may be taken in its widest sense as practically synonymous with "productivity" and "output" or "yield". If an exact definition is sought, it will be seen that the word "efficiency" does embrace the idea of productivity, but goes beyond it in that it expresses an aptitude or capacity - in short, a quality of the unit, the productivity of which is under consideration. The word "efficiency" may, in fact, be regarded as expressing the quality of a unit of definitely adequate productivity, but which is constantly striving to improve this productivity by conscious and successful effort on reasoned lines.

25. The term therefore expresses better than "productivity" and "output" the idea of an organising brain and a process of intellectualisation of effort with a view to deriving the best advantages from the means employed to achieve the desired end. The word "efficiency" is, moreover, rarely used to mean the specific productivity of material factors. The term would not apply to land, a raw material, or a form of power; but it can be used with reference to a man, a technique, a firm or institution in describing any of these obtaining concrete results by a deliberate effort to improve productivity.

EFFICIENT

26. This adjective will be used in preference to "productive" to describe a unit which achieves adequate productivity and constantly develops it by conscious effort. The use of the unqualified adjective "productive" is inadvisable, as no absolute value can be attached to productivity. A firm may show high

productivity for altogether fortuitous and temporary reasons. In such a case, it cannot be called efficient.

YIELD

27. The term "yield" seems originally to have meant only the relative result, expressed as a ratio, of a physical transformation, especially the transformation of power. In this restricted sense, output is the ratio between the amount of power actually obtained by transformation, and the amount of power used in the process. The main future of this concept is its lack of dimension, as the result obtained is, in principle, of the same nature as the means employed, result and means being consequently expressed in the same unit. As, however, the concept sometimes appeared over-theoretical and hard to apply, the next step was to express, for instance, the output of an engine in amount of fuel per horsepower-hour. Such an expression of output, which is basically equivalent to the first, eliminated the former's lack of dimension. In this way, perhaps for reasons of convenience in expression, the term "output or yield" was finally applied to any quotient of a result, expressed in any unit, divided by a means, usually expressed in a different unit.

28. Although in many cases the term is applied, as originally, to the ratio between a result and a means consumed (yield from beet, aluminium yield from the power consumed in an electrolytic furnace), it is also applied to the ratio between a result and a non-expendable means, such as a tool or any other fixed production factor. The most striking example is the yield from land expressed in quintals of wheat per hectare. In this case, yield is the production per unit of area of arable land per unit of time (yield per hectare implies per crop, i.e. per year).

29. In the matter of human labour, the term "output" has also been used to define and differentiate the results obtained by a worker or team of workers, and thus output bonuses and wage incentives are spoken of, so that the word evokes, rightly or wrongly, a tendency to step up the performance rate and exact the last ounce of effort from the human machine. It may be considered that the term "output", as applied to human labour, is more restricted than "productivity" in that it is generally applied to individual workers or small groups, and seems to depend mainly on material means, whereas "productivity" is applied to larger groups and depends on intellectual or even effective factors.

30. It should be remembered that, apart from the various meanings referred to above, there is also the yield of a publicity campaign or of a stock exchange transaction; it is evident that the meaning of the term has become somewhat deformed with use. It seems advisable to limit it to the relationship between two measurable quantities, one of which is regarded as resulting from the other. In point of fact, the various outputs which can be calculated constitute only special kinds of ratios showing a cause-and-effect relationship between the two terms.

QUALITY

31. From the economic standpoint, quality, combined with quantity, is a factor in the evaluation of goods. Other things being equal, an article is of greater value if its quality renders it more useful to the user. One of the basic problems of purchase is to decide whether the price asked by the seller corresponds with the "utility value" conferred by the quality of the article.

32. Two kinds of quality should be distinguished, according to whether the consumer sets store on the article for the pleasure it affords, or for its economy in use. The quality linked with pleasure may be called hedonistic (in the sense of the Greek word hedone, pleasure); it can be judged only subjectively. The quality shown in use may be called technical; it is objective insofar as economy in use can be assessed. This technical quality has two further aspects; physical quality results from the mechanical, chemical or biological properties of the article considered; functional quality, from its fitness or convenience for use.*

33. For a given purpose, the different technical qualities (physical and functional) of an article help to determine its utility or wearing value. The utility value of an article, in comparison with that of another article chosen as a standard, can be assessed, production being equal, by the actual value of the saving effected by using the article concerned, as compared with that effected by using the standard article. This definition can serve as a guide in estimating technical qualities. There can be no exact criterion for assessing the hedonistic quality.

34. The concepts of quality and productivity, which have often been contrasted, are closely related to each other, in two ways:

1. In estimating the productivity of a firm or industry, an improvement in quality (technical or hedonistic) is, economically speaking, linked up with an increase in quantity; with equal expenditure and for a constant quantity produced, an improvement in quality raises the productivity index;

2. On the other hand, productivity in any firm is greatly influenced by the technical quality of the goods used as production factors.

35. From what has been said, it will be seen that the effort to improve the quality of a product reached its economic limit when the achievement of a higher quality would fail to bring a gain in satisfaction commensurate with the extra expenditure. This observation leads to the postulation of the concept of "adequate quality".

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* It should be noticed that the effect of quality can sometimes be expressed by quantitative measures, for example, the quality of a tyre by the "number of miles" that it eventually travels.

PROFIT-EARNING CAPACITY

36. This concept is linked with the idea of financial equilibrium. In particular, the lower limit value of an investment is determined by comparing the extra cost entailed and the resultant savings. The degree of economic soundness may be defined by measuring in some way the gap between the actual position and lower limit value.

37. It is interesting to work out the relationship between the productivity and profit-earning capacity of a firm taken as a whole. As long as factor costs and prices of products remain constant, profit-earning capacity and total productivity of factors move together, upwards or downwards. On the assumption that prices remain constant, any saving in means, i.e. any increase in total productivity, results in higher profit-earning capacity for the firm.

38. On the other hand, the relationship between profit-earning capacity and productivity ceases to hold good if the price structure changes as the firm expands. For instance, a rise in product prices combined with a fall in factor costs may increase profit-earning capacity, even if total productivity has dropped at the same time. Conversely, improved productivity, if prices move in the opposite direction, may coincide with lower profit-earning capacity.

39. To sum up, the affinity between the technical concept of productivity and the financial concept of economic soundness is obvious, as may be seen from the expression "marginal value of an investment"; but this affinity may be falsified by variations both in factor costs and product prices; price movements may be such that productivity and profit-earning capacity, instead of developing in parallel, may move in opposite directions.

II

ALTERNATIVE PRODUCTIVITY CONCEPTS

By Dr. Laszlo Rostas

THE VARIOUS PURPOSES OF PRODUCTIVITY MEASUREMENT

1. Productivity measurement can be used for a variety of purposes. These may be briefly summarised as follows:

- General economic analysis. Productivity is one of the determinants of the national product. Consequently with the increasing application of the national income analysis as a tool for shaping general economic policy and fiscal policy, productivity estimates are increasingly used for the forecasting of national income and output, occupational shifts, labour requirements and so on. It is an element in labour costs and thereby in the competitive power of various industries in different countries. It is a factor in the distribution of the product of industry and thereby in some sense it is relevant for collective wage bargaining. Users in this group include politicians, administrators, economic "planners" both in government and industry, trade associations and unions, economists, as well as the general public.

- Intensive industry studies. Such studies bring out common characteristics as well as inter-firm differences in productivity levels in selected industries, and also indicate the technical, economic and managerial factors determining the level of productivity.

- Measurement at the plant level. The measurement at this level might relate: a) to the whole plant, b) to individual processes, and c) to individual operations and operatives. The purpose is to throw light on one aspect of "managerial effectiveness" in an individual plant or group of plants under the same management.

2. In the second and third cases we can measure the variation in productivity of the various producing units (plants within the industry) or the changes in productivity over time of the same units and of the industry as a whole; also we can compare interspatially, interregionally or internationally, the productivity of selected units or of the industry as a whole.

3. The productivity concept and the method of measurement relevant to these various uses will obviously differ: nevertheless there are bound to be common characteristics in all the concepts and all the methods of measurement and the lessons learned, and the results obtained in any of these fields are of interest to both research workers and users in the other fields.

4. The concept which we have accepted in our terminology is that of productivity of human labour. We agreed that when the word productivity is used without further qualification, the productivity of labour is understood. I personally remain convinced that, for reasons elaborated a little later, this remains the most appropriate concept, and indeed this concept was the basis of much of the practical measurement work undertaken in Member countries. At the same time the validity and the usefulness of this concept have been challenged in our discussions by a variety of scholars. We have made it clear in our terminology that we regard productivity of labour as a measurement of general efficiency in the use of labour and not of the effort of the labour which latter is obviously too narrow a concept to be of much value. We have also stated that productivity of labour is influenced by the combined effect of a large number of separate though inter-related factors such as the amount and quality of equipment employed, technical improvements, managerial efficiency, the flow of materials and components, the relative contributions of units at different levels of efficiency as well as the skill and effort of workers. The effect of some of these factors can be measured and thus separated, others cannot. Thus it might be possible to differentiate between productivity increases due to an increase in the amount of capital equipment employed, and increases due to other factors, an important consideration for the European economy. Nevertheless the main criticism directed towards our concept is that it relates output to one factor of input only, namely labour. The alternatives proposed include separate measurement of ratios of capital to output or of raw material input to output or some combined measurement of all elements of input in relation to output. The measurement of input ratios other than labour is undoubtedly valuable by itself although these ratios do not possess the same general significance as the measurement of the productivity of labour. A joint measurement of all elements of input has not so far proved successful. If all elements of input are measured and added up in man-hour terms this is sometimes impracticable and always difficult to interpret. If, on the other hand, all elements are measured and added up in money terms, this usually ends up in measuring something other than productivity such as, e.g., profitability of an enterprise or industry; interpretation is again made difficult by including, in addition to productivity factors, the effect of all factors which determine prices. These points are elaborated a little on later pages. The doubts about the appropriateness of the labour productivity concept are strongest and admittedly most justified in the case

of measurement on the individual enterprise level where labour productivity measurements will have to be linked up eventually with measurements of other elements of costs. But even when measuring productivity mainly for purposes of general economic analysis, a number of alternative concepts are feasible. In the rest of this paper I will consider some of these alternative concepts and their meaning.

THE CONCEPT OF THE PRODUCTIVITY OF LABOUR

5. In the broadest sense productivity is an indicator of the utilisation of resources measured in some sort of physical terms. High utilisation of resources in relation to some standard, e.g. producing more output from given resources or a given output from less resources is usually regarded as high productivity, and a low utilisation of resources as low productivity. It is difficult to define, let alone to measure, an absolute level of productivity; consequently we define and measure relative productivity levels : e.g. in comparison with a level achieved in the past or in comparison with another unit in the same industry or in comparison with the level achieved by another nation and so on. High productivity in relation to some such chosen standard can be achieved in two different ways : i) the right allocation of resources between different uses (e.g. between different industries, firms, products); ii) the best possible utilisation of resources in the narrower sense within the field for which the resources were allocated. High productivity strictly speaking would imply the best utilisation in both senses, but emphasis is generally on the second aspect and with some exceptions it is this second aspect of productivity which we try to measure. Consequently, more concretely, we regard as productivity the ratio obtained by dividing the output of goods and services by one or all of the factors of production necessary to achieve the result. In this way it is possible to speak of the productivity of capital, of investment, of raw materials, etc., according to whether output is related to capital, investments or raw materials and so on.

6. The most usual and in many ways the most important meaning of productivity is that of productivity of labour. There are manifold reasons for choosing labour productivity as the primary subject of measurement: its importance is derived from the central position of labour and is particularly appropriate for a society in which, in Marshall's words, man is both "the end and an agent of production". In such a society, as was pointed out recently by a student of this problem, * current human labour should be rendered scarce in comparison to other inputs and to output. The goal should be a simultaneous and steady increase in the real output and voluntary leisure, i.e. "economic welfare".

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* Siegel, I.H. Concepts and Measurement of Production and Productivity. BLS, Washington, 1952.

7. It is through this dual role that productivity of labour becomes an important indicator of the standard of living. The standard of living depends on a number of factors; the richness of available resources, the relative abundance or scarcity of manpower to other material resources and so on. But given the quantity and quality of available resources, it is largely the productivity of labour which determines the standard of living. The importance of the utilisation of labour as a determinant of the standard of living is a factor of general application operating pretty well at all times and in all countries. Its importance is, however, enhanced in periods like ours when there is full employment, i.e., full utilisation of resources. In such periods increased productivity, i.e. better utilisation of labour, becomes the most important way in which the national output, and consequantly real incomes, can be increased, while in individual sectors of the economy where labour supply becomes a bottleneck increased productivity, apart from redistribution of the manpower, is the main way of overcoming such difficulties.

8. Another reason for concerning ourselves primarily with labour productivity is that labour is required almost universally for carrying through all types of production and for providing all types of services, so the concept has real meaning in many which might not be true of other measures. To put it in another way : labour is an element of costs, and in most cases an important element of costs, in all branches and sectors of productive activity. Its importance will vary from industry to industry. A third more practical reason for choosing labour productivity as our subject is that labour as an input factor is a measurable quantity while such a factor as capital is usually not easily measurable. This applies both to the concept as well as the availability of statistical data on plant, industry and national levels.

9. The importance of labour productivity derives from the fact that it provides a general measurement of the economy and efficiency in the use of labour. Thus, as mentioned, it reflects and is influenced by the combined effect of a large number of separate though inter-related factors. A shortcoming of this measurement of labour productivity follows from its generalised character. Information on productivity levels, whether in comparisons with other units or other periods or other nations, does not give any information on the factors determining these levels. Consequently, the analysis of the causes requires special investigation. Thus an increase in productivity in the economy as a whole does not necessarily imply a more efficient use of all productive resources, although both a priori considerations and historical experience indicate a fairly close correlation in the rates of change in these factors over long periods. Over short periods or in smaller sectors of the economy, e.g., individual industries or even more in individual plants, any discrepancy between increased productivity of labour and more efficient use of all productive resources becomes of increasing importance. Generally speaking, the more important the share of labour in costs, the less is the danger of

a discrepancy. But in industries where this proportion is small, and the importance of other factors in total costs high, the measurement of labour productivity only may not lead us very far without the measurement of productivity of other input factors.

10. When considering the meaning and value of the large variety of alternative concepts, perhaps it should be stated at once that while output per unit of labour is a universal concept in the sense that it has some use at least for productivity comparisons of all types, alternative concepts have usually a more limited application and their usefulness might be confined to one of the three main fields only.

ALTERNATIVE INPUT CONCEPTS AND MEASUREMENT

11. From the point of view of "concept", alternative input measurements are the main problem. I might mention that once the problem of concept is decided upon, and one proceeds to measurement, the problem of measurement of output becomes the vital issue. The following alternative input concepts and measurement can be distinguished :

Monetary measurements

- Price per unit of output
- Total costs per unit of output
- Profits per unit of output
- Prime costs per unit of output
- Wages costs per unit of output

Physical measurements

- Capital per unit of output
- Horsepower per unit of output
- Labour requirements per unit of output
  - Man-hours unweighted
  - Man-years unweighted
  - Man-hours weighted
  - Man-years weighted
- Composite physical input measurement

MONETARY MEASUREMENT OF INPUT

12. A common characteristic of all monetary measurements of both input (and also of output to be discussed in the next section) is that they are based on prices of both products and factors of production, and thus will reflect economy in the utilisation of resources only under competitive conditions. These conditions very seldom are obtained in real life and consequently prices are distorted in the sense that they are influenced by market imperfections of various kinds. Thus neither price movements over time nor relative prices of different things at

a given moment will reflect relationships determined purely by considerations relevant to productivity. No type of productivity measurement, not even those based on physical data of output or labour, can be compiled without some reliance at least on price data, e.g., for purposes of weighting, but in the latter case the effect of potential distortion may have been less than in the case of purely monetary measurements.

13. Under competitive conditions or conditions approaching them, prices, costs and profits per unit of output are superior indicators of productivity as compared with physical measurements as they will reflect to a certain extent both the allocation as well as the utilisation of resources. Also, they will take account of all the input factors and measure them in a convenient and uniform unit. Difficulties of measuring output in relation to costs remain however the same as in the case of physical measurement of input.

14. Just because these measurements are more comprehensive measurements of input, their meaning and interpretation are rather more difficult. We can look at prices and costs as made up of two elements: the amount of resources used per unit of output (e.g. of labour, fuel, capital, etc.) and the price of these resources (e.g. wages per unit of output, price of coal per ton, etc.). Both elements are influenced by a very large number of factors, and some factors of course influence both the amount of resources utilised as well as their price. While the global knowledge of prices and costs per unit of output is of great value, the detailed knowledge of the effect of single elements making up the global picture is not only valuable but for many purposes is quite essential. Some elements are more amenable to control by the nation or the industry or the individual manufacturer than others and consequently their knowledge is essential for any policy and action. For example, it is interesting to know that given competitive conditions, prime costs of Firm A are well below those of Firm B, but one would also like to know whether this is due to Firm A paying lower wages or having higher output per worker or to some other reason. A practical point worth mentioning is that cost data are usually more difficult to obtain than physical productivity data.

15. Taking the various dimensions of productivity measurement, prices and costs per unit of output are poor measures of intertemporal changes as factors other than resources utilisation are bound to have a more profound influence on their movement. Profits per unit of output provide, however, under competitive conditions, at least a pointer. All the monetary measurements, except prices per unit of output, provide useful indications of inter-firm variations. If prices are fairly similar and deviations merely reflect small quality differences, and if buyers are well acquainted with the market, costs per unit of output should yield a good basis for comparing the efficiency of individual producers.

16. Measurements expressed in monetary terms, whether those of input or of output, are not immediately useful for

international comparisons. For this purpose they must be converted into a common currency by an exchange rate. The appropriate rate of exchange for this purpose is the rate which is calculated in terms of prices of the relevant products. But even if costs or prices per unit of output are expressed in a common currency with the help of these special commodity exchange rates, differences will not necessarily reflect productivity differences; they may reflect merely differences in the price of the factors of production. In view of potential international differences in the classification of costs, international price comparisons might prove more reliable than international cost comparisons.

17. Thus, to sum up the general consideration of monetary input measurements :

Prices per unit of output are :

unsuitable for inter-temporal comparisons as the effect of other factors, e.g., changes in wages or raw material prices or of purely monetary factors, is more important than changes in resources utilisation;

unsuitable for inter-firm comparisons as competitive firms would quote broadly the same price, subject to minor deviations due to quality differences;

suitable for international comparisons provided the appropriate rate of exchange in terms of the products concerned can be calculated and the effect of other potential differences (in wages, material, prices, etc.) is accounted for.

Costs per unit of output are :

unsuitable for inter-temporal comparisons for the same reason as prices;

suitable for inter-firm comparisons provided prices are fairely uniform and buyers are well acquainted with the market;

suitable for international comparisons in the same way as prices.

In the case of cost comparisons it is of importance to cover the same range of costs, and although a comparison of prime costs has more meaning in economic analysis than that of total costs the latter is probably more reliable. A comparison of wage costs is less comprehensive than either total costs or prime costs and throws light only on the utilisation of labour. On the other hand as data on wage rates, etc., are usually available they provide a useful indirect indication of physical labour productivity.

Profits per unit of output or even total profits (i.e., the difference between total revenue and total costs) are :

strictly speaking, not an input measurement but can be most conveniently discussed together with the above two input measurements;

they provide a pointer, if a somewhat crude one, for purposes of inter-temporal changes requiring further investigation of the reasons for their variations which might or might not be better utilisation of resources;

suitable for inter-firm comparisons in the same way and under the same conditions as costs;

unlikely to throw light on international differences even in the case of availability of appropriate exchange rates owing to structural differences in market structure, system of distribution margins, etc.

ALTERNATIVE PHYSICAL MEASUREMENTS OF INPUT

18. Physical measurements of input either i) measure individually the several elements of input or ii) attempt some aggregative measure of the several input elements.

19. Measuring individually items of input involves measuring output per unit of labour, output per unit of capital, output per unit of fuel, output per unit of land and so on. These are not alternative measures of the same thing, but complementary measures. They have their own individual importance which will vary with the scarcity of the particular resources in the economies concerned and with the specific importance of those elements of input other than labour in total costs. All these concepts raise problems of measurements of their own (e.g. measuring capital invested), in many cases more complicated than those involved in measuring the productivity of labour.

20. More relevant for consideration for our purposes are the attempts to provide aggregative measurement of all input elements. The two ways in which they can be aggregated are in money units (in the case of inter-temporal comparisons on some sort of constant price basis) or in labour units. The former presupposes the availability of separate input measurement in physical terms of the various input factors as well as the prices of these input factors. The latter method shows similarities to a calculation of the labour content of a product. It can be justified theoretically for a study of long-term economic progress, and as Siegel states : the goal of reducing current labour expenditure for a given volume of output might well be extended to the minimisation of the cumulated total labour cost to a "generalised man". As a current measurement of productivity it involves however two fold difficulties :

1. The measurement of past labour incorporated, say, in capital equipment raises serious new problems: should it be measured by the original labour input or by current input relevant to the post technique known at that time or by current input relevant to current technique.

2. Interpretation of such composite measurement of both constant price and man-hour data of all input elements

is extremely difficult; indeed it is insoluble without knowledge of the productivity of the various elements of input.

MEASURING LABOUR INPUT ONLY

21. Conceptually this provides the most meaningful measurement and this can be undertaken in physical terms. The following alternative and complementary measurements can be compiled;

Output per man-year or man-week or man-hour paid or man-hour worked. The first is more relevant for estimating future national income, for real income comparisons, for estimating labour requirements, etc. The last is more relevant for measuring productivity in the more technical sense, while, e.g., man-hour paid is more relevant for measuring labour costs.

Output per all employees or output per operatives (production workers); output per direct and indirect workers, etc. All these concepts are relevant but they measure different aspects of productivity. There are definition difficulties and there is also a lack of availability of data.

Weighted and unweighted labour measures. Existing measures make no allowances for differences in skill, age or sex. Their importance is greater in international and inter-temporal comparisons than in inter-firm comparisons. Methods of computing "standard" labour units (e.g., new equivalents in terms of relative wages, etc.) have not so far been wholly successful.

ALTERNATIVE OUTPUT MEASUREMENTS

22. Alternative output measurements are fewer in number. One can again distinguish :

Monetary measurements:
- The value of gross output.
- The value of net output.

Physical measurements:
- Physical output.
- Physical input of materials.

23. The main shortcomings of monetary measurements have already been discussed in paragraph 12 and following. They are : common theoretical limitations; lack of availability of price data; problems of price indexes. The three main dimensions of productivity comparisons are discussed below from the output angle.

1. Alternative inter-temporal measures of output.

Estimating the changes in net physical output.
Estimating the changes in gross physical output.
Deflating the value of gross output.
Estimating the changes in physical input of materials.

In all cases what we try to measure is the production done during the period, i.e., the net output content. The nearest approximation is provided by the net physical output index. This index however raises a number of problems of its own (e.g. about adequacy of relative prices of products and materials, etc.) and data are seldom available. The best substitute methods are : gross physical output index, retaining some "netness" by use of net output weights. Its advantage is that it relates directly to what we want to measure. Disadvantages arise from the complicated product structure of all industries and from variations and changes in quality. The deflated value of output index provides in a single figure measurement for a large and varied assortment of goods, also it makes automatic allowance for quality changes. It is usually based on the use of inadequate price data. An index of input of materials may give incomplete coverage for production done in the period; also it is not directly related to the "value added" and to changes in value added to the materials.

2. Alternative inter-firm measures of output.

Physical output per unit of labour.
Value of net output per unit of labour.
Value of gross output per unit of labour.

Physical output is the best measurement as it relates directly to what we want to measure. Its use is confined to industries producing homogeneous products which are few; moreover, in real life few firms produce identical products, let alone identical product mixture. The value of net output concept overcomes this difficulty, but its usefulness is confined to cases where firms produce broadly the same sort of article and buyers are sufficiently well informed to ensure that prices are kept fairly well in line. It has the advantage that it makes allowances for variations in fuel and material consumption. The value of gross output per unit of labour is inferior to that of the value of net output and unless the firms concerned cover the same process it might be grossly misleading.

3. Alternative international measures of output.

Physical comparisons.
Comparison of the value of net output per unit of labour.
Comparison of the value of gross output per unit of labour.

Physical comparisons are the most satisfactory. They raise however serious difficulties in respect of processes covered, product mixture and quality, as I have discussed elsewhere in detail. Comparisons of the value of gross or net output raise the important problem of exchange rates, referred to in paragraph 6.

ALTERNATIVE WEIGHTING METHODS

24. Alternative weighting methods of output indexes are perhaps more important in bringing out conceptual differences

than the distinction between physical and monetary measurements. To mention only one example : it is in this way (i.e. through weighting) that we can measure productivity changes due to shifts of production from one set of (less efficient) firms to other (more efficient) firms or from one industry (of lower net output per head) to another (with higher net output per head).

THE FUTURE OF INTERNATIONAL PRODUCTIVITY COMPARISONS

25. As a postscript to the discussion of alternative concepts, I would like to mention the importance attached to international comparisons by the Productivity Studies Sub-Committee of O.E.E.C. The problem of meaningful international comparisons was, of course, discussed from the onset. It was realised, however, that a great deal of further development in the field of national productivity statistics was required before we could proceed to international comparisons. It was also realised that the joint discussion of terminology concepts and methods of measurement was bound to foster such comparisons at a later stage. Surveying the field, one can record a welcome development of productivity measurement in several countries during the last few years. As it happened, most of the Member countries gave priority to national inter-firm comparisons as most conducive to guiding policy towards actual productivity increases. In addition to the United Kingdom, this was the case, e.g., in France, the Netherlands and Denmark. A number of countries have developed national indexes with some official status measuring inter-temporal changes. This has been the case, e.g., in Germany and Norway. Some countries, e.g., Austria, have done some work in both fields. At present there are more (though still insufficient) national data on productivity to give an impetus to international comparisons. Three broad fields appear to be feasible, in all cases based primarily on the productivity of labour concept.

1. An international comparison of inter-temporal changes of productivity.

It is desirable that many more countries should provide their own national data which, if not official, should have at least some authority. Some countries are already bold enough to do so, and one hopes that others will follow. Such statistics will have many limitations which are not different in kind, only in extent, from limitations attached to, say, price indexes or production indexes. An international comparison of inter-temporal productivity changes would be highly valuable, and could be more reliable if based on solid national data rather than on a series computed by an international organisation without the national know-how.

2. A second field of international comparisons is the sort of global comparison of absolute levels of productivity, industry by industry, which I have attempted for British and American industry.

The limitations of such comparisons and the wide margin of error attached to them are well known, and consequently big differences only can be regarded as significant. Such comparisons are in my opinion of value in calling attention to the problem which can then be explored further by more sensitive tools. It is a further advantage of such comparisons that they can be correlated with such structural characteristics of national industries as the average size of plant or firm, the degree of concentration, the degree of mechanisation, etc. Incidentally, both the international comparisons in time and space discussed above are greatly facilitated by, and indeed largely dependent on, the existence of good and comparable census data. Hence the interest of the Productivity Studies Sub-Committee in such censuses and the attention paid by the Census Offices to their potential usefulness for productivity comparisons. This is discussed in a separate paper.

3. A most promising field of international comparisons (and of immediate practical usefulness) is detailed plant comparisons based on broadly homogeneous and comparable products.

It is in this third field that recent progress has been especially conspicuous and here detailed national work has led to accurate and meaningful international comparisons. One good example is the comparison of productivity in British and American cotton spinning (as shown in Chapter IV, 9, of the Productivity Team Report on Cotton Spinning of the Anglo-American Council on Productivity). Other examples are provided by recent French and Dutch experience.

III

ASPECTS OF PRODUCTIVITY MEASUREMENT AND MEANING (1)

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TOWARD HIGHER STANDARDS

1. The interest in labour-saving technology in the United States is deeply rooted, extending back even to Colonial times. The tradition of productivity measurement is hardly as venerable or as continuous, but it may be traced at least seven decades to the first years of the U.S. Bureau of Labor Statistics under Commissioner C.D. Wright. Despite this long history, a seasoned and critical observer is still impressed with the crudities of the theory and practice of productivity measurement and with the consequent need for elevating the standard of makers and users of productivity indexes. The situation in Europe does not seem materially different.

2. Upgrading the sophistication of makers and users of productivity indexes is the key to the improvement of data by governments and by business firms, to the advance of measurement art, and to the rise in the quality of applications. But the task of raising standards is not simple, for one thing, the population of statistical workers, economists, business analysts, etc., having occasion to deal with productivity is a shifting one, and it is also characterised by a wide diversity of primary interests. Over the years, only a small band of devoted productivity students remains, as "the many change and pass." Besides, as J. W.N. Sullivan wrote concerning scientific workers in general, "discrimination is fatiguing". He properly observed that "it is much easier to make measurements than to know exactly what you are measuring". Makers of measurements are no more distinguished than their fellowmen for capacity to criticise their handiwork or to accept criticism from others. Finally, users tend at first to ignore the methodological details of productivity indexes, like the fine print describing the contents of favourite

(1) See notes at the end of this chapter, page 54.

patent medicines. But, when the movement of an index is contrary to expectations and interests, the reaction may be severe and the repudiation of the "expert" too thorough.

3. This paper stresses some of the problems of data, method, and meaning that have to be faced in the interest of further progress, that have to be recognised whether or not they can be resolved. It acknowledges the conventional character of index numbers but assumes them to be worth constructing and using nevertheless. It insists that a certain purism is desirable in appraising the appropriateness of techniques employed and applications made.

PRODUCTIVITY CONCEPTS AND MEASURES

4. "Productivity" has many connotations in economic and business literature. Furthermore, various other terms have been used to describe kindred notions (e.g., Walras' "coefficients of fabrication"). We restrict the sense of "productivity" here to the class of conceivable measures depicting output per unit of associated input in a sequence of compared periods. We say "associated" rather than "corresponding" because the input and output figures are most often dissimilar in scope. For example, output is typically measured gross with respect to input, thus reflecting the contribution of all (rather than of the last few) stages of productive activity.

5. Although productivity may be conceived with reference to any or all input factors, practical choice is limited to the significantly measurable ones. Measurability is hampered by the extreme heterogeneity of a definable input class, either within a given period or over time. (Heterogeneity of output will be considered later.) Thus, the essence of entrepreneurship cannot be captured by so spiritless a measure as man-hours. Nor can the "volume" of capital services be satisfactorily reflected by routine deflation, by the division of total payments for such services by (say) the "price" of a particular unchanging variety (2).

6. The input elements contributing to a given product complex cannot always be elucidated completely. Certain private costs of production are transferred to society, and some business services are provided by government at less than full cost or "free". Some factor inputs are also obtained free from nature or have not been reckoned correctly in the long-term normal price of "land" - air, sunshine and rain. Some intermediate social product is privately appropriable, so that a firm may reap where it did not sow - scientific knowledge, public patents, technological applications developed at government expense (e.g., on war contracts), etc.

7. Labour productivity measures are computed for a variety of reasons. One is the practical measurability of labour. That is, crude summations of workers or man-hours of diverse skills are commonly accepted, even as population totals including persons of both sexes and in different age groups. A second

reason is the actual or assumed relevance of the labour productivity concept to various problems - like the analysis of trends in wages and unit labour costs, the comparison of wage and price flexibility, and the projection of employment or output. A third reason stems from the dual role of man as the end of production as well as a means of production, as the seeker of maximum material welfare with minimum work (and, a fortiori, maximum voluntary leisure). This humanistic view, treating technological advance as incidental to the struggle of man against nature, seems especially appropriate for the very long run.

8. All intermediate production - the creation of institutions, knowledge, non-human energy, processed materials, capital instruments, etc. - may be regarded as strategic, as presumably leading to a larger flow of ultimate benefits than would result from alternative uses of the same labour input. This interpretation hardly suggests that labour productivity is a good proxy for all-factor productivity, especially in the short run.

9. The computation of labour productivity indexes does not imply that labour is the only relevant factor, the unique and universal "standard of value". Such an index must, therefore, not be interpreted causally. It reflects, at best, the average productivity - not the marginal productivity - of labour in a sequence of static equilibrium situations. But a precise economic interpretation is unwarranted, even where labour's net product can be formally computed. This point will be pursued below.

10. Under modern conditions, changes in labour intensity are not of decisive importance in explaining the movements of labour productivity indexes. Thus, fluctuations in the degree of capacity utilisation, due to physical conditions like power failures or economic conditions like market sluggishness, are very pertinent. In the long run, the change in technology (through entrepreneurial initiative, competition, pursuit of military security, etc.) is decisive in raising the productivity of current labour input. To attribute the long-term rise in manufacturing output per man-hour to labour effort would make as little sense as ascribing the gain in farm output per horse to greater equine effort (3).

11. What we have just said is probably not so often misunderstood as popular business literature may imply. American labour leaders do not claim that labour effort and labour productivity are historically correlated. They seek wage increases on vague moral or ethical grounds of entitlement to a fair share in the "joint" national productivity dividend; or on "Keynesian" grounds that the prosperity of all is ever endangered by the threat of under-consumption. The AFL's "social wage" demand of the 1920's and the more recent CIO discovery of the "annual improvement factor" were not inspired by some vulgar version of the labour theory of value. It might also be observed here that neither Marx nor his Russian Communist successors (like

Lenin and Bukharin) confused intensity of labour effort with the productivity potential of a technological-cultural State.

12. The usual productivity indexes must be distinguished from measures derivable from econometric equations involving production and one or more elements of input. As has already been observed, the usual indexes refer at best to average productivity in each period, not marginal productivity. The values for different periods do not represent conceivable alternatives for a given resource situation; they are historically discrete. On the other hand, differentiable mathematical functions of production and input (e.g., Cobb-Douglas or other regression equations) permit the calculation of what at least formally resembles marginal productivity. Such functions imply the interconnection of the whole sequence of time periods in a known manner. They may allow for a systematic change in the productivity level through the introduction of time or the treatment of cumulative output as an explicit variable (4).

MULTIPLICITY AND CONVENTIONAL NATURE OF INDEX NUMBERS

13. A general commonsense definition of a concept like productivity admits numerous measures. That is, the pre-operational meaning of a broad term is compatible with many operational meanings. If the requisite data are available, then many measures are constructible. All these measures are conceptually satisfactory in the absence of a closer specification of purpose or use.

14. The definition of productivity as output per unit of composite input or per unit of labour does not imply a unique production concept. It says nothing about the preferred breadth of product or input classes, units of measurement, formulas, and weights. If constructible, each alternative productivity index would make sense, in that each would have its special validity and be albegraically most appropriate to some definable context. The maker and user would then be able to pursue "pas la couleur, rien que la nuance". The measure best satisfying advance specifications would be best for its particular use but not for any other closely defined situation (5).

15. Although a productivity (or any other) index ought ideally to be constructed in accordance with a purpose, limitations of available data preclude such a luxury - and also the attendant intellectual responsibility. Not only are the practical alternatives severely restricted, but compromises and improvisations are necessary. The problem of the conscientious index maker or user becomes largely the recognition of the difference between what a particular context ideally requires and what is actually constructible or available. Such a conscientious student might also be concerned with the implications of settling for the poor best that could be done. For example, he might hazard a guess as to whether the actual measure is higher or lower than the one preferred (6).

16. An illustration of the frustration now experienced by the meticulous maker or user of productivity index numbers is the general unavailability of data for constructing a direct productivity index for a manufacturing industry. Such an index, of the aggregative type with production weights, is necessarily an internal average of the individual productivity relatives. It may also be rewritten as a ratio of a quantity index (with unit-labour requirement weights) and the labour input measure. A U.S. Bureau of Labor Statistics programme designed to obtain the necessary data for such productivity indexes was unfortunately rescinded after a short career. The alternatives which have to be used for individual manufacturing industries are ratios of quantity indexes with unit-value weights and the corresponding labour-input measures. Since the unit values are unlikely as a rule to be proportional to unit labour requirements, the results may be quite different from those yielded by the preferred direct indexes. Indeed, the results need not be internal means of productivity relatives. They may be shown to equal in general the product of a desired direct index and an extraneous index reflecting the change in output structure(7).

17. Finally, the arbitrary, conventional character of productivity and all other historical indexes must be acknowledged. Makers and users should be aware that all such economic measurements, useful as they are, rest upon weak theoretical foundations. Historical index numbers are based on economic data, but they do not therefore reflect economic choice. They are not equivalent to those contemplated in the so-called "economic theory of index numbers". They are "atomistic", in Frisch's terminology, rather than "functional". They do not reflect the comparison and ordering of two or more states by a well-defined person or collectivity acting in accordance with the familiar principles of economic rationality. Data wrenched out of their original (presumed) equilibrium situations and recombined in some other way in indexes are deprived of their original contextual significance. The indifference or substitution map which describes the behaviour of the mythical decision-maker underlying a typical aggregative index is only a caricature of the kind of map discussed in economic texts. Our "demon", being oversimple, is much too presumptuous in attempting cardinal, rather than ordinal, comparisons; in asserting how much better or worse the situation in one period is than the situation in another (8).

PRODUCTION CONCEPTS AND MEASURES

18. Special attention must be given to production indexes because they typically enter into the computation of productivity changes. The short-lived exception of the B.L.S. "direct" productivity measurement programme has already been noted.

19. Certain conventions of labelling are misleading. Thus, a so-called measure of "physical volume" of output is not physical at all. The weights applied to the gross production quantities in

a typical aggregative index are usually money prices or unit values, and these weights convert the quantities into a particular kind of "homogeneous" dollars. If unit labour requirements could be used as weights, the quantities would be converted into "homogeneous" man-hours. If unit labour added weights could be isolated for use in a net output approximation, then these aggregates too would be expressed in money. The same is true of the numerator and denominator of a conceptually more suitable index of net output - in which the weighted quantities are first reduced by similarly weighted inputs of materials, purchased energy, etc. before formation of the quotient (9).

20. Another careless statement is that the use of, say, the same price weights in the numerator and denominator of a production index "eliminates" the effect of price changes. Of course, some of the effects remain embedded in the very quantities. We also know that, even if the price level had not changed over time, different quantities would still be associated with different prices along a given demand or supply curve.

21. A most common error is the identification of the time base of an index with the weight base. Thus, the mistake is often made of asserting that the aggregates in a production index constructed on the base 19-- = 100 are expressed in "19-- dollars", whatever the actual formula. Furthermore, the translation of a time base is incorrectly said to convert the aggregates into dollars of the new time period. Finally, the result of deflation of a value index by a price index is frequently misrepresented as a quantity measure expressed in dollars of a common time base, whatever the formula of the deflator. All these errors show an unwarranted indifference to the fact that differently weighted quantity or price indexes need not be identical or even close.

22. Returning briefly to the meaning of a production index, we may ask : If it does not compare "physical" magnitudes, what does it measure ? Although production has the object of creating utility, an index cannot be said to compare cardinal utility sums. The operational implication of a definition like "net output content" is unclear. A notion like "value added in constant dollars" at first may seem quite satisfactory. But this definition can lead to at least two families of indexes, which have already been mentioned: a) aggregative indexes of gross quantities with net (say, unit-value-added) weights and b) aggregative indexes in which the fully weighted gross quantities are reduced explicitly by the weighted consumption of materials, purchased energy, etc. Furthermore, unit-value-added weights for individual products are difficult to determine in principle and approximations are almost non-existent, so expedients of doubtful merit are adopted. For example, it may be assumed that gross quantity indexes with unit-value weights are adequate for individual industries; and that the use of industry value-added weights in making subsequent industry combinations restores netness. Or it may be assumed that a gross price index is good enough for deflating value added. Similar substitutions and

compromises must be made in attempts to approximate the reduced aggregative indexes of net output. B. L. S. is now following the Canadian example and Geary's pioneer effort for Ireland in calculating experimental net estimates for the United States (10).

23. Deflation is a deceptively simple technique for deriving production indexes when quantity data are not available or when the products are very heterogeneous. But a good rule to remember is that, if a meaningful product complex cannot be imagined for direct temporal comparison, then deflation cannot, even under the best of circumstances yield a result which somehow incorporates a sound product frame. Most often, the deflator is obviously deficient in scope and concept for the use made of it.

24. One of the clichés of the literature of production measurement is that the indexes have a "downward bias" due to persistant improvements in quality. But such a statement often conceals the natural prejudice of a latter-day observer in favour of the particular course history happens to have taken. Secular deteriorations of quality are seldom noted - and even then they may be rationalised as improvements after all (11).

25. Incidentally, the acknowledgment of unmeasured quality change as an unfortunate omission tends to reinforce the view that a production index does not portray "physical volume". Furthermore, where such change occurs, a special burden is placed on the price index used in deflation - for this index must not only conjure up a meaningful, stable product frame but also in so doing must convert quality change into quantity change. Finally, it is curious that, in the construction of productivity indexes, no reference is made to possible "bias" due to neglect of differences in labour skill and quality.

26. The basic production data also suffer from discontinuities other than quality change and from incompleteness of reportage. New products are introduced, some old ones die or "just fade away", and product classes are continually being redefined. New and minor products of an industry are commonly reported, not by quantity, but by value and also in combination. Assumptions and ingenuity take the place of data as chain indexes are worked up, as value- and employment-coverage adjustments (of the Mills-Fabricant-Devons variety) are made, etc. The algebraic implications of these techniques require close scrutiny and their validity should be empirically tested whenever possible (12). (Incidentally, the relation between value adjustment and price deflation should be noticed.)

27. It is probable that chain indexes and value adjustments for coverage tend to understate the rise in output of at least the United States. The chain index records no rise from zero for any new product. The value-coverage adjustment implies the similarity of price movements for directly measured products and for other products. But this assumption appears unjustified if the products reported by value only are new; their prices

decline as a rule with respect to the prices of established, directly measured products.

28. For periods characterised by significant change in the product universe, more attention ought to be given to the "free-composition" index as a substitute for the chain index. The former is the logical extension of the straightforward fixed-base aggregative formula. In addition to products made in both the base and comparison periods, it includes products made in either (i.e., new or dying). Before introduction, a product has a zero quantity; a defunct product also has zero quantity. If a Laspeyres formula is used with an early base, then numerous synthetic weights must be introduced for the many new products. These weights, corresponding to null quantities, would tend to be rather high. If a Paasche index could be constructed, then the problem of artificial weights for new products would be avoided. This index could be derived by deflation of the value index by a Laspeyres free-composition price index which likewise involves no artificial entries (13).

29. The concept of free-composition indexes can be applied, of course, to measurement of other entities than production and prices. In principle, it could be employed in the construction of a direct labour-productivity or unit-labour-requirement index. A Laspeyres measure of the latter could be derived by deflation of the labour index by a Paasche free-composition output index. Neither the Laspeyres measure nor the Paasche output index would require fictional weights for new products (14). Another application is to the very problem of quality change. An item which changes drastically in its relevant attributes may be treated like a new product having a new weight. The old form has zero quantity in the period of change; the new form has zero quantity in the (early) base period.

30. At this point, mention should be made of another novel approach which may overcome various measurement problems: the "subproduct" approach. A subproduct is a well-defined, more or less homogeneous, operation, activity, or result corresponding to the arc of a longer process cycle. Thus, a typical gross or end product of an establishment's entire activity is really a sum of sequential subproducts. If so regarded, then only the work done is counted during a period, whether the gross product is completed or not. The subproduct method would thus yield production indexes which are closer homologues of input indexes; more validly reflect activity where the process cycle is long compared to the measurement period; and tend to be invariant to changes in the degree of technical integration of establishments. It provides the theoretical key to a hierarchy of consistent production and productivity measure ranging from the job and department through the plant and industry to the national economy. It could also be useful for measurement in instances of extreme heterogeneity and instability of final output composition: subproducts may have less variability over time, and some are common to many end products (15).

31. For the time being, subproduct data are scarce. But compilation of such data will become more common as the notions of "unit processes" and "unit operations" spread from chemical engineering to other industrial activities; as the Leontief-Evans input-output technique and linear programming prove their practical value; and as the "automation" and "automatic factory" movements advance. Firms and governments will be disposed to recast accounts and statistics in terms of subproducts as technology progresses. The increasing variety of end products will tend to be reduced to multiples and complexes of a comparatively small "alphabet" of elementary standard of unitary processes or effects.

FURTHER REMARKS ON PRODUCTIVITY INDEXES

32. It has already been noted that the quotient of any production index and a labour input index need not be an internal average of productivity relatives. The result should not be interpreted as though it were a true average. A striking illustration of externality is afforded by indexes of man-hour productivity for the private sector of the U.S. economy and for the farm and non-farm components of this sector. The geometric mean rate of productivity rise for the whole private sector exceeds the rates for the two components in the interval 1909-50 and in sub-intervals like 1929-50 and 1939-50 (16). In the absence of information about the components, the statistical euphoria of the total could easily be misunderstood.

33. Now, a caution will be offered regarding unit-labour-requirement weights (which are rarely ascertainable in the first place). If properly defined, computed, and applied, such weights could lead to production indexes which in turn yield internal averages of productivity relatives. Otherwise, they too may lead to production measures which do not assure internality, just like unit-value weights or routine deflation. The labour concept entering into the unit-labour-requirement weights must be the same as that of the labour input index. Furthermore, the production data and weights must be available in entirety to exhaust the whole range of activity covered in the labour input index. Such co-extensiveness assures the cancellation of one of the weighted aggregates in the output measure and one of the weighted aggregates in the input measure. If sound-unit-labour requirement weights are available but do not refer to the base or comparison period, cancellation or approximate cancellation may not be achieved and internality cannot be guaranteed. This fact is generally overlooked.

34. At this point, we should also observe that sound unit-labour-requirement weights do not yield the "best" production index for derivation of a unit-labour-cost index. In the latter case, the preferred production measure for deflating a payrolls index would have unit-labour-cost weights (17).

35. Furthermore, if we wish to define consistent productivity and unit-labour-cost indexes, we should start afresh with the verbal identity,

Payrolls index = productivity index x unit-labour-cost index x labour input index,

and proceed to implement it algebraically. Each index would have two (joint) weights instead of one. More than one variant index aggregative (in fact, four) may be constructed for each of the three entities. While any aggregative productivity and unit-labour-cost indexes satisfying the identity need not imply the same intermediate production measure, it is possible to juxtapose variant indexes which do correspond to the same production measure (18).

36. The above paragraph opens the door to some important generalisations. Multiplicative identities involving more than two indexes (and hence having more than two elements within each weighted aggregate) show the importance of consistency in algebraic as well as verbal formulation. They indicate the nature of valid deflation, whatever the number of entities. They permit extensions of the time-reversal, factor-reversal, and other formal index-number tests. If the geometric mean is taken of all the algebraically consistent statements satisfying a verbal identity, the result is the generalisation of Fisher's "ideal" index. In the case of three entities, six such statements may be written, and each generalised "ideal" index is a sixth root (19). We have data troubles enough, of course, in our usual two-dimensional index-number world. Knowledge of the demands of higher space should provide some confort as well as necessary theoretical perspective.

37. What has been said above about deflation, co-extensiveness, and cancellation of aggregates should guide us in the definition of preferred productivity formulas in the first instance. The scope of theory must not be limited by the extent and quality of data available for implementation. Thus, it appears desirable to place a net output measure, embracing all of value added, over a co-extensive factor input index. Since cancellation of a pair of aggregates is assured, the resulting productivity formula may be rewritten as a weighted internal mean of productivity relatives for the individual net products. If we accept the usual gross industry production index with unit-value weights, a co-extensive input index (embracing the current services of factors of production and consumed materials, energy, etc.) could be defined. Or, instead of seeking a mean of such comprehensive productivity relatives, we may ask instead; What sort of labour-input index must be defined to obtain a mean of labour-productivity relatives from an output index with unit-value weights? The answer is simple: the "homogeneous" unit for labour would be money, the value of the labour must be stretched to the same order as that of gross output, and the labour input for each product would have to be weighted by value productivity (20).

38. Since every Laspeyres or Paasche quantity index, whether it refers to input or output, may be regarded as the result of a proper deflation (21), a productivity index may be written as a ratio of appropriate "price" indexes. Thus, a labour productivity index derived from gross output is the ratio of indexes of the gross value productivity of labour and product price. A gross productivity index referring to all cost inputs (factors, materials, etc.) is equivalent to the ratio of a cost index to a gross-product-price index. A net productivity index comprehending all current factor input (value added) is a ratio of a factor-price and product-price-margin indexes (22). Expressed in the form of such ratios, productivity indexes tell us that the impact of technology, etc. is to make output cheap compared to input; to make utilised resources in the guise of output cheap compared to utilised resources in the guise of input. Since labour in the broad sense of man's participation in productive acts is the "first price" of all things, then we may see again how the struggle against nature literally aims at making human effort "expensive" compared to nature's yield.

39. Finally, a word about partition formulas which may be computed to reveal the "independent" contributions of changes in productivity, etc. to the total change in, say, employment or value added. First, it must be noted that the conventional methods of estimating "technological displacement" in the 1930's were too pessimistic; they allowed no offset in the form of market expansion as productivity itself advanced (23). Second, the attempt to isolate "pure" effects is economically artificial though of statistical interest. Third, if all calculations of change are made from a common time base, then "joint" as well as "pure" effects arise. The mistake is commonly made of combining a joint effect with a pure - and in such a fashion that the explicitly recognised variables are not affected symmetrically. Fourth, the mistake is sometimes made of attributing joint effects to "other" residual variables not explicitly recognised in the partition. The impropriety of the assymmetrical treatment of recognised variables or of the introduction of extraneous explanatory variables becomes evident when it is recognised that all the effects are simply the terms of a Taylor expansion of a sum of functions of "independent" variables with zero remainder. Fifth, when we have only two variables (e.g., when we break a change in labour input into effects of changes in unit labour requirements and production), a partition formula may be set up which symmetrically distributes the joint component between the other two. In the case of more than two variables, no compromise partition formula involving only symmetrical additive components seems to be definable (24).

ENVOI

40. Although this paper has dwelt largely on errors of practice and on theoretical requirements which may not readily be satisfied, its intent is constructive. It seeks to direct the attention of index makers and users to the opportunities for improving concepts, data collection, and methods; to the

opportunities which lie outside the ruts of convention and complacency. A favourable attitude toward experimentation must be developed, toward even the crude implementation of advanced theoretical ideas. At the same time the limitations of that which is done or is practicable must be recognised and acknowledged. In the absolute sense, "progress must be slow", as Marshall observed in his "Principles". But what matters more is that, as he also wrote, "progress may be hastened by thought and work".

NOTES

(1) Based in part on two unpublished mid-century review papers on production and productivity measurement presented by I.H. Siegel at the December 1950 annual meeting of the American Statistical Association; and on his Concepts and Measurement of Production and Productivity, U.S. Bureau of Labor Statistics, Washington, 1952.

(2) For a recent attempt to compute productivity for all factor inputs, see J. Schmookler, "The Changing Efficiency of the American Economy", Review of Economics and Statistics, August 1952, pp. 214-31.

(3) This comparison was suggested by Professor (Emeritus) W.I. King.

(4) On the treatment of cumulative output as an explicit variable, see, for example, W.Z. Hirsch, "Manufacturing Progress Functions", Review of Economics and Statistics, May 1952, pp. 143-55. For a recent use of time as an explicit variable, see the equation of P.J. Verdoorn, Econometrica, April 1951, pp. 209-10.

(5) For a recent attempt to replace the pragmatic notion of "best" by a dogmatic one, see B.D. Mudgett, Index Numbers, Wiley, New York, 1951, and a review of this book by I.H. Siegel in Journal of Economic History, Winter 1952, pp. 69-71.

(6) For this purpose, it would be useful to know the algebraic conditions for one index formula or weighting system to yield a higher or lower result than another. Correlation coefficients (Pearson, von Bortkiewiez, and Spearman) and Lagrange's identity (in matrix or vector form) are effective instruments for such analysis. See, for example, the essay on Concepts and Measurement cited in note (1) and the following Journal of the American Statistical Association articles by I.H. Siegel : "The Difference between the Paasche and Laspeyres Index-Number Formulas", September 1941, pp. 343-50; "Further Notes on the Difference between Index Formulas", December 1941, pp. 519-24; "Index-Number Differences : Geometric Means", June 1942, pp. 271-74; and "Note on a Common Statistical Inequality", June 1943, pp. 217-22.

(7) For a discussion of the relation between a direct productivity index and the quotient of an output index with unit-value weights and the correspondint labour-input index, see W. D. Evans and I. H. Siegel, "The Meaning of Productivity Indexes", Journal of the American Statistical Association, March 1942, pp. 103-11; and Concepts and Measurement, p. 54. On the B. L. S. direct productivity reports programme, initiated in 1945, see G. E. Sadler and A. D. Searle, "Measurement of Unit Man-hour Requirements", in Bulletin 993, B. L. S., Washington, 1950, pp. 42-49; or S. Weiss, "Progress and Status of Productivity Measurement in the United States", a paper presented at the 28th Session of International Statistical Institute, Rome, September 1953.

(8) On the arbitrary character of productivity and other indexes, see Concepts and Measurement, especially Chapter 2. See also sources cited there are Schmookler, loc. cit., p. 215.

(9) The preferred formula is of the kind considered by S. Fabricant and R. C. Geary. See Concepts and Measurement, pp. 58-60, on the algebraic difference between the preferred formula and the aggregative index of gross quantities with unit-value-added weights.

It should be noted that the preferred formula may be written (among other ways) as an aggregative index of net "quantities" with full price weights. Thus, the Laspeyres index of net output may be written as

$$\frac{\Sigma p_0 q_1 - \Sigma S P_0 Q_1}{\Sigma p_0 q_0 - \Sigma S P_0 Q_0} = \frac{\Sigma p_0 \left(q_1 - \frac{S P_0 Q_1}{p_0} \right)}{\Sigma p_0 \left(q_0 - \frac{S P_0 Q_0}{p_0} \right)} ,$$

where the small letters refer to prices and quantities of gross products, and the capital letters (except S) refer to consumed materials, purchased energy, etc. S stands for the aggregate (of materials, etc.) entering into a particular gross product. The index may also be written, of course, as a weighted arithmetic or harmonic mean of net output relatives

$$\left(g_1 - \frac{S P_0 Q_1}{p_0} \right)_i \div \left(g_0 - \frac{S P_0 Q_0}{p_0} \right)_i$$

(10) On the Canadian indexes, see, for example, V. R. Berlinguette, "Measurement of Real Output", Canadian Journal of Economics and Political Science, February 1954, pp. 59-75.

(11) R.G. Collingwood, The Idea of History, Oxford, London, 1946, pp. 324-27, makes some pertinent remarks on "progress as created by historical thinking".

(12) In Census of Manufactures: 1947, Indexes of Production, the U.S. Bureau of the Census and the Federal Reserve Board made a commendable inquiry into the consequences of coverage adjustments. Thus study also follows a wholesome practice in presenting 6 alternative indexes for each industry for 1939-47, 3 unadjusted and 3 adjusted ones.

(13) The value index may be factored into a Paasche free-composition production index and Laspeyres free composition price index as follows :

$$\frac{\Sigma' p_1 q_1 + \Sigma'' p_1 q_1 + \cancel{\Sigma''' p_1 q_1}}{\Sigma' p_0 q_0 + \cancel{\Sigma'' p_0 q_0} + \cancel{\Sigma''' p_0 q_0}} = \frac{\Sigma' p_1 q_1 + \Sigma'' p_1 q_1 + \cancel{\Sigma''' p_1 q_1}}{\Sigma' p_1 q_0 + \cancel{\Sigma'' p_1 q_0} + \cancel{\Sigma''' p_1 q_0}} \cdot \frac{\Sigma' p_1 q_0 + \cancel{\Sigma'' p_1 q_0} + \cancel{\Sigma''' p_1 q_0}}{\Sigma' p_0 q_0 + \cancel{\Sigma'' p_0 q_0} + \cancel{\Sigma''' p_0 q_0}},$$

where the single prime refers to products common to both periods, the double prime to products not appearing in the base period, and the triple prime to products no longer available in the comparison period. A strike-through shows that a particular sum equals zero. It is easier to estimate fictitious $(p_1''')_i$ for defunct products than fictitious $(p_0''')_i$ for products not yet produced.

(14) A man-hours index could be factored into the following free-composition indexes, the first a Laspeyres measure of unit labour requirements and the second a Paasche measure of production :

$$\frac{\Sigma' l_1 q_1 + \Sigma'' l_1 q_1 + \cancel{\Sigma''' l_1 q_1}}{\Sigma' l_0 q_0 + \cancel{\Sigma'' l_0 q_0} + \cancel{\Sigma''' l_0 q_0}} = \frac{\Sigma' l_1 q_0 + \cancel{\Sigma'' l_1 q_0} + \cancel{\Sigma''' l_1 q_0}}{\Sigma' l_0 q_0 + \cancel{\Sigma'' l_0 q_0} + \cancel{\Sigma''' l_0 q_0}} \cdot \frac{\Sigma' l_1 q_1 + \Sigma'' l_1 q_1 + \cancel{\Sigma''' l_1 q_1}}{\Sigma' l_1 q_0 + \cancel{\Sigma'' l_1 q_0} + \cancel{\Sigma''' l_1 q_0}}.$$

The l_i refer to unit labour requirements (analogous to price in note (13)).

(15) For a discussion of subproduct indexes, see I. H. Siegel, "The Concept of Productive Activity", Journal of the American Statistical Association, June 1944, pp. 218-28. (Spanish version appears in Estadistica, December 1952, pp. 727-38).

(16) J. W. Kendrick presents labour-productivity estimates for the private sector and its farm and non-farm compoments in "National Productivity and Its Long-Term Projection", a paper appearing in Long-Range Projection, NBER Studies in Income and Wealth, XVI, Princeton, 1954. The underlying figures for "real" product, derived by deflation, are said to be expressed in "1939 dollars"; the "influences of price changes are eliminated" by means of "appropriate indexes of market prices". Kendrick distinguishes between measures of "economic efficiency"

and "technical efficiency", the former reflecting structural shift as well as the "pure" productivity change within components;

The fact of externality receives no comment in The Measurement of Productivity, Council for Technological Advancement, Chicago, August 3, 1953, even though it is strikingly revealed in a chart (p. 8) of the 1909-50 man-hour productivity indexes for the private sector and its farm and non-farm components.

(17) For the verbal identity, payrolls : unit labour cost x production, one alternative is :

$$\frac{\Sigma c_1 q_1}{\Sigma c_0 q_0} = \frac{\Sigma c_1 q_1}{\Sigma c_0 q_1} \cdot \frac{\Sigma c_0 q_1}{\Sigma c_0 q_0} ,$$

where the C_i stand for unit labour cost. The Laspeyres index of production here need not, of course, be identical with $\Sigma l_0 q_1 / \Sigma l_0 q_0$, yielded by the verbal identity labour input = unit labour requirements x production. The difference may be analysed by methods mentioned in note (6).

(18) For example, one system satisfying the verbal identity is

$$\frac{\Sigma \pi_1 c_1 m_1}{\Sigma \pi_0 c_0 m_0} = \frac{\Sigma \pi_1 c_0 m_0}{\Sigma \pi_0 c_0 m_0} \cdot \frac{\Sigma \pi_1 c_1 m_0}{\Sigma \pi_1 c_0 m_0} \cdot \frac{\Sigma \pi_1 c_0 m_1}{\Sigma \pi_1 c_0 m_0} ,$$

where the π_i refer to productivity and m_i to labour input. If the productivity index (first expression on right) is multiplied by the labour-input index (third), the resulting output measure is the same as that derived as the quotient of the payrolls index and the (same) labour-input index : $\Sigma \pi_1 c_0 m_1 / \Sigma \pi_0 c_0 m_0 = \Sigma c_0 q_1 / \Sigma c_0 q_0$, also the same as in note (17). On index systems arising out of verbal identities, see Concepts and Measurement, pp. 83-86.

(19) See I. H. Siegel, "The Generalised "Ideal" Index-Number Formula", Journal of the American Statistical Association, December 1945, pp. 520-23.

(20) The quotient of the Laspeyres net output index and the co-extensive Laspeyres factor input index is

$$\frac{\Sigma p_0 q_1 - \Sigma SP_0 Q_1}{\Sigma p_0 q_0 - \Sigma SP_0 Q_0} \div \frac{\Sigma Sw_0 f_1}{\Sigma Sw_0 f_0} = \frac{\Sigma p_0 q_1 - \Sigma SP_0 Q_1}{\Sigma Sw_0 f_1} = \frac{\Sigma \left[Sw_0 f_1 \left(\frac{q'_1}{q'_1} \Big/ \frac{f_1}{f_0} \right) \right]}{\Sigma Sw_0 f_1} ,$$

where $(p_0 q_0)_i = (Sw_0 f_0 + SP_0 Q_0)_i$ etc., and the $(q'_1 / q'_0)_i$ are net product relatives as in note (9). $(Sw_0 f_0)_i$ refers to all the weighted factor inputs corresponding to the total quantity of a particular product.

The quotient of the Laspeyres gross output index with unit-value weights and a comprehensive input measure is

$$\frac{\Sigma p_0 q_1}{\Sigma p_0 q_0} \div \frac{\Sigma (S w_0 f_1 + S P_0 Q_1)}{\Sigma (S w_0 f_0 + S P_0 Q_0)} = \frac{\Sigma p_0 q_1}{\Sigma (S w_0 f_1 + S P_0 Q_1)} = \frac{\Sigma \left[S w_0 f_1 \left(\frac{q_1}{q_0} \Big/ \frac{f_1}{f_0} \right) + S P_0 Q_1 \left(\frac{q_1}{q_0} \Big/ \frac{Q_1}{Q_0} \right) \right]}{\Sigma (S w_0 f_1 + S P_0 Q_1)}$$

The quotient of the Laspeyres gross product index with unit-value weights and a coextensive labour-input index is

$$\frac{\Sigma p_0 q_1}{\Sigma p_0 q_0} \div \frac{\Sigma \left(m_1 \cdot \frac{v_0}{m_0} \right)}{\Sigma \left(m_0 \frac{v_0}{m_0} \right)} = \frac{\Sigma p_0 q_1}{\Sigma \left(v_0 \cdot \frac{m_1}{m_0} \right)} = \frac{\Sigma \left[v_0 \cdot \frac{m_1}{m_0} \left(\frac{q_1}{q_0} \Big/ \frac{m_1}{m_0} \right) \right]}{\Sigma \left(v_0 \cdot \frac{m_1}{m_0} \right)}$$

where $(v_0)_i = (p_0 q_0)_i$.

(21) The Edgeworth and many other formulas unfortunately do not have certain algebraic properties of interest to us here; but they may give useful approximations (the Edgeworth is a weighted mean of the Laspeyres and Paasche measures), and they may have other attributes fitting them peculiarly to certain defined needs.

(22) The gross productivity index for weighted labour input in note (20) becomes, as a result of double deflation,

$$\frac{\Sigma v_1}{\Sigma \left(m_1 \cdot \frac{v_0}{m_0} \right)} \div \frac{\Sigma p_1 q_1}{\Sigma p_0 q_1} = \frac{\Sigma \left[v_0 \cdot \frac{m_1}{m_0} \left(\frac{v_1}{v_0} \Big/ \frac{m_1}{m_0} \right) \right]}{\Sigma \left(v_0 \cdot \frac{m_1}{m_0} \right)} \div \frac{\Sigma p_1 q_1}{\Sigma p_0 q_1} ,$$

a ratio of two Paasche price indexes. The gross productivity index for all cost inputs - factors, materials, etc. becomes :

$$\frac{\Sigma S w_1 f_1 + \Sigma S P_1 Q_1}{\Sigma S w_0 f_1 + \Sigma S P_0 Q_1} \div \frac{\Sigma P_1 q_1}{\Sigma P_0 q_1} ,$$

also a ratio of two Paasche "price" indexes.

The net productivity index for all factor input becomes

$$\frac{\Sigma S w_1 f_1}{\Sigma S w_0 f_1} \div \frac{\Sigma p_1 q_1 - \Sigma S P_1 Q_1}{\Sigma p_0 q_1 - \Sigma S P_0 Q_1} ,$$

again a ratio of two Paasche "price" indexes.

(23) See the interesting analysis by E. Schiff, The Primary Employment Effects of Productivity Gains, Council for Economic Advancement, Chicago, January 15, 1954.

(24) On the Taylor expansion and partition formulas, see Concepts and Measurement, pp. 86-92. To illuminate the present discussion, let us break employment change into component production, unit-labour requirement, and "joint" changes :

$$\Sigma l_1 q_1 - \Sigma l_0 q_0 = \Sigma l_0 (q_1 - q_0) + \Sigma q_0 (l_1 - l_0) + \Sigma (l_1 - l_0)(q_1 - q_0) .$$

A common error is the absorption of the third component into one of others so that the right-hand terms become, say: $\Sigma l_0 (q_1 - q_0) + \Sigma q_1 (l_1 - l_0)$. The "joint" component could just as well have been incorporated in the other right-hand term (the production effect). A symmetrical compromise, favoured by S. Fabricant and used earlier by L. Amoroso, is :

$$\tfrac{1}{2} \Sigma (l_1 + l_0)(q_1 - q_0) + \tfrac{1}{2} \Sigma (q_1 + q_0)(l_1 - l_0) .$$

IV

THE ROLE OF OFFICIAL STATISTICS IN MEASURING PRODUCTIVITY

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BASIC CONCEPTIONS AND DEFINITIONS

1. What is meant by an "increase in productivity"? Apparently, the aim is to increase the efficiency of the production factors which are available for a certain production process or can be used for it, so that the production result becomes greater or less expensive. This aim can be reached in various manners. Human productivity can be increased by higher wages, a better working climate, better food, and many other incentives which may increase the yield of the production factor labour. The efficiency of the fixed capital such as buildings, machinery, apparatuses, and other equipment can be improved, whereby the efficiency of the production factor capital can be raised. Finally the entrepreneurial performances can bring about a better playing together of human labour and machinery by organisational improvements of the production processes; or a better utilisation of the market position, cheaper raw and basic materials, a limitation of the incidentals, and small profit margins may result in a cheaper product. Accordingly, a productivity increase is far from being identical with a production increase, for a production increase - i.e. an expansion of production - is, for instance, possible also by the erection of new establishments, which follow exactly the production methods used so far.

2. In addition, it does not appear to make much sense to distinguish between "technical" and "economic" productivity, as is done in some cases. The increase of productivity is an economic problem, which cannot be dealt with separately from the problem of costs. The production target should be obtained at a minimum of costs, and high or low costs can finally be given only in terms of values. If a production increase is obtained only by a more intensive use of the production factors (which means that it is produced more expensively), it is true that a production increase has been arrived at, but simultaneously a productivity decrease.

3. Accordingly, the statistical task is, on the one hand, to measure the "production result", and, on the other hand, to ascertain the efficiency of the individual production factors, by the playing together of which the production result is obtained. In this connection it is important to consider the efficiencies of the individual production factors separately from one another, for the sum of those efficiencies is - in terms of money - the value of the production result or output. Accordingly, numerator and denominator are equal, when the sum of the yield of all production factors is related to the production result. Differences cannot be recognised from comparisons in respect of time or localities, unless one of the production factors concerned is related to the production result (or output). One must, however, be careful not to draw any conclusions from the changes in the relation thus obtained, for instance with regard to the efficiency (or productivity) of the production factor used for that illustration, as it is the production result of all factors that is related to one single factor only.

4. If, for instance, the production result per worker or per man-hour increases, this does not provide any knowledge on an increased productivity of the factor labour. If, for instance, a factory producing electric bulbs acquires new automatic machines, which, as heretofore, can be operated by one worker per machine, but which have double the output, the production result per man-hour has become twice as high, but the individual effort of the worker has remained quite the same. On the contrary, one may always be able to start from the assumption that an apparent increase in the production result per worker is due to a productivity increase of other factors (e.g. better machinery, better raw materials, a better organisation, etc.). Where working rhythm and working speed depend on the machine or assembly-line, the range for the increase of the individual productivity of the worker is often rather small. These connections appear to be so self-evident that one is afraid of uttering them. The misunderstandings, which frequently occur, may be explained by the fact that, relatively spoken, the production factor which lends itself most easily to a statistical measurement was the production factor labour, so that in most cases only the relation : production result to production factor labour is available, whereas the other relations are not to hand. In addition, the United States Bureau of Labor Statistics, which is most active and successful in the measurement of productivity, for a long time used the not very suitable expression "labour productivity" and thus gave rise to the impression that the measure in question really illustrates the productivity of labour, i.e. the changes in the efficiency of human labour.

5. Sometimes the objection is raised, that every kind of economic productivity originates from human labour, so that the term "labour productivity" is justified. But that can never be the case, if limited sectors (products, industry branches, but also national economies) are considered. It is true that in

the above-mentioned example of the electric bulb factory, the higher output of the machine originates also from the better "labour" of the engineers and engineering workers, but it certainly does not make any sense to attribute this higher working capacity of the machine which results from another sector to the productivity of the workers in the electric bulb factory. These "labour" performances of the engineering industries are performances of the factor "capital" in the considered sector of the electric bulb factory.

CONNECTION BETWEEN THE AIM SET AND THE STATISTICAL SOURCES

6. For each measurement of the productivity changes it is important to measure the "production result" on the one hand and the yield of the individual production factors (cost factors) on the other. This fact is common to all studies, regardless whether their object is a final product available for consumption or investment, or a semi-finished product, or the production result (output) of an industry branch, of a larger economic sector such as the total of manufacturing industries, or even the production result of the total economy. Each greater sector builds itself up upon the smaller sectors, and the production result of the total economy is nothing but the sum of the "net value added" of larger sectors of the economy, of industry branches, or establishments, whereby this "net value added" can be attributed either to the producing or distributing establishments, enterprises, or industry branches, i.e. to the operating institutions, or to the individual commodities, which is the case when the production result of the economy, i.e. the "national product", is regarded as the sum of the goods and services produced which are available for consumption or investment. For the total economy the sum of the "net value added" remains the same, for it does not exercise any influence on the total result, whether the same "net value added" is subdivided by "establishments" or attributed to the individual "commodities" which pass through the various establishments.

7. For all these studies it is important in statistical practice that the statistical data relating to the production result (output) on the one hand and to the production factors (cost factors) on the other originate from the same statistical source. They must refer to the same establishments or products and to the same periods of time. As soon as results originating from different sources are combined, the difficulties of the technical, local and time limitations become so serious that they may too easily lead to mistakes and false conclusions. This is the reason why the possibilities of a - very rough - statistical measurement of productivity, where the production result and the production factors would have to be taken from different sources, have not been considered in the present essay.

8. According to the economic aim to be reached and the type and volume of the statistical material required, three groups of studies may be distinguished :

General productivity studies

9. In this connection it is the economic aim, to compute the productivity change for individual industry branches, larger industry groups, larger economic sectors (e.g. agriculture, industry, building, transport, retail trade, etc.), or finally for the total economy. All these sectors, whether their range is narrower or wider, are composed of a smaller or greater number of enterprises or establishments, for which the changes in productivity must be measured. The common criterion of this group of studies is that they have to take into consideration all establishments which belong to the selected sector or at least a representative sample of these establishments. Accordingly, such studies must include small and large, well and badly organised establishments, in order to arrive at a real picture of productivity. To select for such studies particularly well organised and comparable reading or pilot establishments does not make much sense. Productivity changes may occur in the described larger and therefore always heterogeneously composed sectors also by the fact that the importance or the weights of certain production processes and production programmes shifted to other production processes within the same industry branch. The productivity of the total industry "stones and earths" may increase, for instance, by the fact that within this group the production and processing of quarry stones and the production of bricks decrease, whereas in the same time the importance of the cement industry and the production of larger or more suitably shaped cement stones increase. Accordingly such a productivity increase of a total industry branch may occur, even when the production methods and the productivity of the individual establishments belonging to this branch remain unaltered. If the economic sectors under consideration become greater and greater, until we finally arrive at the productivity of the total economy, these shiftings within the production programme, the shifting of the importance from one industry branch to another or from one larger sector to another play a constantly growing part.

10. It will not be possible to separate the general productivity studies of the type described from the duties of the official statistics, for their pre-requisites are the collection of statistical information from all establishments, and as a rule such statistical collections are only possible, when both well and ba y managed establishments are obliged to report, i.e. when those collections of statistical information are based on a binding legal order. The statistics of this first group are intended to illustrate the general backgrounds of the economic productivity trend. The results thus obtained will, in the first place, give rise to general measures of economic policy, which must be taken by the Government; they are less useful

for developing measures which the individual entrepreneur may carry out for rationalising his production.

Comparisons between establishments

11. The second group of productivity studies may best be termed "comparisons between establishments". Studies of that kind which are to provide a farther-reaching illustration of the causes of the productivity differences, cannot be, or can seldom be, carried out for the total range of an industry branch, but start from the selection of establishments of a similar type, i.e. establishments with equal production programmes, of an equal size, with equal production terms, equal production ranges, etc. In order to provide the possibility of carrying out detailed comparisons of the individual cost factors within the individual establishments, such studies consciously or unconsciously frequently refrain from including numerous factors which influence the productivity of the total industry branch, particularly from the shifting of the importance from badly to well-managed establishments or from the shiftings within the production programme. For such comparisons between selected establishments the assessment of both the production result and the individual production and cost factors can be done in a considerably more detailed way than is possible for the first group of general studies.* But it must not be forgotten that utmost care should be taken when the statistical results on those establishments which enter into the comparison and which are in most cases well-managed are used to draw conclusions on the conditions prevailing in the total industry branch or the total economic sector, to which these selected firms belong.

12. Such comparisons between selected establishments will generally be the domain of the entrepreneurial organisations or institutes especially set up for such purposes. Comparisons between establishments may supply a guide for rationalisation measures within the establishment, i.e. for measures being the exclusive responsibility of the entrepreneur himself. Such a guide can, as already mentioned, scarcely (or only to a limited scale) be obtained from the statistical results obtained from the first mentioned group of general productivity studies.

13. The first two groups, i.e. the general productivity studies and the comparisons between establishments, always affect the enterprise or the establishment and are, in principle, based on the information provided by the business or operating accounts. This information again refers, in most cases, to the total production programme of the establishment, but not to individual selected products. A passing over to the product, i.e. to the

* To this group of comparisons between establishments there belong, in my opinion also the studies referred to by the Bureau of Labor Statistics as "factory performance data", even though they were chosen so as to serve the special purpose of the international comparison between American and European establishments.

individual commodity, can in most cases be made possible at this and other ends only by a selection of establishments producing solely or particularly the commodity to be considered. It must, however, be remembered that the values obtained by such proceedings can with regard to selected products only be approximate values. There may scarcely be any establishments which have so narrow a production programme that they produce only one single commodity, and during longer periods of time always the same and comparable commodity, so that figures from the accounts, which refer to the establishment, may be related to one commodity without further manipulations.

Productivity comparisons for commodities

14. As a third group we can take together all productivity studies, where the investigations concerning the production results and the production costs relate to one single and exactly specified commodity. Only these studies related to commodities permit of international comparisons, which may lead to practical rationalisation measures within the national establishments. All detailed investigations into the production techniques can be carried out only on the basis of the production process for a certain commodity, but not for the production processes and facilities of an entire establishment, the production programme of which contains a great number of commodities. Frequently attempts are made to analyse not the costs which arise at a certain production stage - i.e. in an establishment - but the price of a commodity ready for use, in order to find out whether a reduction in the price can be obtained more effectively by altering the production techniques or by reducing the costs of the raw materials, rationalising or shortening the transport routes, or reducing the dealers' margins in wholesale or retail trade. Such studies run up against the difficulty that these different costs affecting the price of a commodity accrue in different establishments, so that they cannot be statistically assessed in one and the same place. For such purposes rather difficult cost analyses and enquiries are necessary. Accordingly, such investigations will scarcely be executed by the official statistical offices; productivity centres will be better suited to undertake such studies with the aid of establishments co-operating on a voluntary basis.* In addition, it is obvious that enquiries relating to selected commodities are even less suitable than the comparisons between establishments mentioned as a second group of studies for obtaining a picture of the productivity changes within an industry branch, a larger economic sector or even in the total economy.

15. The above outlines reveal that official statistics can mainly or exclusively serve the general productivity studies of the first group. For that purpose the official statistics must

* This group also includes the suggestions of an international comparison of costs, submitted by R.K.W. as the German Productivity Centre to the O.E.E.C. and prepared by Mr. Harten. (Cf. Vol.II) and Note 3).

endeavour to supply unobjectionable statistics of the production result and of the services of the individual production factors within the various economic sectors of the national economy, in order to arrive finally at an overall picture of the productivity changes in the national economy. In order to facilitate the discussion of this extraordinarily voluminous, difficult and far-reaching task, the problems of measuring the production result and the yield of the production factors will, in the present article, be illustrated only by the example of industrial production. This, however, does not mean that relevant studies for the agricultural production, the sector of transport, the distribution sectors of wholesale and retail trade, the service trades, banking, insurance, and, last not least, for the public administration would be of minor importance. In principle, the considerations relating to the manufacturing and mining industries are applicable also to the other sectors mentioned above.

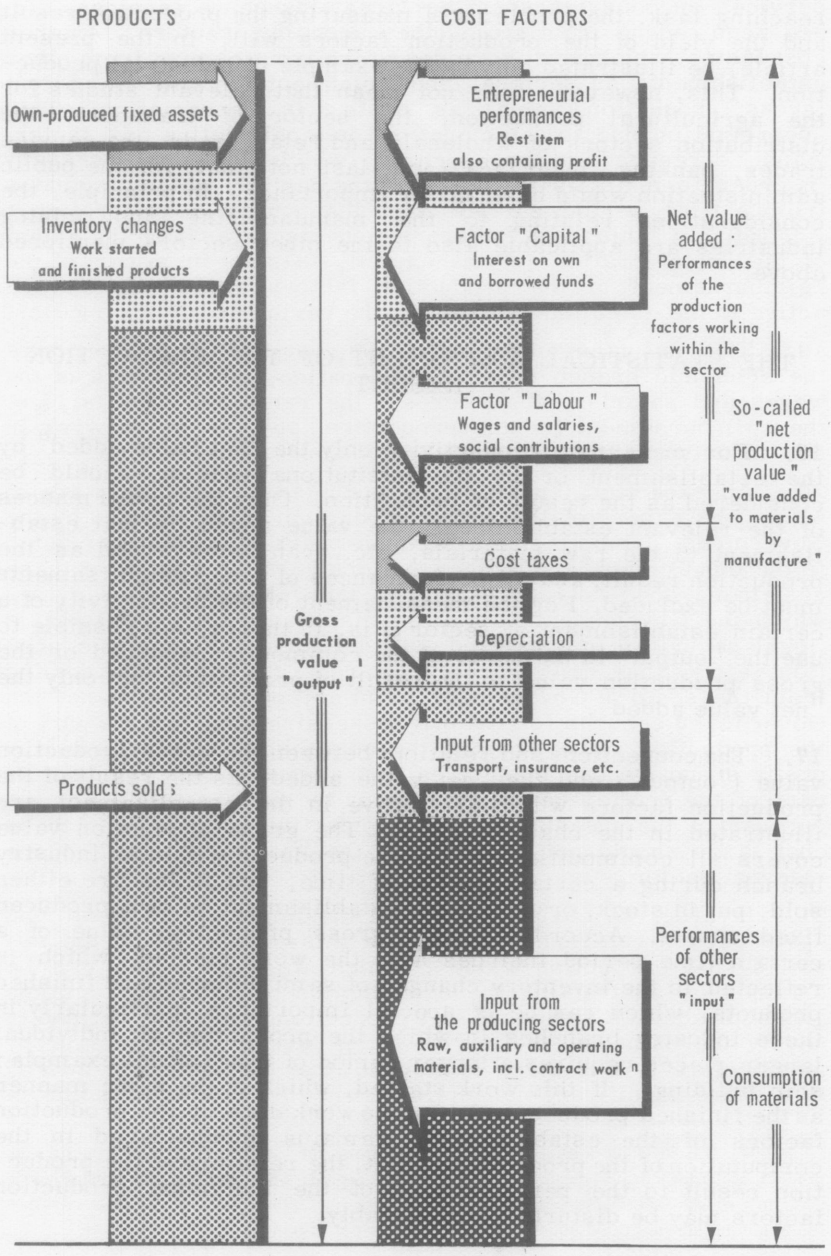
THE STATISTICAL ASSESSMENT OF THE PRODUCTION RESULT

16. For measuring productivity only the "net value added" by the establishment or by the institutional sector should be considered as the result of production. Only the performances of the relevant establishment, the value added by that establishment to the raw materials, etc., can be regarded as the production result, and all performances of other establishments must be excluded. For the measurement of the productivity of a certain establishment or sector it is, in theory, not possible to use the "output" in the sense of the commodity produced or the gross production value as the result of production, but only the "net value added".

17. The connections and relations between the gross production value ("output") and the "net value added" as the result of the production factors which are active in the establishment are illustrated in the chart attached. The gross production value covers all commodities, which are produced within an industry branch during a certain period of time, and which are either sold, put in stock, or used in the establishment as own-produced fixed assets. Accordingly, the gross production value of a certain time period includes also the work started, which is reflected in the inventory changes of semi-finished and finished products, which can be of special importance, particularly in those industry branches in which the production of individual larger pieces requires a longer period of time (model example: ship building). If this work started, which in the same manner as the finished products reflects the work done by the production factors of the establishment, remains unconsidered in the computation of the production result, the relations of the production result to the performances of the individual production factors may be disturbed considerably.

OUTPUT AND NET VALUE ADDED

(Schematic Presentation)



18. The gross production value is composed of the cost of materials, i.e. the raw, auxiliary and operating materials acquired from other establishments and industry branches. These materials represent the input coming from other producing sectors. In addition to these materials, the cost of services such as transport services, insurance services, etc. are acquired as input from other economic sectors. Another cost factor, which must be added to the input coming from other establishments or sectors, and which enters into the output (gross production value) as costs, is depreciation. This "depreciation due to deterioration" is a calculative cost factor, which corresponds to the expenses, which would be necessary in order to maintain the value of the capital, which originates from a time period earlier than that under consideration.* Accordingly, this cost factor, which compares with the extent of the "deterioration" of the capital, does not form part of the reimbursement of the production factors either, which are active in the establishment during the period under observation.

19. The "net value added", i.e. the result of the production of the economic branch under consideration, is composed of the wages and salaries, the interest, the rents and profits, i.e. the reimbursement for the production factors, which work in this industry branch during the period under observation.

20. An exceptional position is occupied by the cost-taxes, which are a part of the gross production value claimed by the Government, and which in common practice are not attributed to the input coming from other sectors. As the amount of these cost-taxes does not correspond to the volume of the services which the Government puts at the disposal of the establishment (legal security, internal and external security, general education, etc.), they can scarcely be regarded as input coming from the sector "Government". But as, on the other hand, the Government secures for itself by assessing cost-taxes a part of the production value whether the establishment has made any profit or not, these cost-taxes can scarcely be regarded as part of the profit taken in advance by the Government. For the purpose of the measurement of productivity, however, these cost-taxes should not be added to the "net value added" of the relevant sector.

21. In order to obviate misunderstandings which again and again occur, reference is made in this connection to the so-called "net production value", which in most cases can be obtained by subtracting the consumption of materials from the gross production value. A net production value thus defined is nearly the same as the term "value added to materials by manufacture". But there is no doubt that the "net value added" is a more significant conception from the economic point of

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* This kind of consideration originates from the definition of the net national product at factor costs = national income, which regards only those performances of an economy which exceed the performances necessary for maintaining the wealth available at the beginning of the period under observation as the performances of that period.

view, because it excludes also from the production result of the sector under observation the total input coming from other sectors, and not only the input in form of raw material consumption. The use of the "net value added" is the only way to avoid duplications in adding up the net value added by different industry branches to larger sectors and finally to the total national product.

22. For the purposes of the measurement of productivity, the chart clearly illustrates that, if it is intended to relate the production result to the production factors, it is self-evident that only the production result which has been created by the relevant production factors - the "net value added" - can be related to the production factors, whereby all cost factors which originate from other sectors have to be excluded.

23. We have so far considered the production value only, whereas in all productivity studies the quantity relations receive prior attention, such as the "quantity" produced to the "quantity of labour" performed and similar relations. But it will never be possible in general productivity studies and comparisons between establishments to abandon the concept and the use of production values as a starting point, for the value, and, as the case may be, the value at constant prices (in general referred to as "volume"), is the only amount which can be used for adding up quantities for different products and for different industry branches. Only on the basis of such values at constant prices is it possible to calculate series of a "development of quantities" (which will then always be a "development of volumes"). Individual studies, which are limited to a certain product, are more suitable for undertaking calculations of a quantitative nature on the direct basis of the quantities stated. But in each study, which covers the total production of an establishment or of an industry branch, it will only be possible to arrive approximately at a quantification by means of the above-mentioned calculations of volume figures, i.e. by the application of constant prices to the relevant quantities produced or performed. There will be no doubt that these findings give rise to immense additional problems.*

24. In order to make the statistical presentations of the production result suitable for the purposes of the measurement of productivity, it is necessary to compute the volume of or at least the changes in the "net value added" for the various branches of industry. This can be done without any objections from the statistical point of view only when current statistics on the production result, i.e. the so-called "output", are available on the one hand, and the consumption of materials and performances coming from other sectors (including depreciation and cost-taxes), i.e. the so-called "input", are known on the other hand. It is much easier statistically to calculate the "net

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* See also "Sozialprodukt zu konstanten Preisen" (The National Product at Constant Prices - Problems and Methods) by Dr. Bartels, published in "Wirtschaft und Statistik", 5th Year, New Series 1953, Volume 2.

value added", from the difference "output" minus "input", than it is by the other way, viz. by adding up wages and salaries, interest and profits, because the difficulties arising with regard to the statistical assessment of the various cost factors, and particularly of profits, are frequently unsurmountable. In addition, the conversion of the computations to "quantities", i.e. the calculation of "volumes" or values at constant prices for the individual production factors, is even more burdensome because of the difficulties to split up the value into "quantity" and "price", than a relevant splitting up of "output" and "input", which are composed of those commodities and services that permit of an easier quantitative measurement. As for the profit, the splitting up into a quantity and a price component cannot even be thought of.

25. The German official statistics have so far tried two different ways of solving that statistical task. The 1950 cost structure survey, which formed part of the general population, occupation and dwelling census and the census of industrial establishments, has on a sampling basis supplied a subdivision of the gross production value by individual cost factors and therewith certain basic figures for the "input", i.e. the consumption of materials and of other services coming from other sectors, including depreciation due to deterioration and cost-taxes.

26. A second way for the solution of the problem was tried in connection with the industrial reporting system. All establishments covered by that report were asked to supply information on the consumption of materials in 1950, whereby the transport expenses etc., which are regarded as "other input", were to be added, as far as possible, to the consumption of materials. Also by this way it has been successful (even though the simplified form of the questions somehow affected the desired clearness) in obtaining so-called "net quotas", which came close to what is understood as "net value added". Deficiencies of minor importance must, however, be tolerated, where deficiencies result from the fact that part of the not so very important input coming from other sectors, which does not represent deliveries of material, are included in this net quota. A difference far more important is that in addition to the "net value added" these "net quotas" include also depreciation and cost-taxes.

27. In the revision of the German index of industrial production, for which purpose the above-mentioned collection of the net quotas on a post-war basis was an unavoidable prerequisite, care will be taken that the so-called "production" index will be adjusted to the development of the "net value added" as far as possible. In principle the index calculated at present corresponds with this conception, as it keeps up-to-date the "net production values" of 1936, whereby also in future and for practical reasons, the current calculations must, as heretofore, be based on the assumption that the net quotas remain unaltered during a certain period of time. No other way is possible, because the official

German statistics permit only of approximately keeping the "output" up-to-date by current adjustments, and because corresponding current records of the "input", which are possible and available in other countries, and which would provide the possibility for an unobjectionable assessment of the production result (in the sense of the "net value added") from the difference "output" minus "input", are not available at this end so far. This roughly described procedure of keeping the "net production values" (which come as near the concept of the "net value added" as possible) up-to-date by an index of industrial production will, however, supply data on the production result, which can be used for the measurement of productivity, particularly if a relatively late post-war basis is chosen.

28. The above statements reveal that statistics of the production result, which are widely based on figures related to the gross output, can and must lead to wrong results, when the proportion of the "net value added" on the one hand and the consumption of materials on the other hand have considerably altered in the course of the years. The following two examples illustrate the difficulties which arise in this connection :

In shoe production, and particularly in the production of men's shoes, the influences of fashion have brought about considerable changes in the relation between the consumption of materials and the net value added as compared with pre-war times. Quite different bottom fastenings, a much greater number of quiltings, perforations and decorations have become fashionable, so that the amount of human and mechanical labour, in others words "the net value added" per pair, is to-day considerably higher than it was formerly with regard to simple shoes. If the production result is measured only by means of the number of shoes produced, the fact that because of their fashionable design the shoes of to-day incorporate a higher "net value added" - i.e. higher wages and capital costs - is not accounted for. If the development of the number of pairs is taken as a measure for the production result and compared, for instance, with the number of man-hours worked, the production result per man-hour thus arrived at is lower than that which would be obtained, if the more correct method were adopted, i.e. to compute the net value added as the difference between "input" and "output" and to relate this figure to the man-hours worked (it is regretted that this is not possible at the time being).

Similar difficulties arise when, for instance, the production result of the foundries is measured on the basis of the changes which have occurred in the produced quantity of castings (given in terms of weights). When, for reasons of reducing the weights of the finished products, castings of a lower weight are to be produced for the customers, it is possible that this smaller quantity of weights may also incorporate a higher amount of labour and capital

per kg. than the former heavier castings. This is another clear illustration that productivity cannot be measured reasonably on the basis of the gross production value, but in each case only on the basis of the net value added.

29. It should be kept in mind that the statistical assessment of the "net value added" within the various economic sectors other than manufacturing and mining industries must, in principle, follow the same lines. Accordingly, it must be started in all sectors from the "output", i.e., as the case may be, from the products or services, etc. sold, from which the "input", viz. the purchases of the sector considered from other sectors as well as depreciation and cost-taxes, have to be subtracted. Only if this procedure is consistently followed can the production results of all sectors (in the meaning of the "net value added" by them) be added up to the total result of the economy or to its national product. Then, and not before, the prerequisites for measuring the changes in productivity within an economy have been created.

THE STATISTICAL ASSESSMENT OF THE PERFORMANCES OF THE INDIVIDUAL PRODUCTION FACTORS

The production factor "labour"

30. When the basic conceptions were discussed in this paper, it was already mentioned that the relatively easiest task is to record statistically the performances of the production factor labour. This can roughly be done by recording the number of persons employed or the number of hours worked. In this connection it may also be possible to obtain better insight of the productivity trends than heretofore by means of a more suitable subdivision of the data on the persons employed, which data could be taken from general statistical survey (e.g. census of industrial establishments, industry report). A rough subdivision of the persons employed according to their function in the establishment could already be of assistance. For such a purpose the persons employed would have to be subdivided in the following groups :

engaged in the preparation of the production;
engaged in the supervision of the production;
engaged in the direct production;
engaged in the administration of the establishment;
engaged in distribution work;
engaged in transport work.

31. If subdivisions of this kind are available, fictitious changes in productivity, which are due to the fact that an industrial establishment has increased the number of persons employed, because it develops a larger distribution service with own vehicles, may be avoided. In this way, it would also be possible to obtain insight into the shiftings between the preparation of the production and the actual production or between the administration and the production, etc.

32. In addition to the number of persons employed and hours worked it is most useful for the measurement of productivity to possess statistics on the wage and salary pay-rolls, which are paid to the various groups of persons employed, i.e. the costs of the production factor labour. These costs are, in a way, an average of the hours worked weighted with the wage rate, but it is necessary to separate the quantity from the price component if quantitative and volume calculations are needed. The practical problems of measuring the performances of the production factor labour are only roughly touched upon by the remarks above; they are, in reality, very great. The unit of time, i.e. the working hour, must, for instance, not necessarily be the correct measure for the quantity of the work performed, and particularly not, where piece wages are concerned. In addition, the unit of time renders it difficult to distinguish between qualified and less qualified work (at different wage rates). This problem of measuring the working performance is even more difficult in other economic sectors, where the preparedness to work - in addition to the actual work itself - is of considerable importance. Also the assessment of the costs of the production factor labour gives rise to quite a number of questions, particularly which of the so-called voluntary social contributions of the entrepreneur must be regarded as a wage component and therewith as part of the costs for the production factor labour. To illustrate this problem we need only make reference to the following: reimbursements of removal expenses, separation allowances, travel grants, death benefits, allowances for cases of emergency, contributions to all kinds of funds of the establishment, expenses for factory welfare, common catering, factory dwellings, etc.

33. The data at present available from German official statistics mainly originate from the industry report, which supplies at least for a key-date (end of the month) information on the number of persons employed, even if the subdivision is not yet very satisfactory for the purposes of measuring productivity. For more exact comparisons between the "net value added" and the persons employed or the man-hours respectively it would, however, be necessary to have average figures for the total year, because otherwise, and particularly in those industry branches where the number of persons employed is subject to strong seasonal fluctuations, deviations may occur between the available key-date figures and the average number of workers, who during the year have created the "net value added". As an example, attention is drawn to the results of the building report, where during the months when, for seasonal reasons, building is started and building is stopped (in spring and in winter), considerable differences can be observed which depend on whether the hours worked during the month or the persons employed at the end of the month are used as a basis for productivity calculations.

34. The industry report supplies data also on the payroll (sum of wages and salaries paid). Here also it is still difficult to adjust the data relating to payment periods exactly to the month

or another time period, to which the investigation refers. A detailed description of the problems which arise with regard to the measurement of productivity from payments made to workers when they are absent for reasons of leave, sickness, etc., cannot be given within the scope of this article.

35. The cost structure survey, which was already mentioned among the statistics of the production result and in which the various cost factors, including the cost factor labour, are shown separately, can also be used for comparisons between the cost factor labour and the production result. The 1950 cost structure survey shows the following sub-divisions for the cost of the production factor labour :

Wages and salaries

Wages
- Manufacturing wages (direct wages)
- Wages for intra-plant performances
- Auxiliary and other wages

Salaries

Social expenses

Legal
Others (voluntary)

If such figures were available for different dates, they could be usefully applied to measuring changes in productivity.

36. In all other sectors outside manufacturing and mining, the statistical recording of the persons employed and the time worked by them as well as the wages and salaries paid including the social expenses is relatively easy. In Germany it will at least be possible, roughly to measure productivity also for the sector of personal services, i.e. on the basis of the output or turnover, which is known from the 1950 census of establishments, and on the basis of the persons employed, which is available from the same census. The most important step towards the improvement of productivity measurement will, however, be a more suitable breakdown of the item "persons employed" in the current industry and building reports and in the handicraft report under preparation.

The production factor "capital"

37. The chart on page 68 shows that it would be possible statistically to measure the contributions of the production factor capital to the production result of an industry branch or an economic sector by measuring the interest on this capital. For the measurement of productivity, it is, for this reason, not absolutely necessary to possess data relating to an asset account, which shows the total amount of "capital" available for production. It is sufficient to know the costs which were caused by the production factor capital during the period under consideration. If it is remembered that these costs do not only consist of the

interest paid on the fixed assets which work in the establishment, but also of the interest paid on the assets circulating in the establishment and that both are or may be composed in part of own and in part of borrowed funds, it is understandable that the statistical measurement of this use of capital meets with very serious difficulties.

38. In order to supply a complete statistical picture of the payments for the capital performances, it is necessary to know the interest actually paid on borrowed funds (i.e. interest on credit balances, interest on arrears with regard to suppliers, discount deductions, etc.) and the rentals actually paid. It may be relatively easy to ascertain the amounts actually paid, but frequently the rentals paid include also reimbursements for other performances (e.g. maintenance), which under the definitions given earlier in this paper, cannot be regarded as payments for the use of capital.

39. In addition to this interest on borrowed funds, it is also necessary to know the operational interest on the operational capital, i.e. a calculative item for the enterprise's own funds, in order to complete the picture of the capital costs. It is quite obvious which difficulties arise in this connection for both operating accounting and for the calculation of costs as well as for the statistics based thereon. A figure for the operational interest as a calculative item can be calculated only if the fixed and circulating assets, which are continuously serving operating purposes, are known, whereby all questions of valuation and the problem of the calculative amount of the interest rate to be used for the purpose of these calculations enter again into the picture. According to the circumstances, whether these imputed interest rates on the enterprise's own funds are high or low, considerable shiftings between the capital costs and the "payments" of the entrepreneurial performances may occur. This can have rather disturbing effects, when it is intended to compare the "net value added" with the capital performances.

40. The attempt so far made by German official statistics to approach these problems is the 1950 cost structure survey, where, within the framework of the complete breakdown of total costs, data were collected on the interest on borrowed funds, rentals and operational interest (as calculative costs). Whether and in how far this attempt has led to satisfactory results, cannot yet be guessed, as the compilation work for these statistics is not yet finished. As the same survey provides information also on the production result of the same establishments, and as it does so in the unobjectionable form of the net value added, a repetition of the cost structure survey could essentially contribute to the measurement of the performance of the production factor capital.

41. A second way could lead via the German balance sheet statistics (drawn from published balance sheets of corporations). These statistics, however, provide a picture only based on the actual payments, and on actual depreciation allowances and not on allowances corresponding to normal depreciation. The

released balance sheets of the "Aktiengesellschaften", which are for the time being nearly the only basis for these statistics, are not detailed enough to provide the possibility of a statistical assessment of the costs for the enterprise's own and borrowed funds. If one wants to get a step further on the way via the balance sheet statistics, relevant information would have to be collected also for establishments of other legal forms. But it appears that a repetition of the cost structure survey would be a greater help for measuring productivity.

42. All this said, we shall abstain here, for reasons of space, from discussing the problems connected with the calculation of capital costs at constant prices. Such calculations, which would become necessary for capital costs as well as for all other cost factors would raise serious additional difficulties.

The statistical measurement of entrepreneurial performances

43. Whereas it appeared somehow possible, at least roughly, to measure the performances of the production factor labour and to see certain possibilities for measuring the capital performances, the statistical measurement of the entrepreneurial performances gives rise to still greater problems. For general productivity studies, it will be unavoidable from the beginning to renounce the attempt of splitting up the entrepreneurial performances into their multiple components, and we shall have to be satisfied with the possibility of ascertaining the "value" of these entrepreneurial performances at least in the form of a residual amount, which remains after the deduction of all other and better definable costs from the total production value. In the calculation of such a remaining amount, which contains the profit, but is far from being identical with it, difficult problems of limitation arise, which can, in this connection, only be indicated by a few examples. Many tasks which the "entrepreneur" has to comply with - as for instance to secure the best playing together of all production factors - are to-day carried out by "salaried employees" (not to say by "managers"). These directors and managing employees receive salaries, which appear as costs among the wages and salaries, and which are thus allocated to the production factor "labour". In the case of firms under the proprietorship of one or under the proprietorship of several persons, it will be suitable to insert a calculative entrepreneurial wage, i.e. a suitable reimbursement of the work performed by the owner and the family helpers who are active in the establishment, and add that amount also to the production factor labour, for otherwise it could happen that in handicraft or other retail firms there would not be any factor "labour" at all, but only an "entrepreneurial profit". In addition to this question whether the "entrepreneurial wage" as a reimbursement of the entrepreneurial performances has to be statistically presented or added to the "wages and salaries", there arise other problems, e.g., the operational risks or

the question whether and in how far voluntary social contributions are still costs of the factor labour or whether they are already parts of the entrepreneurial profit used for social purposes.

44. The statistical presentation of the residual item described, i.e. that part of the gross production value which remains after the deduction of all other costs (including the calculative costs), was a great statistical venture in Germany. On the one hand there was the trouble that the "residual item", which still includes numerous elements, could erroneously be used as the assessment of profit. On the other hand it was admitted that a very far-reaching breakdown of costs is most useful for counterbalancing the danger that owing to the absence of more exact statistical data interested circles may try to gain a picture on the profit position by means of the very rough "residual item", which is obtainable by only subtracting the consumption of materials and the wages and salaries from the gross production value.

45. By very much time, patience, work and skill of convincing on the one side, and very much comprehension, understanding and good will on the other side - the latter being the merit of the voluntary co-operation of wide entrepreneurial circles and their representatives in the 1950 cost structure survey undertaken on a sampling basis - it was possible in Germany to obtain a reasonable, detailed breakdown of the entrepreneurial performances. Even though the figures thus ascertained are - for the purposes of measuring productivity - only a beginning, they supply nevertheless valuable corrective items, which permit of a better understanding of the development of the relations between the production result and the various production factors.

FINAL REMARKS

46. The outlines set forth above have revealed that the "measurement of productivity" for individual industry branches, for larger economic sectors and for the economy as a whole does not in principle, raise problems which would be entirely new for the official statisticians. The measurement of the production result, the measurement of the individual production factors and their performances are tasks which the official statistics have always endeavoured to solve, without being, however, always quite conscious of the interrelations and interdependencies of the various entities involved. All definitions and all requests with which the official statistics are faced if they aim at improving the measurement of productivity, are, in principle, identical with the demands and aims, which in the interest of improving the calculations of the national product are followed by the Federal Statistical Office for some time past. It has, for instance, been found that the cost structure survey, which was executed for purposes of the national product calculation, is the best aid also for measuring productivity. All

considerations which arise, for instance, in the recalculation of the industrial production index or with the improvement of the industrial statistics, all considerations which serve to establish a consistent system of price indexes and to facilitate the elimination of price influences from recorded values, will also help to improve the economic measurement of productivity. The measurement of "productivity" is, in principle, nothing but a special angle, from which the overall picture on the performances of the individual production factors and their results can be seen. This picture is, however, equally important for other purposes than productivity.

47. The statistical material which comes to hand in connection with these "general investigations", and particularly the questionnaires of the cost structure survey and also the data reported in the framework of the industry report on production, persons employed, wages and salaries, could, if this is wanted, be used with a certain advantage also for productivity studies described as "comparisons between establishments", as is already done with similar material in other countries (e.g. in the Netherlands). But the German official statistics have, at the time being, no relevant order and no financial means for this task.

V

PRODUCTIVITY, EFFICIENCY AND WAGES

by Dr. Erik Ruist (Sweden)

INTRODUCTION

1. In economic discussions in Europe we find one theme constantly recurring : the development of productivity. This subject arises in the most varied connections on both the national and the international plane. From different quarters we find questions like the following being posed: Is the rate of progress fast enough? Cannot business efficiency be increased more rapidly so that the competitive position of our country may improve? And on the other side we get questions like this : Have wages kept pace with productivity, or have the gains in efficiency only profited other groups of the population than the wage-earners ?

2. The interest in productivity has sometimes been regarded with a certain amount of surprise by the entrepreneur class. It is pointed out that a rise in the production per man-hour, which is the customary definition of productivity, is quite evidently a desirable thing in itself. The resulting reduction of labour costs should, however, be regarded as balanced by an increase in the use of other production factors as a result of which the total costs may remain unchanged and there would then be no enhancement of efficiency, nor would there be any scope for wage increases.

3. These differences of opinion about what is involved in a change in productivity are for the most part based on a confusion of terms. In everyday parlance the word productivity is used as if it were practically synonymous with efficiency, but when it is necessary to measure productivity it is generally defined as the production per man-hour, which moreover is wrongly thought to be an unambiguous concept. I propose to discuss what connection there is between these two concepts, or, to put it more explicitly : Can we measure efficiency in business enterprise with the help of production per man-hour (PMH) ? Section 2 of this study attempts to answer this question for the productive system of a country as a whole or for one branch of production. On the basis of this the next section discusses the distribution of gains arising from efficiency increase, and

especially the reasonableness or otherwise of the claim that wages should rise step by step with PMH. Section 4 deals with the question of measuring efficiency by PMH in an enterprise. Finally, the connection between different PMH measurements is discussed in Section 5.

MEASURING EFFICIENCY FROM THE VIEWPOINT OF SOCIAL ECONOMICS

4. In lay discussions a rise in PMH is often regarded as equivalent to an increase in efficiency. Since PMH is the inverted value of the consumption of manpower this means that a reduction in the work per unit produced must always be regarded as desirable. Why then has labour attracted so much attention as compared with other factors of production? From the viewpoint of an enterprise the labour costs are as a rule only a small part of the total costs and instead of PMH it would be equally reasonable to estimate production per ton of raw materials or per kilowatt-hour of electrical energy and so on. Probably, however, it is not man's position as a factor of production which has led to so much stress being put on manpower but rather his capacity as a consumer. If we take a long view of social-economic development it is clear that the standard of living, and therefore the consumption per individual, has only been able to increase because the production per individual has risen. Accordingly, if the standard of living is to continue to rise it is important that PMH should grow. This is especially the case in conditions of full employment, when production cannot be increased by drawing on a reserve of unemployed persons. Thus from the community's point of view a rise in PMH is regarded as equivalent to an improvement of efficiency in the productive system, and this is probably the explanation of the fact that PMH and efficiency often are treated as synonymous. This in its turn has led to the statement that the struggle to bring about greater efficiency both in business as a whole and in the individual enterprise should take the form of measures for raising PHM. To a business executive such an argument must generally appear untenable as he cannot go all out to reduce labour costs (and thereby raise PMH) without regard to what effect this would have on other cost elements. This difference of approach is due partly to the fact that efficiency in a business may be regarded from several different points of view and partly to the fact that a PMH measurement for a single enterprise has to some extent a different meaning from a similar measurement for the productive system as a whole.

5. What then is efficiency? In a very general way it may be defined as the relation between the total output and the quantity of all the factors of production used. The more an enterprise can produce without an increase in the quantity of inputs used, the more efficient it is. To this extent there is no difference of opinion. It is not until it becomes necessary to make concrete measurements of production and the factors of production

employed that the point of view from which one regards the enterprise in question becomes important. When the Government for example, talks about the efficiency of business it is thinking of what one might call social efficiency, and the total production is judged from the point of view of its social usefulness. Different groups may, however, have different views as to how this usefulness should be assessed and consequently as to whether a change in production implies an increase in efficiency or not. In the same way different opinions may of course arise when it is a question of granting an import licence for one commodity rather than another or a building permit for one project rather than another. When it is a matter of making a quantitative evaluation it is the value of money that is usually thought of, but this is not the only possible measure. For certain purposes there are other accepted measures, for example calories in the case of foodstuffs. It is therefore quite possible to conceive of assessing the efficiency of agriculture by comparing the production in calories with the amount of factors of production of various kinds employed.

6. In practice, however, it is difficult to construct any completely new system of evaluation for all the goods and services produced by the productive system as a whole, and therefore the only method so far used is to use the price system during a given year. In strict principle, changes in preference - i.e. changes in relative prices - should also be reflected by using the price system prevailing for each year and only eliminating changes in the price level in some summary manner. The difficulty of course is to make this elimination satisfactory from a theoretical point of view.

7. Corresponding problems of evaluation arise in measuring the quantity of factors of production used. Assuming we have decided to measure production in terms of value, we cannot do the same with the inputs. The difference between these two, which of course enter in the measurement of efficiency as numerator and denominator respectively, would then only be the net profit and the measurement as such would be of little interest in this connection. There are, however, many conceivable bases of evaluation. The substitution of one factor of production for another may in certain connections be regarded as a gain, in others as a loss. Sometimes the supply of a factor of production may be so limited that a reduction in the consumption of that factor may be regarded as a gain, however much, within reasonable limits, the consumption of the other factors is increased. Such was the situation in the nineteen-thirties in the Japanese cotton industry, where the available machinery was quite inadequate and where efficiency was therefore calculated on the basis of production per machine-hour. A corresponding state of affairs may generally be said to exist in conditions of full employment, when there are no reserves of manpower to resort to and a reduction in the use of labour may in general be regarded as enhancing the efficiency from the social point of view, so long as the raw-material resources of a country are not over-exploited and the consumption of capital

is not unduly great. If we look at the whole chain of production from the gathering of the raw materials right up to distribution as a single process, there can be no doubt that labour costs - if we include in this salaries paid to administrative staff etc. - constitute by far the largest portion of the total costs. Even from this point of view it may therefore be justifiable to pay no regard to any factor of production other than labour in calculating social efficiency, which thus might be measured on a PMH basis. A calculation of this kind is, however, very difficult to carry out, at any rate for units smaller than the productive system as a whole, owing to the fact that even the labour which is expended in raw materials and semi-manufactured goods, must be referred to the end products. In other words one must treat the production of a commodity as if the process of manufacture was characterised by complete vertical integration. Thus, in the case of a ready-made clothing factory, a reduction in the cloth used per garment must be regarded as a reduction in the consumption of manpower, since it saves manpower in the weaving-mill and in even earlier phases of production.

8. It is obvious that in that case a PMH calculation must start from the national product. This is the total value of all goods and services produced in the country during a certain period. All double calculations are eliminated so that only the final products are included. Deductions are also made for raw materials etc., which are purchased abroad, so that the national product comprises only those values which have been created within the country. In this connection the national product should be calculated net, that is to say a deduction should also be made for the wearing out of capital equipment which has occurred during the period. By putting the net national product in relation to the total number of working-hours which have been expended in creating it, we obtain what may be called the nominal social PMH. As the net national product is extremely difficult to calculate, the gross national product is always used instead, which means that depreciations are also included in the value. The use of a PMH defined as the gross national product divided by the number of working-hours, as a measure of efficiency, must then be based on the assumption that the depreciations always form a constant proportion of the gross national product.

9. It should also be observed that the calculations of the gross national product which are carried out in most European countries are characterised, because of the lack of primary material, by so great a degree of uncertainty that changes in the social PMH of up to 5 per cent generally lie within the margin of error.

10. If it is to be capable of being used as a measure of efficiency the social PMH must of course be freed from the effect of changes in the price level. In the case of some activities, e.g. trade and administration, it is, however, practically impossible to make any conversion to a fixed price system as it

is not feasible to adopt any quantitative basis and consequently any prices for fixed services.

11. We can, however, limit ourselves to certain activities and estimate, for example, the contribution of manufacturing to the national product, divided by the number of hours worked in manufacturing. Here it is easier to make a recalculation at fixed prices and we should therefore be able to arrive at an indicator of the social efficiency of manufacturing. The most usual way, however, of calculating PMH in manufacturing is to add together with fixed weights the quantities produced of all goods in order to form a production index, and to divide this by an employment index. This method does not give a particularly good indicator of the social efficiency of manufacturing, as all products are included and not only final products. As a result of this a rationalisation in the ready-made clothing industry, with production unchanged, which leads to a reduced use of cloth, will be reported as a diminished production in the weaving mills and a corresponding decline in working hours in those mills, but not as a rise in PMH. According to the definition of social efficiency employed, however, such a development is to be regarded as a gain in efficiency. As savings in raw materials and semi-manufactures play an important part in manufacturing a PMH measurement calculated in the usual way would consequently be quite misleading if used as an indicator of efficiency.

12. The conclusion from the above is that a PMH measurement may be used in order to measure the efficiency of production as a whole or of a branch of production, from the point of view of the community, on the assumption that manpower is to be regarded as considerably more valuable than other factors of production - on the ground, say, that full employment prevails. The type of PMH measurement which is usually employed for manufacturing is not applicable in this connection, and it would probably be very difficult in practice to carry out calculations in such a way that the divergence from a theoretically satisfactory measure was smaller than the annual fluctuations.

WAGES AND PRODUCTIVITY

13. Intimately bound up with the idea of PMH as a measure of efficiency is that of the connection between wages and PMH. Every section of the population is naturally concerned that it should get its due share of any improvement in efficiency and the standard of living, and it is from this that the generally held thesis that earnings should rise step by step with PMH is derived. If a comparison shows that earnings have in fact failed to keep pace with PMH this has been interpreted to mean that there is scope for further increases in wages and salaries. We shall now for the time being disregard the practical difficulties of calculating PMH and try to find out what assumptions lie behind this thesis.

14. What then is meant by "scope for wage increases". From one point of view it may be said that there is such scope if the capacity of a business to pay higher wages is not entirely exhausted. How this is to be decided is a matter for discussion, but one conceivable indicator is the net value of the enterprise, e.g. its manufacturing value minus all costs except those for labour and interest on capital, divided by the total number of working hours. The fact that an increase in the net value has occurred shows that there is a larger amount to share between labour and capital. It can, then, it is said, be regarded as "reasonable", that time-earnings should rise in proportion to the net value per working hour. If therefore it is found retrospectively that the PMH defined in this way has risen more than the time-earnings, it is claimed that there is scope for wage increases.

15. If we add together the net values for all work done in the community, we arrive at the net national product. The PMH as defined above for the individual enterprise has thus a counterpart in the nominal social PMH for the productive system as a whole. We can now regard the national product - and the social PMH - from different points of view. In this connection the income and expenditure aspects are of interest. The sum of all incomes during the year is called the national income, which in most countries is for all practical purposes equal to the national product and can be divided up into income from work and income from capital. The thesis that the average time-earnings in the community should increase in proportion to the social PMH is a subjective proposal for the solution of the problem of the distribution of the yield of production between labour and capital, and implies that the two components of income should increase at the same rate. If the amount per worker of capital applied to production rises at the same rate as PMH, this means an unchanged rate of interest for capital. In the long run, and for the community as a whole, it is of course not altogether unlikely that the development might be like this, although the lack of statistics makes it difficult to arrive at any definite opinion on the matter. Both for an industry and for an individual enterprise it is true that the income from work and the income from capital add up to the net value. However, the smaller the unit dealt with, the more likely it is that the capital per worker will expand in proportion to the PMH.

16. As defined above, both incomes from capital and incomes from work contain items which are not usually reckoned as income from the point of view of the individual income receiver. Thus incomes from capital include company taxes and profits ploughed back into the business, while incomes from work include appropriations to pension funds, etc. Incomes from work of course include not only the earnings of the workers but also salaries paid to administrative staffs and executives. This should be noted when attempting to compare PMH and wages with the aid of available statistics.

17. From the point of view of enterprise economics, however, the scope for wage increase cannot be determined by the average PMH. Classical theory tells us that, when wages and prices are free to find their own level, enterprises tend to pay their workers as much as the increase in the value of production which is obtained by putting one additional worker into the manufacturing process without making any other changes. This can of course be regarded as a PMH for that worker or a marginal PMH for the enterprise. If wages become higher for any reason, it pays the enterprise to replace some of the manpower by other factors of production, e.g. machinery, or simply to curtail production by laying off workers. For the community as a whole this makes itself felt as unemployment. If on the other hand wages are lower than the marginal PMH there arises a tendency towards manpower shortage. Marginal PMH differs from the average PMH for all workers, which is what we always have to deal with in practical calculations. Progress in mechanisation causes both these PMH figures to rise, and while it is of course possible that they increase to the same degree it is not possible to be certain about this. If such is not the case, wages will rather follow the marginal PMH, provided that enterprises are not prevented by controls from acting with a view to a profit, and the difference between marginal PMH and wages decides whether there is any scope for wage increases from this point of view.

18. In order, however, that wage increases shall come about and really represent increased real income as well it is not only necessary that there should be scope for such increases in the sense used above. For if money wages rise so rapidly that the supply of goods and services does not suffice, without a simultaneous rise in prices, to meet the rising demand resulting from the higher incomes, the rise in real wages will not be as great as the rise in money wages. From this point of view, therefore, we can state that the scope for an increase in real wages depends on the quantity of goods and services available for consumption, or, to use another terminology, on whether a planned rise in incomes does not lead to an inflationary gap.

19. In order to see what this condition implies we should look at the national product from the expenditure side and divide it up into a part which is used for consumption and a part which goes to investments. In order to keep the connection with the earlier arguments clear, both consumption and investments can be split up into the parts which are financed by incomes from work and incomes from capital respectively. In this way we get four categories to work with. It is improbable that the proportion of incomes from work which is saved, i.e. which is finally employed for investment, varies within very wide limits. Therefore if incomes from work rise this must mean that on the whole consumption is increased in the same proportion. If now we look forward and calculate in unchanged prices, the increase in the national product is the frame within which consumption and investments can expand. Assuming that the share of investments is constant, the total consumption can expand at the same rate

as the national product. Finally, if consumption out of incomes from capital is a constant proportion of the total consumption, the consumption out of incomes from work, and therewith incomes from work themselves, can rise in proportion to the national product, i.e. time-earnings can rise proportionally with PMH. If the increase in wages is greater the result will be a rise in prices which causes the real increase to be less than the nominal one.

20. If an increase in wages is to be able to take place and to be a real as well as a nominal increase, there must be scope for this in both the senses discussed above. Thus if scope for wage increases exists from the point of view of enterprises, so that wages are under the marginal PMH, but on the other hand there is no scope for an increase in consumption, an increase in real wages may be obtained either by the whole of increase in incomes being saved, or by investments being cut down so that consumption can expand, or, finally, by reducing consumption out of incomes from capital. If this cannot be done the further scope can only be created through a rise in PMH. This has been the situation since the war in many European countries with full employment.

21. So far we have only dealt with the changes in the average income in the community. It is, however, no more than natural if a group, for example the industrial workers, claim the same privileges and must put up with the same restrictions in regard to income as other groups. In certain cases an uneven distribution of wage increases may nevertheless be accepted; this happened in Sweden during the war, when wages in agriculture and forestry rose at a considerably faster rate than in manufacturing. Such a development may come about, for example, through a real PMH increase in manufacturing being used to reduce prices instead of to raise wages, at a time when both a rise in prices and an advance in wages are taking place concurrently in agriculture.

22. If in spite of this it is desired to compare for example the average time-earnings in manufacturing with a PMH for the whole community during a certain period, this should be calculated in a different way from the social PMH. It is necessary to take account of the fact that an increase of the average income can take place both as a result of a general wage increase and by people changing over from low-paid occupations and industries to better-paid ones. In the same way PMH may be raised either by a PMH increase for individual undertakings or by a shift of production as between different industries, goods or enterprises. If a gain in PMH due to such causes takes place it cannot of course affect the average wages within a given industry as the gain goes to those who move. This is a matter of current interest in Sweden, where the shift from agriculture to manufacturing, transport and other activities has been of considerable dimensions and is still proceeding. Thus an appreciable part of the increase in the total real social PMH which took place during

the 1940's may be ascribed to this shift. Accordingly, to enable PMH to be compared with average wages in manufacturing it should be calculated as the mean of the PMH in manufacturing, mining, agriculture, and so on, no regard being taken to transferences between these activities. If our object is wage comparisons for a particular industry, all shifts down to that level should be eliminated and we shall get an average industry PMH for the whole community. *

23. The comparisons between wages and PMH dealt with so far have in every case concerned a PMH measurement for the whole community. This is by no means necessary. Thus the average time-earnings for manufacturing can quite well be compared with a PMH measurement for manufacturing and so on. From the consumption point of view it is of no importance whether there is a parallel rise in all wages or whether the wages in each economic activity are geared to this PMH. On the other hand it means that the distribution of income is changed. If a comparison is made in real terms, an equality in the rate of increase in an industry will indicate that the rise in PMH has altogether benefited the people connected with that industry. If the comparison is on the basis of nominal values it only relates to the distribution of income within the industry in question. Such a comparison will show whether the workers' earnings have expanded in parallel with those of administrative staff and of the employers and the remuneration of working capital. In this case it is important to take account of the effect of the relative increase of administrative staff. The PMH measurement should therefore be calculated with due regard to the hours worked by all groups employed and not only the wage earners.

24. The same comparison can of course be made for smaller and smaller units, but at the same time the thesis that wages should advance step by step with PMH becomes less and less tenable as one goes down the scale, even apart from the fact that equilibrium only prevails when the wages coincide with the marginal PMH. The assumption that the capital applied per worker grows proportionately with PMH becomes less and less realistic and it certainly does not apply in the case of a single enterprise. This seems to be one of the reasons why views on the suitability of PMH as a basis of comparison for wages have been so divided. What from certain points of view may be regarded as reasonable in relation to the community as a whole becomes absurd when applied to the individual firm.

25. It was stated above that a comparison between PMH and wages would have a different meaning according to whether it was made in real or nominal terms. The real measures were then assumed to have been arrived at in some undefined way with the aid of a price index. By reason of the fact that different

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* The effect of a transfer depends of course on the difference between the marginal PMH of the industries, not the difference between their average PMH. Consequently the industry PMH does not indicate exactly what would have happened if there had been no shift.

indices are used for PMH and for wages the result will then be different from that obtained in the case of the direct, nominal comparison. Differences in principle may also, however, arise. Let us analyse more closely the case when a PMH increase in manufacturing was used for higher wages in agriculture by way of falling prices of industrial products and the rising prices for farm products. If the other circumstances remained unchanged this would mean that the nominal net value and PMH remained the same in manufacturing but rose in agriculture. In real terms the exact opposite was the case. A comparison would therefore show that the real wages of industrial workers had remained unchanged or had actually declined, whereas the real PMH of manufacturing had risen. In spite of this there is no scope for wage increases, as the PMH profit had already been used for reducing prices. The nominal comparison eliminates such effects and leads to the conclusion that as neither PMH nor wages have changed there is no scope for wage increases. Whether the general price level is unchanged, as assumed above, or is rising does not affect the conclusion that from this point of view the nominal comparison gives a more accurate result than the comparison in real terms.

26. A transference effect of the same kind as that from manufacturing to agriculture may make itself felt even if one takes the whole community into consideration, and therefore here too the real and the nominal comparison may give different results. For if a deterioration in the terms of trade takes place this involves a transference to other countries of the gain from a domestic PMH increase. An improvement in the terms of trade has of course the opposite effect. These changes may be of the same order of magnitude as the annual "internal" change in PMH.

MEASUREMENT OF EFFICIENCY IN AN ENTERPRISE

27. The social efficiency of a business must be distinguished from its "business" efficiency or efficiency from the profit-making point of view. This of course is determined by the capacity of the enterprise to buy suitable raw materials, to produce those goods which are most profitable from various points of view, to keep down manufacturing costs and to sell on the markets which give the greatest profit. The measurement of this efficiency presents a number of serious problems, which will not, however, be treated here at length. One obvious indicator is the monetary results of the business, but this is influenced by a number of factors over which the enterprise has no control, e.g. the market situation, raw-material prices and wages fixed by collective agreement. The use of any PMH measurement in this connection is quite out of the question. Owing to the divergence in the norms of evaluation it is of course by no means certain that the respective standpoints of the community and of the various enterprises will in every case coincide, and an increase in PMH which is regarded by

some groups as a social gain may be looked on by the individual business as an increase in costs.

28. It is, however, possible to separate out that part of business efficiency which most closely concerns the contribution made to it by the technicians. This is the capacity to produce the selection of goods decided upon by the management, with due regard to the market and to other relevant circumstances, at the lowest possible price. Let us begin by assuming that the prices for labour, raw materials and all other factors of production are kept unchanged. A reduction in costs could then only be brought about by diminishing the consumption of at least one of the factors of production. In that case it is therefore possible to assess the technical efficiency of an enterprise or an industry by reference to the total cost of current production compared with the corresponding cost if the consumption figures for the base year had continued to hold good. If we divide the former by the latter we obtain the change in the consumption of all factors of production where the weight of each factor is determined by its total cost. If the cost falls, the efficiency rises and we could then use the inverted value of this average figure as a measure of technical efficiency.

29. As soon as we set aside the assumption of unchanged prices for the factors of production the situation becomes more complicated. If, however, the figure for the consumption of all factors of production is changed in parallel the measure of efficiency will of course be the inverted value of the change on consumption. Thus, if the consumption of all factors falls by 10 per cent the efficiency measurement will be 100/90 = 1.11 and the efficiency may then be said to have risen by 11 per cent. When the consumption figures are changed in various ways it is necessary to weight them together in some manner in order to arrive at an efficiency index. In doing this, however, we immediately encounter serious difficulties, as the following example shows:

30. Assume that in a process of production only two factors of production are used. Their prices during two consecutive periods are :

	Factors of production	
	A	B
period 0	1	5
1	2	6

During the first period 100 units of the first factor and 10 units of the second factor are used, and the total cost will therefore be 150. After the rise in price the total cost would go up to 260, but it is possible to resort to substitution of the factors in such a way that the same total output is obtained by using only 80 units of the first while increasing the second to 15 units. As a result the total cost falls to 250. In this particular situation, the substitution must of course, be regarded as efficient. It is therefore, quite possible to use the current

prices in the measurement of efficiency, and in this way the measure 1.04 (260 divided by 250) is obtained. If, however, the prices then return to the situation during period 0 the total cost will be 155, unless a new substitution is made in such a way that the original situation with the cost at 150 is restored. This new substitution is of course efficient and according to the method of measurement used the co-efficient will be 1.03 (155 divided by 150). If we now compare the first period with the one last mentioned, we arrive at an efficiency increase of 7 per cent (1.04 x 1.03 = 1.07), in spite of the fact that both prices and the factor-consumption figures are the same.

31. In order to avoid this anomaly we can weight the consumption of factors with the prices during a base period, let us say period 0. This is what is done in a standard cost calculation. The standard cost during period 0 is 150 and it rises during period 1 to 155, which would indicate a decline in efficiency. This rise in standard cost has, however, been brought about because the real costs have been reduced by a substitution from 260 to 250, which must be rational. Thus this weighting procedure is also unsatisfactory.

32. It is on the whole probably true to say that there can be no satisfactory method of weighting the consumption of factors together. If we know the consumption of each factor used we can of course make a subjective judgment of the change in efficiency. As PMH is the inverted value of the manpower used per unit produced it is naturally of great interest to know it together with similar data for raw materials, fuel, power, etc. A sufficiently far-reaching breaking down of the PMH measurement can moreover enable us to localise a change to a certain process or section in an enterprise, and this may be of importance if we are looking for an explanation of the change in question. In itself, however, the measurement tells us nothing about the reasons for a change.

33. The PMH measurement which will be used here is not exactly the same as any of those mentioned up to this point, since it involves the elimination of the effect of quantitative shifts between different goods. Such a measurement is constructed as a production index where the quantities produced are weighted with the manpower consumed per unit during a base period, divided by an employment index. This might be called the average commodity PMH. The connection between this and the earlier measures is discussed in further detail in Section V.

34. It has been stated in various connections that the PMH measures here defined measure the technical efficiency in an enterprise or an industry. For this to be accurate the saving of all factors of production must, if technical efficiency is defined as above, have occurred roughly in parallel. As in the long run, the price of manpower has risen considerably more than the price of any other factor of production, most of the saving done has been on manpower. Since technical efficiency must be affected by all consumption figures the increase obtained

is therefore too steep if PMH is used as an indicator. In industries where labour costs constitute a large proportion of the total costs this over-valuation is perhaps not too important, but when the proportion is more than half, the over-valuation becomes impossible to assess. In Swedish industries such a proportion is the rule rather than the exception, and it is therefore altogether misleading to say that a PMH increase is a gain in efficiency, a step towards rationalisation, etc. To attempt to measure the international competitive capacity of an enterprise of an industry by means of PMH is even more misguided, as this capacity depends partly on the technical efficiency - which cannot be measured by PMH - and partly on relative changes in the price level and rates of exchange, over which the enterprise has no control.

THE CONNECTION BETWEEN DIFFERENT PMH MEASUREMENTS

35. As shown above, PMH is not an unambiguous term but represents a measurement which can be calculated in many different ways. It is therefore very important that one should know exactly what is required before deciding how the calculations shall be carried out.

36. The various PMH measurements are not of course entirely independent of one another, and if they are arranged in a certain order they can be regarded as the results of a successive elimination of different causes of variation. The measurement in most general use is the nominal social PMH, defined as the gross national product divided by the total number of hours worked in the productive system. If we eliminate here the effect of transferences of manpower between industries by having a weighted average of economic PMH in these, we obtain the industry PMH mentioned in the section on wages, this measurement of course still being nominal. If we limit the measurement to certain industries we can at this stage eliminate price changes and obtain the corresponding real PMH. From this, by keeping the structure of production constant, we can go on to calculate an average commodity PMH. As pointed out above, this may be of interest when assessing efficiency within an enterprise but it can also be calculated for a whole industry. It can then with the same reservations as for the enterprise, be useful when estimating the technical efficiency of the industry. This measurement is, however, also effected by shifts between enterprises with varying PMH figures. If we want to discover the average of the changes within enterprises the effects of the shifts must be eliminated; the result will be an average enterprise PMH.

37. When in this way we successively refer the variation in PMH to smaller and smaller units in business we also imply a change in the composition of the goods entering into the index, since in principle only final products are to be included at every stage in the calculations. Not all the things which are to

be reckoned as final products for an enterprise, however, are final products for the industry as a whole, and the final product of the industry are not the same as final products for the productive system as a whole. This means that it is not possible to obtain by any simple operation the commodity PMH, for example, for a certain industry from the corresponding measure for all firms in the industry. For this we require in addition information about the transactions going on among the enterprises. The same, of course, applies when calculating the PMH for an enterprise on the basis of the PMH for each section of it. The calculation of the "higher" forms of PMH is therefore attended with considerable practical difficulties, so long at least as we are not content with nominal measurements.

38. Disregarding changes in the composition of goods in the index the successive elimination of causes of variation can be described in formulae in the following way :

Let GNP represent gross national product,
C_i the contribution to GNP from industry i,
H the number of working hours in the whole productive system,
H_i the number of working hours in industry i,
$A = GNP/H$ total social PMH,
$A_i = C_i/H_i$ social PMH in industry i.

1. Nominal social PMH can then be written as

$$A = \frac{GNP}{H} = \frac{\Sigma C_i}{\Sigma H_i} = \frac{\Sigma \frac{C_i}{H_i} \cdot H_i}{\Sigma H_i} = \frac{\Sigma A_i H_i}{\Sigma H_i} .$$

If we compare two periods of time and let the upper index represent the period of time we obtain:

$$\frac{\Sigma A^{(1)}}{\Sigma A^{(0)}} = \frac{\Sigma H_i^{(1)} A_i^{(1)}}{\Sigma H_i^{(1)}} \cdot \frac{\Sigma H_i^{(0)}}{\Sigma H_i^{(0)} A_i^{(0)}} .$$

2. Now let $H_i^{(0)} = H_i^{(1)}$ for all i so that shifts between industries are eliminated. We then obtain the nominal industry PMH :

$$\frac{\Sigma A_i^{(1)} H_i^{(0)}}{\Sigma H_i^{(0)}} \cdot \frac{\Sigma H_i^{(0)}}{\Sigma A_i^{(0)} H_i^{(0)}} \cdot \frac{\Sigma A_i^{(1)} H_i^{(0)}}{\Sigma C_i^{(0)}} = \frac{\Sigma \frac{A_i^{(1)}}{A_i^{(0)}} \cdot C_i^{(0)}}{\Sigma C_i^{(0)}} ,$$

i.e. a weighted average of the social PMH's of the industries.

3. Let p_{ij} and q_{ij} represent the net value per unit and the quantity produced of commodity j in industry i. Then

$$C_i = \Sigma_j p_{ij} q_{ij} .$$

Let us now assume that the net values p_{ij} of all goods are constant = $p_{ij}^{(0)}$. The real industry PMH for an industry will then be

$$\frac{A_i^{(1)}}{A_i^{(0)}} = \frac{\Sigma_j p_{ij}^{(0)} q_{ij}^{(1)}}{\Sigma_j p_{ij}^{(0)} q_{ij}^{(0)}} : \frac{H_i^{(1)}}{H_i^{(0)}} ,$$

which can be put into (3). This is the most usual form for a PMH index.

4. If the change in the structure of production is now eliminated by placing in the above all $q_{ij}^{(1)} = q_{ij}^{(0)}$ we obtain the commodity PMH of the industry from (5)

$$\frac{A_i^{(1)}}{A_i^{(0)}} = \frac{\Sigma_j h_{ij}^{(0)} q_{ij}^{(0)}}{\Sigma_j h_{ij}^{(1)} q_{ij}^{(0)}} = 1 : \frac{\Sigma \frac{h_{ij}^{(1)}}{h_{ij}^{(0)}} H_{ij}^{(0)}}{H_i^{(0)}} ,$$

where hij represents the labour used per unit for the commodity j in industry i.

5. Now let h_{ijk} and q_{ijk} represent respectively the manpower used and the output in enterprise k of commodity j. If shifts between enterprises are eliminated, i.e. if q_{ijk} is constant, then

$$\frac{h_{ij}^{(1)}}{h_{ij}^{(0)}} = \frac{\Sigma_k h_{ijk}^{(1)} q_{ijk}^{(0)}}{\Sigma_k h_{ijk}^{(0)} q_{ijk}^{(0)}} = \frac{\Sigma_k \frac{h_{ijk}^{(1)}}{h_{ijk}^{(0)}} \cdot H_{ijk}^{(0)}}{H_{ij}^{(0)}} ,$$

which when put into (6) gives the average enterprise PMH.

VI

INDICES OF INDUSTRIAL EFFICIENCY

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THE SETTING OF THE PROBLEM

1. The topic set for discussion is "productivity", but it may be useful to look behind the immediate topic to the more fundamental ends to be served by such measurement. It may be suggested that the immediate purpose of productivity comparisons is to pinpoint those products or processes for which ameliorative action would seem to be particularly relevant. This is true whether the comparison is one between two countries or between two points of time.

2. Physical productivity figures provide only an indirect and incomplete road to the above end. This is because the highest possible productivity, in the meaning of a high output per man-hour, is not normally a target for industrial action. The quest for productivity is subject to economic limitations. The output per man-hour can generally be increased by using better raw materials (a fibre that breaks less easily, a richer ore, etc.), or by the purchase of more productive machinery, etc. Yet the ultimate criterion of industrial efficiency, against which these ideas for improvement will have to be tested, is: "Will it pay?"

3. The limitations of physical productivity comparisons are also confirmed by Dr. Rostas' comparative study of industrial productivity in the United States and in the United Kingdom. This pioneer study shows that in 20 out of 28 industrial sectors compared, the United States employed either more horsepower per worker in approximately the same proportion as its higher output per worker, or (in 14 out of 20 industries) disproportionately more horsepower. Only in 8 cases was the United States' lead in productivity greater than its superiority in machine power. These figures support what might be expected on a priori grounds, namely, that mechanisation is important to productivity. But this factor is not much subject to immediate

ameliorative action.* Moreover, since there is no consistent relationship between Europe's inferiority in physical productivity for a given industry and its inferiority in machine power, it is not possible to define what portion of the difference in physical productivity is attributable to factors other than superior machine power. In the final analysis, we are left very much at the start of our enquiry in paragraph 1.

4. It may be granted that these figures may mean something to the person intimately acquainted with the two industries compared. Furthermore, the likelihood of practical conclusions is increased tremendously when the comparison is brought down to individual products and processes as is the case for the Bureau of Labor Statistics' factory performance data. But if the problem is one for national governments of locating those industrial sectors, where measures to increase industrial efficiency are particularly indicated, it may be doubted whether overall comparisons of physical productivity provide much guidance. The fact that international differences in the output per man-hour have formed the departure for much valuable work to explain these differences, does not mean that future work would not benefit from a more relevant point of departure.

5. The purpose of the present paper is to find easily computable and reasonably sensitive indicators of industrial efficiency. Such indicators would add strength and better direction to the productivity drive. They would also help to place the problems of a common European market in a relevant and practical perspective by indicating those industrial sectors in a given country, where there are good opportunities for increased efficiency and good prospects for doing away with protection and subsidies and those sectors, on the other hand, for which the country lacks a sound economic basis, and where other solutions must be found.

6. A competitive selling price is a generally accepted measure of economic health. In an international comparison of selling prices, however, certain corrections would clearly have to be made for differences in the prices of important input factors. The new measure of relative industrial efficiency proposed in this paper is, in essence, a comparison of selling prices systematically corrected for differences in factor prices.**

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* The United States and European countries devote approximately the same proportion of their annual gross national product to investments. Since the per capita annual national product in the United States is anywhere between 2 1/2 and 4 times as high as in European countries, the difference in machine power is likely to grow in absolute terms. The immediate prospects for power supplies on the two Continents point to the same conclusions.

** This paper is devoted primarily to problems of comparing the performance of a given industry in different Member countries. Certain implications of a similar analysis for comparisons of productivity over time are tentatively suggested in Appendix B.

THE CONCEPT OF INDUSTRIAL EFFICIENCY

7. Industrial efficiency may be defined as the ability to produce at the lowest possible cost given a) the product, b) the prices of all available factors of production and c) the quality of all factors other than the single factor of management. *

8. Taking the product as given imposes one important limitation upon our concept - a limitation common also to comparisons of physical productivity. By definition we exclude from industrial efficiency the successful adaptation of products to the requirements of consumers and the balancing of the value and the cost of added variety. Not only is our concept of industrial efficiency transposed into a more limited concept of production efficiency. We also introduce a bias in the costs of the "given product", namely to the extent that better adaptation and more variety cost money. This observation is not a matter of theoretical interest only : in the producers goods field the cost of added variety may be more than compensated by economies in the next stage of production; in the consumer goods field it may be compensated by better value per unit of expenditure.

9. In the following, the usefulness of alternative measures will be analysed from two veiwpoints :

the theoretical characteristics and mutual relationships of alternative proximate indicators of industrial efficiency;

the practical problems in computing alternative proximate indicators of industrial efficiency in plant or industry comparisons.

10. The freezing of prices and qualities of factors of production is generally approximated with respect to establishments operating in the same national market. In comparing such establishments at a given moment, the inverse of the relative cost price (including a normal profit on the capital investment) of a specified final product or of the relative average cost price for a specified "basket of products" would therefore be a direct measure of industrial efficiency. Such cost comparisons are sometimes carried out by industrial associations, and it may be assumed that they serve as a stimulus to efficiency.

11. In a comparison of cost prices between two points of time or between two countries, prices and qualities of factors of production are likely to vary. The quality aspect may be quite important, and must be brought into a final judgment, but it will not be considered here. There are two possible ways out of the price dilemma :

adjusting cost prices in a systematic fashion to a common price level for the factors of production used. This involves computing what we shall term "an index of industrial efficiency";

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* See on this subject Chapter I, Section II.

using approximations for the index of industrial efficiency, like physical productivity, or cost prices expressed in terms of some kind of wage equivalent,* or using simply the actual cost price assuming differences in factor prices to be less important than other causes of differential efficiency.

12. Before going any further, it is important to define more precisely the nature of the suggested "index of industrial efficiency". This is done most easily by a reference to how it would be computed. Suppose we could transplant an American mill as a going concern to a European country, operating there in exactly the same way as in the United States from a purely operational point of view, but with that difference only that it would pay European prices for all factors of production (raw materials, labour, investment funds, equipment). The ratio of the total costs at such an imaginary mill to the actual costs under current operations in the European country concerned would be a measure of the relative economic performance (at European factor prices) of American and European mills. From a rigid logical point of view, there are two limitations to this concept, neither of which would seem to be of decisive importance. The comparison would normally be biased in European favour, since the relative dearness of certain factors of production in Europe as compared with the United States should make possible savings through a certain number of modifications in American practice. Secondly, it may not be practicable to duplicate the American operations, but this is not an intrinsic limitation of our measure.

THEORETICAL PROPERTIES OF ALTERNATIVE INDICATORS OF INDUSTRIAL EFFICIENCY

13. Mathematical expressions for the alternative measures introduced in paragraph 11 are given below in the form of indices showing the efficiency in the production of a given product for some period or country A in relation to a "base" period or country B. The following symbols will be used (the suffix -a referring to the country under review, the suffix -b to the "base" country);

q_a, q_b = quantity required of any one factor of production

q^1_a, q^1_b = number of man-hours required

p_a, p_b = price of any factor of production

p^1_a, p^1_b = average price per man-hour

The letter S will be used to indicate a sum.

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* This notion is one which has attracted in particular French productivity researchers. They have used the term "real cost price" for cost price expressed in current average hourly wage earnings as the unit of account /Cf. Chapter 1/.

14. We can then define our measures in the following way :

Index of Industrial Efficiency $(I^{A/B}) = \frac{S(q_b p_a)}{S(q_a p_a)}$

Inverse ratio of cost prices $(P^{A/B}) = \frac{S(q_b p_b)}{S(q_a p_a)}$

Inverse ratio of man-hour requirements $(R^{A/B}) = \frac{q^1_b}{q^1_a}$

Inverse ratio of cost prices expressed as wage equivalents $(FA/B) = \frac{S(q_b p_b)}{S(q_a p_a)} \times \frac{p^1_a}{p^1_b}$

15. Before investigating the mutual relationships of these indicators, it is necessary to clarify one further point. In speaking about "the relative industrial efficiency in producing a given product", we have implicitly assumed an identical degree of "integration" (i.e. that the raw materials enter all plants at the same degree of preparation and that end products leave at the same stage of finishing). The practical, as distinguished from the theoretical, implications of differences in the degree of integration will be studied later. At this point it should be emphasised that we are not normally interested in the whole production process, including efficiency in the production of purchased materials and services, but only in the contribution made by a given "industry". It will be seen that the price relatives P and F reflect the efficiency of industries supplying raw materials and services to the industry analysed as well as the efficiency of this industry proper. This could be corrected by adjusting the two prices compared for differences in raw material prices. Another way would be to restrict the comparison to values added. The practical method may be to deduct the approximate cost of major raw materials. In this way, one avoids difficulties arising out of varying degrees of integration. Furthermore, there is no necessity in computing measure F, to use an average of wage rates in the industry primarily measured and in supplying industries. *

16. The following comparisons of the mutual relationships of the various measures are equally applicable whether we

* In using the value added measure, abstraction is made from economies in the use of raw materials, and the possible importance of such economies would have to be considered separately.

define measures I, P and F in terms of "value added at cost" per unit of output, or in terms of cost prices. The practical significance of these mathematical properties, however, will obviously not be the same. Certain mathematical relationships* may be summarised in the following statements :

a_1) If the average prices for the various factors of production, as weighted by the quantities used in the base country, are the same in the country under review as in the base country, P will be a perfect substitute for I.

b_1) If the relative quantities of factors of production other than labour used in the country under review, as compared with the base country, are proportionate to the use of labour, R will be a perfect substitute for I.

c_1) If the relative prices for factors of production other than labour in the country under review, as compared with the base country, are proportionate to the prices for labour, F will be a perfect substitute for I.

17. These propositions may also be stated in the following terms :

a_2) To the extent that the average price level for factors of production is lower in the country under review than in the base country, P will give too high a value as compared with I and vice-versa.

b_2) To the extent that the relative requirements of factors of production other than labour in the country under review, as compared with the base country, are lower than its labour requirements, R will give too low a value as compared with I, and vice-versa.

c_2) To the extent that the relative prices for factors of production other than labour in the country under review, as compared with the base country, are higher than the prices for labour, F will give too low a value as compared with I, and vice-versa.

18. The relative importance of the above biases will obviously differ depending upon the country and products compared. The first preliminary observation at this stage is that, when a comparison is sought, it is important to have all four alternative indicators in mind. Thus if the price levels for relevant factors of production are very similar in two countries, it might be a great waste of effort to engage in a possibly very difficult comparison of physical productivity.

* The proof of these relationships is given in Appendix A.

19. Some additional practical insight may be gained by reference to an assumed comparison, for a given product or industry, between the United States and a European country. In such a comparison, measure P would be obviously deficient. Analysing measures R and F we would expect to find :

that the quantities used of factors other than labour (in particular investment funds and capital equipment) are relatively low in the European country;

that the prices of factors other than labour (in particular of capital equipment and investment funds) are relatively high in the European country.

Under these assumptions, as is clear from paragraph 17, both R and F would give too gloomy a picture of European industrial efficiency.

20. The most interesting question is which of the two measures would, under given conditions yield the present closest approximation of I. It is shown in Annex A that $F_{A/B}$ will be greater than $R_{A/B}$, hence (under the assumptions made in paragraph 19) a closer approximation of I, when

$$\frac{q^1_a p^1_a}{S(q_a P_a)} > \frac{q^1_b p^1_b}{S(q_b P_b)},$$

or in non-mathematical terms, when the ratio of labour costs to the cost price (or to the value added, if this is the basis for measure F) is higher in country A than in country B.

21. If we take the United Kingdom as country A and the United States as country B, there is some prima facie evidence that this condition was fulfilled for a majority of industries in a pre-war comparison. To test this hypothesis on the basis of available data, it was necessary to make certain changes in the above formula with a view to showing that $F_{A/B}$ will be greater than $R_{A/B}$ when the ratio of values added per worker in country B as compared with country A is higher than the ratio of average weekly earnings per worker. The proof of this proposition is given in Appendix A.

22. In October 1938, the average weekly earnings of workers in manufacturing industries were 1.8 times higher in the United States than in the United Kingdom (using an exchange rate of (£1 = $5). The relationship of values added per worker may be seen from the following table (all figures in $; United Kingdom figures converted into $ at the rate of £1 = $5). *

* Figure from Table 8 in Rostas, Comparative Productivity in British and American Industry. The only difference as compared with that table is the use of a constant rate of exchange (corresponding roughly to the 1935-38 level) instead of a variable rate. This was done on the assumption that the devaluation of the £ in 1939 reflected other factors than a change in relative prices in the United Kingdom as compared with the United States.

COMPARISONS OF NET OUTPUT PER WORKER IN CERTAIN INDUSTRIES

INDUSTRY	NET OUTPUT PER WORKER IN THE U.K.	RATIO OF NET OUTPUT PER WORKER U.S./U.K.	PERIOD OF REVIEW U.K.	PERIOD OF REVIEW U.S.
Tin cans	910	3.8	1937	1937
Beet sugar	1445	3.3	1935	1939
Biscuits	1260	3.2	1935	1939
Pig iron	1865	3.0	1937	1937
Glass containers.	1300	2.9	1935	1939
Machinery	1375	2.7/2.8	1935	1937-1939
Linoleum	2100	2.6	1935	1939
Coke	1615	2.4	1935	1939
Paper	1545	2.4	1935	1939
Fish curing	1015	2.4	1935	1939
Soap	3220	2.2/3.2	1935	1935-1939
Grain milling ...	2610	2.2	1935	1937
Rayon fibre	1125	2.1/3.1	1935	1935-1939
Manufactured ice.	2465	2.1/2.7	1935	1935-1939
Motor cars	1440	2.0/2.3	1935	1935-1939
Steel works and rolling mills ...	1690	1.9	1937	1937
Woollen and worsted	955	1.9	1937	1937
Boots and shoes .	810	1.9/2.0	1935	1935-1939
Cotton spinning and weaving ...	730	1.8	1937	1937
Rayon weaving ..	790	1.8	1935	1937-1939
Wireless sets ...	1245	1.7/2.4	1935	1935-1939
Iron foundries...	1045	1.7/2.3	1935	1935-1939
Hosiery	815/875	1.7/1.9	1937-35	1939
Rubber	1960	1.7/2.2	1935	1937-1939
Breweries	4635	1.5/2.2	1935	1935-1939
Brick	1150	1.4/1.7	1935	1937-1939
Seed crushing ...	2270	1.3	1935	1939
Cement	3485	1.1/1.5	1935	1935-1939
Matches	2240	1.0/1.0	1935	1935-1939

23. The above figures may be divided into the following classes :

Indication with respect to thesis that F is better than R	Number of industries
Supporting (3.8-2.0)	15
Indifferent (1.7-1.9)	9
Refuting (.7)	5

The five industries where the prima facie evidence was against using indicator R, were cement, bricks, seed crushing, breweries, and matches. In the first three industries, the ratios of physical output United Kingdom/United States being respectively 1.06, 0.83 and 0.86, were exceptionally favourable to the United Kingdom. In this case, the condition stated at the end of paragraph 20 is not likely to be fulfilled, and measure R, in all probability, will be a better indicator than measure F.

As for breweries and matches, a possible explanation is that the proportion of labour cost was lowered considerably in the United Kingdom through the influence of direct taxes. This, it would seem, is the only way in which one could explain the following difference in the ratios of value of net output per worker as compared with the ratios of physical output.

Ratios United States/United Kingdom

	VALUE NET OUTPUT PER WORKER	PHYSICAL OUTPUT PER WORKER (MILLION BARRELS RESP. MILLION MATCHES)
Brewing	1.5	2.1
Matches	1.0	3.4

The above figures point to the necessity, in computing measure F, to deduct special excise taxes from the respective selling prices.

24. The conclusions from the theoretical discussion may be summarised as follows :

in comparing the overall performance of an industry, as between different countries, the relative outputs per man-hour are no good clue to industrial efficiency;

there is substantial prima facie evidence that relative prices expressed in average hourly wage earnings as the unit of account would be a better approximation of industrial efficiency;

where price levels for important factors of production are reasonably similar in two countries, the relative cost prices of the finished products might be a good first hand indicator of industrial efficiency;

except under the special conditions just mentioned, neither of the proximate measures can be regarded as a reasonably sensitive indicator of industrial efficiency. Hence, the exploration of the practical possibilities of direct measurement of industrial efficiency (measure I) becomes an urgent matter.

THE PRACTICAL ISSUES

25. The practical problem in international comparisons of physical productivity, it appears to me, is the following : If we use published statistics, i.e. census type data, we are up against formidable practical barriers due to differences in product composition, differences in vertical integration and differences in the years for which bench-mark data for different countries are available. For intercensal years, we have to face the lack of output data, for certain industries, other than those based upon man-hour series, differences in the exact coverage of output and man-hour series; and generally, a higher margin of error in our output data.

If we leave aside census type data and concentrate our attention on factory records of man-hour requirements for individual products, we encounter problems of very much the same order as those involved in computing indices of industrial efficiency without obtaining results of the same significance.

26. A problem common to measures P, F and I is the one of obtaining prices for representative and comparable products (and possibly of making an adjustment for more important differences in design or quality). Yet the fact that we are forced from the very beginning to achieve substantial comparability will be a major advantage when evaluating the significance of our indices.

27. In indices based upon measures P and F, a varying degree of integration in the factories compared need not bother us. It is true that, if we compare end product prices, our measures will also reflect the productivity of industries manufacturing raw materials, parts, and sub-assemblies. If we prefer it, however, we may, as already mentioned in the theoretical discussion, deduct the cost of principal raw materials and concentrate our attention on the manufacturing margins. Thus, in comparing wool yarn prices, we may deduct the cost of wool (incidentally checking that the qualities of wool used are reasonably comparable); in comparing prices for household castings, we may deduct the cost of the molten iron, etc. Computing measure F from measure P involves a simple division of prices by average hourly wage earnings. If P stands for the manufacturing margin, rather than the price for the end product, the denominator would be the average hourly earnings in the factories making the products compared.

28. The steps involved in computing measure I are shown in the following hypothetical example :

COMPOSITION OF SELLING PRICE IN COUNTRY B		PRICE INDEX FOR COST FACTOR IN A (B = 100)	COST IN A BASED UPON "TECHNICAL COEFFICIENTS" FOR B	ACTUAL COST IN A
SPECIFICATION OF COST ITEM	ACTUAL COST			
Materials				
M_1	20	100	20	22
M_2	10	120	12	12
Labour				
L_1 (professional)	10	50	5	
L_2 (other)	30	40	12	
Depreciation				
D_1 (building)	4	100	4	
D_2 (machinery)	6	133	8	
Other overhead (advertising, insurance, etc.)	10	70	7	
Interest and profit	10	150	15	
Taxes(1)	6	150	9	
Total selling price(2)	106		92	102
minus taxes	-6	150	-9	-9
Selling price less taxes	100	-	81	93
Manufacturing marging(3)	70	-	49	59

(1) Taxes paid by the manufacturer either in the form of turnover, excise real estate, or income taxes, but excluding pay-roll taxes and social security payments which should be included under labour costs.

(2) After deduction for taxes. The type of sale, e.g. to final consumer or to full service wholesaler, should be clearly indicated.

(3) Selling price minus cost of materials minus taxes.

29. The data required for the above computation may be summarised as follows :

the selling price and its breakdown, by cost elements, in country B;

the selling price only in country A;

price indices for major cost elements in country A, where the corresponding prices in country B = 100.

There should be no difficulty in obtaining comparable selling prices adjusted to reflect the same stage of distribution The practical problems involved in obtaining a cost breakdown and price indices for cost factors merit closer attention.

30. If a plant made only one product, the breakdown of costs shown in the preceding table would roughly correspond both to the debit side of the profit and loss statement and to a cost statement for this single product. Where several products are made, however, the normal cost statement for a given product might look somewhat as follows :

Materials	
M_1	20
M_2	10
Cost Centre C_1	
Direct Labour	10
Factory burden*	20
Cost Centre C_2	
Direct Labour	10
Factory burden*	17
Selling and administrative overhead*	13
Taxes	6
TOTAL COST PRICES **	106

* Including a "normal" rate of return on the capital investment.
** Assumed to be identical with the selling price.

31. This cost statement is not immediately useful in computing measure I, but it may be re-arranged in a suitable manner, if the product is a relatively simple one. Behind the mark-ups on "direct labour" in cost centres C_1 and C_2, and on total factory cost for selling and administrative overhead, there is available a complete breakdown of the elementary cost factors (indirect labour, depreciation, etc.) allocated to these cost centres, so that these elementary cost factors can be ascertained for each cost centre and summed up for all cost centres.

32. When we deal with a very complex product, e.g. an automobile, there would be a very great number of individual cost statements for various parts, for which this type of deduction would have to be made, and the whole process would be too unwieldy. For such a product, therefore, we should have to fall back upon the joint profit and loss account for the firm or for

the department, and we would encounter very much the same problems of differences in product composition and differences in integration, which cause such trouble in comparisons of physical productivity.

33. Price indices for cost factors should not be too difficult or costly to compute. Indices for raw materials and for wages, including social security payments, might be obtained from various published government or private statistics, although direct enquiries in the industries concerned would tend to improve the results. The indices for other factors (e.g., cost of buildings, taxes, rates of interest on industrial loans, executive salaries, professional services included in factory overhead, etc.) would presumably be similar for most industries, and one careful study might therefore provide all the data needed.

34. The art in the application of measure I would be to find relatively simple yet significant cost breakdowns. Below I have attempted a rough and very abbreviated efficiency comparison for a common durable consumer product in two Member countries. My rough estimate was made as follows: *

FACTORS	ACTUAL COST PRICE COUNTRY X	PRICE INDICES	COST IN COUNTRY Y BASED UPON TECHNICAL COEFFICIENTS FOR COUNTRY X
Raw materials	33	90	30
Labour and overhead	57	76	43
Interest and profits	10	150	15
Selling price, deducting taxes	100		88
Actual selling price in country Y, deducting taxes			130

* It so happened that I had some information regarding the cost breakdown of the selling price for this product in one of the countries. The price index for raw materials is a rough estimate, subject to a considerable margin of error. The estimates of the relative levels of capital costs and taxes are also rough. Both labour and overhead costs have been deflated by the price index for the earnings of factory workers in the industry concerned. It would have been desirable, of course, to use a separate deflator for overhead costs other than indirect labour.

35. The general conclusion emerging from the above examination is that it should not be difficult to obtain acceptable measures of I. Moreover, data collection and analysis might be expected to be less costly than a laborious attempt to reconcile census date for different countries. It is unlikely that industrialists should be unwilling to provide the breakdown of costs, by elementary cost elements, since such a statement would provide no real insight into operations. An exception should perhaps be made for profits data. It is important to stress therefore that the actual computations might be made by a statistical agency or by a firm of certified public accountants, and that there would be no need to disclose the details of the cost breakdown, but only the final results - i.e. the price in country B recalculated according to the prices for various cost factors in country A.

APPENDIX A

PROOF OF THE PROPOSITIONS ADVANCED IN PARAGRAPHS 16 AND 17

1. Proposition a_1 and a_2 would seem to be self-evident.

2. The following proof applies to propositions b_1 and b_2.

$$I^{A/B} \geqslant R^{A/B} \qquad \text{when} \qquad \frac{S(q_b p_a)}{S(q_a p_a)} \geqslant \frac{q^1_b}{q^1_a} \; ;$$

which may be restated (using p^o and q^o to indicate quantities and prices of factors of production other than labour)

$$\frac{q^1_b \; p^1_a + S(q^o_b \, p^o_a)}{q^1_a \; p^1_a + S(q^1_{o_a} p^o_a)} \geqslant \frac{q^1_b \, p^1_a}{q^1_a \, p^1_a}$$

and, since $\dfrac{a+x}{b+y} \geqslant \dfrac{a}{b}$ is equivalent to $\dfrac{x}{y} \geqslant \dfrac{a}{b}$,

$$\frac{S(q^o_b \, p^o_a)}{S(q^o_a \, p^o_a)} \geqslant \frac{q^1_b}{q^1_a}$$

which means that $I^{A/B} = R^{A/B}$ when the weighted average B/A ratio for requirements of factors other than labour (the weights used being the prices for these factors in country A) is equal to or greater than the ratio of manpower requirements. If B is the United States and A is a European country, this condition means that the United States would have to use other factors than labour more freely than in Europe.

3. The following proof applies to propositions c_1 and c_2

$$I^{A/B} \geqslant F^{A/B} \text{ , where } \frac{S(q_b p_a)}{S(q_a p_a)} \geqslant \frac{S(q_b p_b)}{S(q_a p_a)} \times \frac{p^1_a}{p^1_b}$$

$$\text{i.e. where} \qquad \frac{S(q_b p_a)}{S(q_b p_b)} \geqslant \frac{p^1_a}{p^1_b}$$

which means that $I^{A/B} = F^{A/B}$ where the weighted A/B ratio of prices for all factors (or, if we want, for factors other than labour) is greater than the ratio of labour prices. If B is the United States and A is a European country, the condition is that labour would be cheaper relative to other factors of production in Europe as compared with the United States.

PROOF OF THE PROPOSITION ADVANCED IN PARAGRAPH 20

1. $F^{A/B}$ will $\geqslant$ $R^{A/B}$ where

$$\frac{S(q_b p_b)}{S(q_a p_a)} \cdot \frac{p^1_a}{p^1_b} \geqslant \frac{q^1_b}{q^1_a} \quad ;$$

which may be written: $\dfrac{q^1_a p^1_a}{S(q_a p_a)} \geqslant \dfrac{q^1_b p^1_b}{S(q_b p_b)}$

which means that $F^{A/B} = R^{A/B}$ when the portion of labour cost in the total cost prices is higher in country A than in country B.

PROOF OF THE PROPOSITION ADVANCED IN PARAGRAPH 21

1. If n_a is taken to represent the total number of units produced in country A in the period under review and v_a the average number of workers engaged in the period, the immediately preceding equation may be restated as follows :

$$\frac{\dfrac{n_a (q^1_a p^1_a)}{v_a}}{\dfrac{n_a S(q_a p_a)}{v_a}} \geqslant \frac{\dfrac{n_b (q^1_b p^1_b)}{v_b}}{\dfrac{n_b S(q_b p_b)}{v_b}}$$

2. The term $\dfrac{n_a (q^1_a p^1_a)}{v_a}$ is equal to the average total earnings per worker in the period under review. The equation will remain valid, if both numerators are divided by m (= the total number of weeks in the period under review), i.e. if they are made to represent the average weekly earnings per worker instead of the average total earnings per worker.

3. We may therefore restate the equation as follows :

$$\frac{\frac{a_b S(q_b p_b)}{v_b}}{\frac{a_a S(q_a p_a)}{v_a}} \geqslant \frac{\frac{a_b (q^1_b p^1_b)}{m v_b}}{\frac{a_a (q^1_a p^1_a)}{m v_a}}$$

which says that $F^{A/B} = R^{A/B}$, where the B/A ratio of net outputs per worker is higher than the ratio of weekly earnings per worker.

APPENDIX B

THE PROBLEM OF MEASURING CHANGES IN INDUSTRIAL EFFICIENCY OVERTIME

1. A question arises as to the exact purpose and significance of time series purporting to show changes in the overall output per man-hour in different industries. Such series may register tremendous gains in productivity, when there has, in fact, been a deterioration in industrial efficiency. This is quite obvious, but may be brought out in a few illustrations. Highly mechanised steel rolling mills projected for a certain relatively underdeveloped and low-wage country, have been characterised by some experts as a misinvestment which would not be an economic proposition even in a highly industrialised, high-wage country. Similarly, there is a trend in some countries towards increased mechanisation of foundries with consequent substantial gains in the output per man-hour. The purpose is not so much to improve industrial efficiency (in fact, costs have sometimes risen) as to make possible an expansion of output in the face of an expected shortage of manpower. Under these circumstances, differences in the rates of growth of physical productivity in different industries may be more a reflection of a relatively high investment effort in certain industries than of a differential development in industrial efficiency.

2. Because of this theoretical ambiguity, and also because of practical difficulties in obtaining statistically adequate expressions for overall changes in physical productivity, great importance must be attached to a firm analysis of the reasons for observed changes. But it is frustratingly difficult, at this overall level, to get down to and to assay the relative importance of various factors influencing productivity. This is done more easily in the case of factory performance data by products,

and is one of the reasons why such data may be of greater practical significance. For internal use within the individual enterprise or factory, physical productivity series may be of great value in spotting short run fluctuations in efficiency, since, in the short run, the inputs of other factors than labour will probably not change very substantially, and, at that level, major changes would not escape attention. The practical value of such physical productivity data will depend upon the industry but there are examples of considerable ingenuity being used to compute productivity indices corrected for current changes in the composition of output. (Cf. "An Index for a Steelwork", one of the case studies presented in the report by the Anglo-American Council on Productivity on "Productivity Measurement in British Industry".)

3. A more common method of efficiency control, particularly at top management levels, would seem to be analyses of variances from standard costs. Among the advantages of this method are the following : it takes into account changes in the inputs of factors other than direct labour, and it distinguishes between changes in efficiency due to variations in the volume of output and those independent of the rate of output. It is possible to include changes in factor prices as an independent variable, explaining one portion of the difference between actual and standard costs. In practice, it is probably preferable to adjust standard costs so as to reflect as far as possible the expected average factor prices over the accounting period, or even to change them in the course of the accounting period when important changes in factor prices occur. Whichever method is used in practice, the development over time in actual costs expressed as a percentage of standard-cost-corrected-for-factor-price-changes would be a sensitive indicator of industrial efficiency.

4. If we accept the necessity of frequent adjustments in standard costs to take into account changes in factor prices, a question arises as to the usefulness of standard costs accounting in factories producing tens of thousands of different items. One large Swedish concern uses the following method to parry this difficulty. It divides its products into groups relatively homogeneous with respect to the cost breakdown of individual products, i.e. the percentage of labour costs to total costs or the proportion of raw materials costs represented by steel as contrasted with copper or brass items. It selects a prototype for each group - which may be an actual product or a theoretical construction - and measures, carefully and at regular intervals, changes in the standard costs for this prototype due to price fluctuations. The percentage change applicable to the prototype is then applied to the standard costs of all members of the group.

5. This practical experience is not without relevance to our present enquiry. The measure I introduced in this paper is substantially the application of the same principles to an international comparison of industrial efficiency.

ANNEXES

ANNEX I

I

NOTES ON THE VALIDITY OF EXPRESSING PRODUCTION IN TERMS OF VALUE IN PRODUCTIVITY CALCULATIONS

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1. For the purposes of this argument, P is assumed to represent a complex of elementary productions of separate products; $q_1, q_2 \ldots\ldots q_n$ represent the physical quantities of these products, $c_1, c_2 \ldots\ldots c_n$ unit consumptions of the factor of production concerned and $p_1, p_2 \ldots\ldots p_n$ unit prices of the elementary productions. All symbols relating to data for the base year carry the sign o (e.g. q_1^o, c_1^o, p_1^o) while symbols relating to data for the current year carry no sign.

2. The classical index for production (Laspeyres' s formula) is:

$$I = \frac{\Sigma p^o q}{\Sigma p^o q^o}$$

The corresponding index for the use of the factors of production is obtained from the formula:

$$i = \frac{\Sigma cq}{\Sigma c^o q^o} .$$

The relationship $J_1 = \frac{I}{i}$ may therefore be taken as an index of productivity, calculated as follows:

$$J_1 = \frac{I}{i} = \frac{\Sigma p^o q \; . \; \Sigma c^o q^o}{\Sigma p^o q^o \; . \; \Sigma cq} .$$

3. Again, the index of productivity for the factor of production concerned may be written as follows:

$$J_2 = \frac{\Sigma c^o q}{\Sigma cq} .$$

This index expresses the relationship between total consumptions for the same structure of production (during the current period) under production conditions during each of the two periods.* The term J_2 may therefore be properly regarded as the only accurate index of changes in the productivity of the current structure of production between the two periods.

4. In practice, the necessary data are often available for the calculation of J_1; but this index is obviously distorted by the presence of unit prices of production which cannot determine the productivity of a single factor. The validity of J_1 can therefore be checked by comparison with J_2.

5. This can be done by comparing the two following expressions:

$$A = \frac{J_1}{J_2} = \frac{\Sigma p^o q}{\Sigma p^o q^o} \cdot \frac{\Sigma c^o q^o}{\Sigma cq} : \frac{\Sigma c^o q^o}{\Sigma cq^o} = \frac{\Sigma p^o q}{\Sigma p^o q^o} \frac{\Sigma c^o q^o}{\Sigma c^o q}$$

This relationship is the quotient obtained by dividing a price-weighted index of production by an index of production weighted on the basis of unit consumptions. When the result is unity, the price weighted index is accurate and significant.

6. Consideration must next be given to the conditions under which the terms of the following equations will be fulfilled (i.e. A = 1; no error);

$$\frac{\Sigma p^o q \, \Sigma c^o q^o}{\Sigma p^o q \, \Sigma c^o q} = 1$$

$$\frac{\Sigma p^o q}{\Sigma p^o q^o} = \frac{\Sigma c^o q}{\Sigma c^o q^o}$$

These two indices of production weighted by prices and unit consumption respectively will be equal:

either if $p_1^o = k\, c_1^o$ (k and h being constant proportional factors for all values of i)

or if $q_i = h\, q_i^o$

In other words, the index of productivity calculated from values at constant prices will be accurate :

a) either if the elementary current productions are proportionate to the basic elementary productions (this occurs if the two structures of production are strictly homothetic),

b) or if prices are proportionate to unit consumptions (as stated previously).

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* This index J_2, weighted on the basis of data for the current period, is the correct index of productivity for the current structure of production. A second index weighted in accordance with quantities produced during the base period would be valid for the structure of production during that period.

7. The next problem is to ascertain whether the error involved in expressing production at constant prices can be calculated.

This error can be represented by :

$$1 - A = \frac{J_2 - J_1}{J_2}$$

$$1 - A = 1 - \frac{\Sigma p^0 q \, \Sigma c^0 q^0}{\Sigma p^0 q^0 \, \Sigma c^0 q}$$

$$1 - A = \frac{\Sigma p^0 q^0 \cdot \Sigma c^0 q - \Sigma p^0 q \cdot \Sigma c^0 q^0}{\Sigma p^0 q^0 \qquad\qquad \Sigma c^0 q}$$

8. The calculation for the general case can be expressed in the following terms:

$$p_i^0 = (k + r_i) \, c_i^0$$

$$q_i = (h + t_i) \, q_i^0$$

where k and h are constant for all values of i, and r_i and t_i are coefficients varying with the value of i.

The numerator $\Sigma p^0 q^0 \, \Sigma c^0 q - \Sigma p^0 q \, \Sigma c^0 q^0$ becomes

$$\Sigma (k + r_i) \, c^0 q^0 \, \Sigma (h + t_i) \, c^0 q^0 - \Sigma (k + r_i) (h + t_i) \, c^0 q^0 \cdot \Sigma c^0 q^0 ,$$

or by using the simplified term $\Sigma c^0 q^0 = E$ and applying the constants k and h wherever possible, this expression becomes:

$$(k E + \Sigma r c^0 q^0) (h E + \Sigma t c^0 q^0)$$
$$- (k h E + k \Sigma t c^0 q^0 + h \Sigma r c^0 q^0 + \Sigma r t c^0 q^0) E$$
$$= k h E^2 + k E \Sigma t c^0 q^0 + h E \Sigma r c^0 q^0 + \Sigma r c^0 q^0 \Sigma t c^0 q^0$$
$$- (k h E^2 + k E \Sigma t c^0 q^0 + h E \Sigma r c^0 q^0 + E \Sigma r t c^0 q^0)$$
$$= \Sigma r c^0 q^0 \cdot \Sigma t c^0 q^0 - \Sigma c^0 q^0 \cdot \Sigma r t c^0 q^0 .$$

The constants k and h disappear leaving a symmetrical expression in relation to r_i and t_i; in other words under the same conditions the degree of error depends, first, on the difference r_i between actual prices and homothetic consumption prices, and second, on the difference t_i between actual productions during the current period and productions exactly homothetic with those of the base period.

9. Clearly, the degree of error is directly proportionate to the differences represented by r or t; in other words, when consumptions are roughly proportionate to prices (as is frequently the case with the labour factor since man-hours are often the determining factor in price variations) the quotient obtained by dividing the classical index of production by the consumption index for the factor of production concerned can justifiably be used as an index of productivity. There is much less justification if the factor of production concerned is only a small item in prices and if, therefore, consumptions of this factor are unlikely to be proportionate to prices. Under these circumstances, the quotient obtained by dividing the index of production by the index of consumption can only be used as an index of productivity, if the productions have shown similar trends.

10. For example, if variations in the productivity of electric energy in a particular industry are studied, the error may be large, as, in general, there is no reason why prices of products should be proportionate to energy consumption, owing to the high cost of the other factors of production. On the other hand, when consumption of the production factor concerned is a more important item in prices, p^o is more likely to be approximately equal to kc. This applies in particular to the productivity of labour. In practice, prices are often roughly proportionate to man-hours, particularly when, as is normally the case, the index used is weighted not by prices but by unit added value.

11. At the same time, the constant effort to raise the productivity of labour has led to the increasing use of more productive equipment which requires less operating manpower for equal production. As income from capital invested in such equipment is normally included in added value, unit added values may have no obvious relation to man-hours (or wages) within the same industrial complex, if the productivity of the equipment used by this industrial complex is not the same for all products manufactured during the base period under review.

12. In view of the foregoing, it is obvious that in sectors where a considerable amount of capital has already been invested in order to raise the productivity of labour, special care will have to be taken in order to obtain results which will show a real increase in productivity and not merely reflect a trend of production complexes towards groups of products characterised by a permanent increase in productivity.

13. Finally, all the productivity calculations discussed above may relate either to a whole industry within a particular country or to a single firm. In the former case, it should be remembered that the structure of production in a national industry is usually fairly permanent owing to the relative stability of demand; as a result, production structures are likely to remain approximately homothetic and the factor t_i, which represents differences in structures of production will be small, as will the degree of error. On the other hand, the structure of production for a single firm is likely to change more rapidly, at least in certain

industries, with the result that the degree of error is likely to be greater when production is expressed in terms of value.

14. Firms which undertake productivity calculations should therefore be urged to exercise great care in using values as weights. In such cases it is much better to calculate unit consumptions c_o from time to time, and to use these figures as the basis for a system of weighting. It is, of course, quite possible for a firm to change its structure of production fairly extensively, with the result that during any given current period, it will not have details of all c_o for current productions, as some will have been introduced since the base period. However, if the equipment of the firm concerned has remained substantially the same, it will be possible, by using consumptions related not to products but to operations carried out with the same equipment, to calculate theoretical elementary consumptions for new productions as if they had been undertaken during the base period.

15. On the other hand, there is generally less likelihood of error in the case of a study covering a whole national economy. At the same time, allowance should be made for the fact that changes in the structure of the production complex may produce artificial variations in productivity.

II

REFLECTIONS ON THE CONCEPTS OF LABOUR PRODUCTIVITY AND OF INTEGRATED LABOUR AT WORKS LEVEL

by Messrs. Rémery and Carrié

1. The object of this study is to recapitulate certain notions which, though simple enough, continue to give rise to much confusion. By drawing attention to the existence of two separate aspects of labour productivity - a "works" aspect and a "product" aspect - an attempt will be made to define the limits to be assigned to the labour expended per unit of product and the resulting notion of integrated labour.

Two ways of looking at labour productivity

2. In practical calculations of labour productivity there is a tendency to use the terms production per unit of labour and labour expended per unit of production, indiscriminately, although for reasons of convenience the latter is usually preferred. Behind the apparent inter-changeability of the two terms, however, there lies a difference of concept deserving closer consideration. It is, in fact, immediately obvious that the terms invert the order of investigation; according to the term used, labour is the known quantity and production the unknown, or vice-versa.

3. The aim of the notion of hourly production is to measure the results of a given activity. If it means the activity of the whole staff of a firm, it will have to be calculated at each stage of production; it would be inconceivable that production should be regarded as non-existent merely because it was localised in the intermediate shops. Hence, at works level the amount of labour expended should not be set against end production but against production at every stage.

4. On the other hand, the idea of labour expended per unit of production pre-supposes a clearly defined product whose material costs it it proposed to analyse in whole or in part. One factor in these costs is represented by labour in the sense of work done during the later stages, i.e. recent work; it would represent an even more substantial proportion if it included the work done at previous stages during the preparation of material, tooling, etc., often known as "incorporated" labour.

5. Thus the term "hourly production" means that the problem has been viewed from the angle of "production at every stage" or "production added", whereas "labour expended per unit of product" corresponds to the "final" viewpoint of a given product taken as a whole. As for labour, in the first case, it is usually clearly defined for any given enterprise; it might, for example, be the work done by the whole labour force. This is the sense in which the viewpoint may be defined as a "works" viewpoint in contrast to a "product" viewpoint. In the second case, however, the labour in question may merely be the work of the enterprise during the later stages of manufacture of the end product concerned. However, it might also include a given category of previous work. In fact the "product" viewpoint pushes into the background the concept of the limits of the enterprise. Hence in this case it becomes particularly important to have a precise definition of the labour expended.

6. The time which elapses between the work done at a given stage and the final result may be regarded differently according the whether the former or the latter viewpoint is adopted. With the former, labour is "present", i.e. completed within a given period, and the resulting production will only later assume the form of an end product, at successive stages in time. The latter viewpoint, however, concerns end production in a given period, and the corresponding amount of labour expended during the various previous periods. It is thus a historical concept, representing the aggregation and integration of various kinds of work.

7. If now the underlying aims of calculations at works level are examined, it will be found that here too both the concepts in question are operative. Calculations whose object is to follow the progress of the enterprise as a whole are concerned to express the results achieved each day and for each man-hour. More than deliveries ex works, or sales expressed in numbers of working hours, the main consideration is what the staff is doing, how the work is "progressing" (in the case of a lengthy cycle of production). In other words, this is truly a "works"

viewpoint, that of productivity at every stage. On the other hand, calculations whose object is to arrive at a sort of cost price of the end product in terms of the number of man-hours needed for a given production, are associated with the "product" viewpoint, as also are those whose object is to compare productivity in various firms for a given type of production.

Definition of labour from the "product" viewpoint, and notion of integrated labour

8. The labour to be set against a given production is essentially previous work, whether done inside or outside the firm. The problem is to know how far previous work should be taken into account, and what categories of labour that have been to a greater or lesser extent integrated or incorporated should be considered. A number of criteria may be applied in this connection: the most immediate one is the question of where the work was done, whether internally or externally; another is that of the order of sequence in time of the various categories of labour; thirdly, there is that of the technological relation between labour and production.

9. The difficulties that may be encountered in adopting the first criterion are well known, as is the wish to find within the firm the major part of the manpower needed. In addition to the problem of defining the limits of work done by the firm (e.g. home work), there is also in inter-firm comparisons the problem of defining jobs in exactly the same terms in each firm so that, because of different degrees of integration between the various units of production in one and the same branch:

some kinds of work not always encountered in that particular enterprise may be disregarded, and,

work which may have been done externally for certain enterprises may be taken into consideration.

10. The adoption of the second criterion may eliminate work which, although done internally, was unduly anterior to production: constitution of stocks, or preparation of raw materials.

11. Undoubtedly, the third criterion is the most important, because it takes into account the actual character of the connection between production and labour, thus establishing in some sort an extension of the notion of fixed and variable cost. While direct labour is by definition substantially proportionate to production, at least in the short-term prospect, the same is not true of the various other categories of labour, which may be either independent of production (fixed costs), or on the contrary bound up with it.

12. This enhances the importance of the productivity of direct labour as a constant characteristic of the firm's operations. On the other hand, the productivity of indirect labour (in its widest sense), only assumes significance at the most general levels (firm, industry, and above all, the national economy) and is always considered in the form of productivity of total labour

(direct and indirect). If we define work done within the firm as "internal" labour, and work corresponding to the various charges of the firm : investments, power, consumption of raw material, as "incorporated" labour, where in the light of the previous criteria is the dividing line between the two categories of labour to be drawn ?

13. The work done by the labour force (direct or indirect) involves no problem except in the case of tool-making or maintenance services. These services are not immediately connected with production, and are often supplied from outside the firm; they are therefore usually eliminated from calculations. The work done by these services will be defined as integrated. Among the other general services within the firm, the following deserve separate mention :

Vocational training, human relations : should be classified under the same head as personnel management, for the activities in question are directly bound up with production (though on a fairly long-term basis) and are designed to improve working conditions.

Welfare services : as the object of these is to assist wage-earners without any appreciable return, these constitute a charge designed to supplement the services normally provided by the community i.e. they are an integrated external factor.

Medical service : classification is more complex here as the service may have multiple aims:

a) watching over the health of the personnel with a view to their greater efficiency and a reduction in involuntary absenteeism;
b) helping to check voluntary absenteeism;
c) assisting personnel by offering free attention which could only be obtained elsewhere against payment.

Hence, in the light of a) and b), this service would be an internal factor, whereas in the light of c) it would be classified among integrated external factors.

Accident prevention service : this is a rather special case because it reduces the risks normally covered by insurance and provides for the safety of the labour force, thus making a direct contribution to the smooth running of the firm, so that it is possible to regard it as "internal".

Fire service : this ensures the safety of equipment and personnel under exceptional circumstances, and thus takes the place of a function normally fulfilled by the community. Hence, integrated labour does not even appear to form part of incorporated labour, and in this context may be regarded as purely external.

Public relations : the objects of this service are invariably very long-term, whether it be to keep the public informed of the firm's activities - in which case it approximates to advertising - or to improve welfare conditions - in which

case, it approximates to human relations. According to the work done by the service, it may be classified with advertising, i.e. as integrated, or with human relations, i.e. as internal.

14. These few examples will suffice to show the advantage of eliminating from calculations all those heterogeneous factors which have just been referred to under the generic term "integrated" labour. They all have the peculiarity of being normally capable of performance outside the firm, and of not being immediately connected with production. It would appear particularly desirable to split up this integrated labour into its component parts when making inter-firm comparisons of productivity.*

III

METHODS OF PRODUCTIVITY COMPARISON

by Mr. Harten and Dr. Rummel

1. All previously suggested methods of rationalisation depart from the assumption that the states concerned are prepared to carry out a mutual exchange of experience. In this way remarkable successes have already been achieved and a large amount of numerical data is available. However, the more one studies these figures the more evident does it become that it is extremely difficult to recognise the causes of discrepancies clearly enough to enable useful conclusions to be drawn for the purposes of individual rationalisation. A brief description and appreciation of some of the most familiar procedures for productivity comparisons is given in the following.

a) Price comparison

2. The figures obtained in an international comparison of the buying prices of similar products simply expresses the buying power of the currency units concerned in relation to the said product. But, apart from the fact that the rate of exchange as between the various currencies fluctuates continually, the above-mentioned buying price does not give any information on productivity as the total structure of the branches of economy compared is not taken into account. However, the buying price still remains an important point of departure for international comparisons (see paragraph 11, the Hour Buying Power Comparison).

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* See Volume II on this subject.

b) Per capita output

3. The man-hour method undoubtedly furnished the most revealing of all possible relevant indices for the level of output as related to the direct manufacturing hours. It is very useful for the comparison of trends over shorter or longer periods of time. Here, however, this comparison mainly reflects the progress of mechanisation. The important point in the productivity comparison, however, is the total number of hours expended for any given product, that is to say, including also the hours expended "behind the scenes", in the installations, in maintenance, in feeder transport, in energy consumption, etc. Above all, these must also include the hours to be amortised which are contained in the investments. All these additional costs associated with progressive mechanisation reduce the savings in direct wages.

4. This must be considered in comparing one individual works with another. In a comparison of the expenditure of work-hours, however, it is not only a question of expenditure in the individual plant, i.e. practically in the final stages of manufacture. What is required is to know the total number of work-hours contained in a product, beginning with the original production of the raw material input, through the various processing stages, down to the finished product as it leaves the plant. The determination of this figure is practically not always possible. Even if one succeeded in establishing the figure with some measure of accuracy for two plants to be compared, the comparability will, in most cases, be upset by the differences in the structure of the works, e.g. vertical integration of works, extent of auxiliary departments and plants, outside services, etc.

5. All attempts of this kind have failed due to the difficulties accumulating from stage to stage. Per capita output figures have been largely established, and are still being established, in one-sided relationship to the direct manufacturing hours. They provide important information for several special purposes, but without further critical analyses it is only in exceptional cases that they permit conclusions to be drawn on transferable rationalisation measures.

c) Added value method (output-input)

6. This procedure is applied internationally in official statistics. It thus primarily services political-economic purposes and can only be used within limits for the productivity comparison as an operational-economic task. Difficulties arise in a comparison of values as they are not expressed in physical units but in monetary units. Price and costs are the decisive bases for value comparisons.

7. A clear distinction must be made, however, between the conceptions of value and price. The price that must be paid by the buyer (market price) emerges from a compromise between considerations of value and of costs. This refers not only to the market price of a finished product but also to the prices which

all intermediate stages forming part of the manufacturing process of this finished article must pay. Mention is made here of the price-regulating influences of supply and demand, of government regulations and measures, etc., which may result in raw materials, intermediate and finished products appearing in the market at prices which may be far above or far below their actual cost.

8. The statement in Section b) on total work-hours for a product makes it appear doubtful whether a total calculation - there on a time basis, here on a value basis - is permissible. As a rule, the ordinary input calculation is restricted to raw materials only; occasionally it is also recommended that account be taken of the energy-bearers. The remaining cost items - ancillaries, investment goods, etc. - are disregarded, though actually, input includes everything except wages, salaries and interest on circulating capital. The disregard of the latter fact and the differences in the structures of the compared plants may lead to far-reaching erroneous conclusions.

d) The transplantation method*

9. This method is based on a mental experiment. One imagines a plant transferred to another country and operated there according to the methods it has hitherto employed. The evaluation of all cost goods and wages, however, is based on the prices which are valid in the transfer country. The resultant costs are established and compared with the actual costs at an actual plant in the transfer country. The idea is that this will show whether and to what extent the one or the other country is lagging behind in its rationalisation. One outstanding advantage of this method is that it dispenses with inconvenient inter-currency conversions.

10. On the other hand, it does not take account of the differences in the basic economic conditions of the comparing countries, and these are frequently so big that the weight of the individual cost groups must be completely different. This difference might perhaps be balanced with the help of a special equivalent calculation. But the question arises: should not the plant have been completely adapted from the outset to the economic structure of the transfer country, i.e. built and equipped on entirely different lines ? Is it not the case that the method of production is frequently determined by existing bottle-necks ? The transfer method can only give a distorted picture of a best possible integration of a works, and will thus lead to incorrect conclusions on the true differences in productivity.

e) The hour buying power comparison

11. If one divides the buying price of a product by the average earnings per hour of a worker a figure is obtained which indicates how many hours (buying hours) a man must work in order to be

* See Chapter VI by Mr. B. Walstedt on this subject.

able to buy this product. The inverse value of this figure is the hour buying power. As in d) the currency unit does not appear in this calculation, which has the further advantage that the established values are expressed in a clearly defined and internationally comparable physical unit, i.e. the hour (or some other time unit). As a rule, however, the data frequently to be found in technical publications are not comparable, as the values and characteristics of the basic conceptions, namely, product, buying price, and average earnings per hour are not indicated with sufficient accuracy.

12. In order to achieve international comparability, exact directives must be laid down and this, moreover, in consultation with experts in the fields of production and distribution economy, of the social system, of official statistics and of the institutes of economic science. As far as possible, account should also be taken of the influence of differences in the legal, tariff, and perhaps also the voluntary social allowances and of taxation, on the measure in which the worker can dispose of his earnings. But to start with, it is sufficient to have the uncorrected average earnings per hour.

13. It may be presumed that in these conditions it will be possible within a very short time to establish definitely informative and comparable results. Controls of this kind could be repeated at specified intervals under otherwise unchanged conditions. They would usefully supplement the control undertaken by government statistical offices or other authorities on global political-economic productivity, wage levels, maintenance of living costs, etc., and on the reciprocal relationships of these factors.

f) Comparison of structure*

14. Apart from its specific purpose, the comparison described under e) of the buying hours or of their inverse ratio, the hour buying power permits a remarkable insight into the level of productivity in the various countries, but it reveals nothing of the causes of the established differences. It is just these causes, however, that are of decisive importance if practical conclusions are to be drawn from the comparison for the purposes of rationalisation. The essence of this comparison is that the figures resulting from the investigation under e) are analysed, i.e. are broken down into partial indices which show at what points differences occur. These then form the points of departure for deliberations as to where and how measures shall be taken to increase productivity, i.e. to rationalise production.

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* See Vol. II on this subject.

ANNEX II

NUMERICAL EXAMPLES OF MEASURES OF PRODUCTIVITY

by a working party of the French National Committee for Productivity

One important point must be noted regarding the definitions given in Chapter II.

Measures of productivity differ for two reasons :

1. There is no single concept of productivity and the meaning of the term varies according to the relationship it is intended to express (gross or net specific productivity, overall productivity, integral productivity, etc.);

2. Furthermore the numerical expression of the concept adopted inevitably requires the introduction of certain conventions, such as reference to a given price system and naturally each convention produces a different numerical result. Clearly the result obtained has to be interpreted in terms of the method of calculation used.

It was felt therefore that it might be useful to illustrate the scope of the definitions given by means of numerical examples.

With the examples given below it will be possible not only to demonstrate the machinery of calculation but more especially to focus attention on the essentially relative difficulties inherent in all measures of productivity.

In particular it will be noted that variations in productivity as a result of changes in the structure of production will appear differently both according to the definition of productivity adopted and according to the price system used for reference purposes.

Finally, it should be pointed out that the numerical example used is extremely simplified, thus eliminating a number of the complications and uncertainties associated with all studies of real cases.

FIRST NUMERICAL EXAMPLE

Statement of problem

The example relates to an industrial operation involving the manufacture of two products (A and B) using three factors: labour (T), one raw material (M) and the services of equipment (E).

Labour and the raw material are assumed to be homogeneous. In particular it is assumed that all labour is equally skilled and that hourly wages are uniform.

Services of equipment comprise the cost of machines (interest, amortisation, maintenance) at current prices plus the necessary energy.

The structure of production is considered at two fairly widely separated periods, 1 and 2.

Production is assumed to have roughly doubled from period 1 to period 2. In addition prices of the various elements have risen from twenty to forty times. As a result of the combined increase in quantities and prices, the monetary value of production has multiplied by fifty.

Table 1 below summarises operating accounts for these two periods. The firm is assumed to sell its products at cost price without profit or loss. (The hypothesis could easily be varied to allow for profits or losses; the method of calculation would not be affected.)

Quantities of factors of production and finished products are measured in conventional units, e.g. labour in man-hours, raw materials in kilogrammes and services of equipment in machine-hours. (In the table the abbreviation "u" is employed to indicate units.)

Table 1

OPERATING ACCOUNTS FOR PERIOD 1 AND PERIOD 2

	PERIOD 1			PERIOD 2		
Products						
Product A	10 u. at	50 fr. =	500 fr.	20 u. at	1,000 fr. =	20,000 fr.
Product B	5 u. at	100 fr. =	500 fr.	12 u. at	2,500 fr. =	30,000 fr.
			1,000 fr.			50,000 fr.
Factors						
Labour T	100 u. at	5 fr. =	500 fr.	80 u. at	200 fr. =	16,000 fr.
Raw material M	50 u. at	8 fr. =	400 fr.	100 u. at	240 fr. =	24,000 fr.
Equipment E	20 u. at	5 fr. =	100 fr.	100 u. at	100 fr. =	10,000 fr.
			1,000 fr.			50,000 fr.

Table 2 shows changes in prices of the various products and factors.

Table 2

PRICE CHANGES FROM PERIOD 1 TO PERIOD 2

		Period 1	Period 2	Index 2/1
Products	A	50	1,000	20
	B	100	2,500	25
Factors:	Labour T	5	200	40
	Raw material M	8	240	30
	Equipment E	5	100	20

These figures show that prices rose as follows: 20 to 25 times for the products, 40 times for labour, 30 times for the raw material but only 20 times for the equipment. These differences are due to increased productivity in the production of the raw material and more especially in the manufacture of machines and the production of energy.

Changes in values at constant prices

In order to measure changes in productivity, differences caused by variations in the structure of prices must be eliminated by revaluing products and factors for period 2 in terms of period 1 prices, and conversely by revaluing products and factors for period 1 in terms of period 2 prices.

These calculations are shown in Table 3 below.

Table 3

RECALCULATION OF VALUES FOR EACH PERIOD IN TERMS OF PRICES FOR THE OTHER PERIOD

	Period 2 values in terms of period 1 prices	Period 1 values in terms of period 2 prices
Products		
Product A	20 u. at 50 fr. = 1,000 fr.	10 u. at 1,000 fr. = 10,000 fr.
Product B	12 u. at 100 fr. = 1,200 fr.	5 u. at 2,500 fr. = 12,500 fr.
	2,200 fr.	22,500 fr.
Factors		
Labour T	80 u. at 5 fr. = 400 fr.	100 u. at 200 fr. = 20,000 fr.
Material M	100 u. at 8 fr. = 800 fr.	50 u. at 240 fr. = 12,000 fr.
Equipment E	100 u. at 5 fr. = 500 fr.	20 u. at 100 fr. = 2,000 fr.
	1,700 fr.	34,000 fr.

In Table 4 below, values at constant prices for periods 1 and 2, obtained by calculating the cost of products and factors in terms of prices for each period, are shown side by side. In order to calculate the net productivity of labour this table gives separate totals for the values of factors other than labour (raw materials, equipment) and for the total value of all factors including labour. Net product (in relation to labour) is obtained by deducting the value of factors other than labour from the total value of products.

Table 4

CHANGE IN VALUES AT CONSTANT PRICES
(based on Tables 1 and 3)

	AT PERIOD 1 PRICES			AT PERIOD 2 PRICES		
	PERIOD 1	PERIOD 2	INDEX 2/1	PERIOD 1	PERIOD 2	INDEX 2/1
Products						
A	500	1,000	2	10,000	20,000	2
B	500	1,200	2.4	12,500	30,000	2.4
	1,000	2,200	2.2	22,500	50,000	2.21
Factors						
M	400	800	2	12,000	24,000	2
E	100	500	5	2,000	10,000	5
Sub-total	500	1,300	2.6	14,000	34,000	2.43
T	500	400	0.8	20,000	16,000	0.8
Grand total	1,000	1,700	1.7	34,000	50,000	1.47
Net product (in relation to labour)	500	900	1.8	8,500	16,000	1.88

Differences in changes in quantities of products and factors

The following table shows that changes in the quantities of products and factors have varied in extent (these quantities in terms of constant prices vary proportionately to values for each factor and product).

	Increase in quantities (number of times)
Product A	2
Product B	2.4
Raw material M	2
Services of equipment E	5
Labour T	0.8

The significant feature of this change is that the firm concerned has more than doubled its production with a 20 per cent saving of labour but at the expense of 400 per cent increase in its consumption of mechanical power; this change was facilitated by the relative drop in the cost of machinery as compared with the cost of labour (Table 2 shows that the cost of one machinery unit fell from one labour unit in period 1 to half a labour unit in Period 2).

Variations in overall values are affected by the price structure used for reference purposes

If we now consider variations in the value of a complex of products or factors as distinct from quantitative variations in each product or factor, we find that the former are influenced by the price structure (1 or 2) used for reference purposes.

The difference for total production is significant, owing to the fact that prices of products are only slightly distorted, but is appreciable both for expenditure and for the net product.

	INCREASES (NUMBER OF TIMES)	
	AT PERIOD 1 PRICES	AT PERIOD 2 PRICES
Total production	2.20	2.21
All factors except labour	2.6	2.43
All factors including labour ...	1.7	1.47
Net product in relation to labour	1.8	1.88

These observations suggest that the index of increased productivity will vary according to whether overall values are expressed in terms of period 1 or period 2 prices.

Change in productivity expressed in different ways

Table 5 below gives details of these calculations.

Table 5

CALCULATION OF PRODUCTIVITY INDICES

(Period 2 as compared with period 1)

1. Gross specific productivities	of labour	2.2 /0.8	= 2.75
	of raw material	2.2 /2	= 1.1
	of equipment	2.2 /5	= 0.44
2. Overall productivity of factors	at period 1 prices	2.2 /1.7	= 1.3
	at period 2 prices	2.21/1.47	= 1.5
3. Net productivity of labour	at period 1 prices	1.8 /0.8	= 2.25
	at period 2 prices	1.88/0.8	= 2.35
4. Integral productivity of labour	assumed index for integrated labour	$\frac{50,000/200}{1,000/\ 5}$	= 1.25
	assumed index for integral productivity of labour	2.2 /1.25	= 1.75

This table does not give absolute values for productivity, but indices of productivity in period 2 as compared with period 1. These indices are obtained by dividing the product indices by the factor indices. The following points should be noted in this connection:

1. Specific productivity of factors

These indices are obtained by dividing the index for gross total production by the index for consumption of each factor.

Table 4 shows that production in period 2 was 2.2 times greater than in period 1 in terms of period 1 prices, and 2.21 times greater in terms of period 2 prices. As these figures are very similar, 2.2 was used throughout.

Table 4 shows that the indices of consumption for the various factors were 0.8 for labour, 2 for the raw material and 5 for equipment.

Specific productivity indices of 2.75 for labour, 1.1 for the raw material, and 0.44 for equipment are obtained by dividing the index of production successively by the indices of consumption for the three factors.

2. Overall productivity of factors

This index is obtained by dividing the index of production in terms of value (2.2 at period 1 prices, 2.21 at period 2 prices)

by the index for the total value of factors consumed (shown by Table 4 to be 1.7 at period 1 prices and 1.47 at period 2 prices).

On this basis, the index for the overall productivity of factors is 1.3 at period 1 prices and 1.5 at period 2 prices.

3. Net productivity of labour

This index is obtained by dividing the index of net production in terms of value (shown by Table 4 to be 1.8 at period 1 prices and 1.88 at period 2 prices) by the index for labour (0.8).

On this basis the index for net productivity of labour is 2.25 at period 1 prices and 2.35 at period 2 prices.

4. Integral productivity of labour

The index for the integral productivity of labour cannot be calculated objectively as the quantity of labour incorporated in raw materials and equipment cannot be measured directly. As a result only a conventional estimate can be made.

Under this method, integrated labour (or total labour) is calculated by dividing total production costs by hourly wages at the firm concerned.

During period 1, for example, total production costs were fr. 1,000 and hourly wages fr. 5. Total "integrated" labour is therefore assumed to be 200 hours made up of 100 hours of "visible" labour and 100 hours "incorporated" labour.

Similarly, during period 2, fr. 50,000 of production costs divided by an hourly wage of fr. 200 give 250 hours of "integrated" labour, made up of 80 hours of "visible" labour and 170 hours of "incorporated" labour.

These figures suggest that integrated labour rose by 25 per cent from 200 hours to 250 hours whereas visible labour fell by 20 per cent from 100 hours to 80 hours; this increase in integrated labour can be attributed to the 70 per cent increase in incorporated labour.

These figures give an index of 1.25 for integrated labour in period 2 as compared with period 1; dividing the index for gross production (2.2) by this new index we obtain the assumed index for the integral productivity of labour (2.2 divided by 1.25 = 1.75).

It must be borne in mind that this calculation is purely conventional. In order to estimate the quantity of labour incorporated in factors other than visible labour (raw materials, equipment, etc.) the cost of these items is divided by hourly wages of visible labour. This calculation is based on two assumptions: a) that these costs consist solely of wages (whereas in fact they include capital income in the form of rent, interest and profits); and b) that the average level of such wages is the same as for visible labour. Clearly these two hypotheses are unreliable. During a period of intense economic activity, raw material producers may earn high profits; wage rates vary considerably between industries and areas (in agriculture, for example, wages are often only half or one third of the figure for the most prosperous industrial branches). Consequently, measures of the integral productivity of labour should be treated with great reserve.

Trend of wage-prices

These conventional and subjective estimates of the integral productivity of labour can be compared with the objective calculation of wage-prices.

The wage-price of a product is obtained by dividing its monetary price by a suitable unit wage (in practice, hourly wages).

Using the figures in Table 1, wage-prices for products A and B in periods 1 and 2 are calculated below, assuming hourly wages to be fr. 5 and fr. 200 respectively.

	Period 1	Period 2
Hourly wages	5	200
Monetary prices:		
Product A	50	1,000
Product B	100	2,500
Wages prices:		
Product A	50 : 5 = 10	1,000 : 200 = 5
Product B	100 : 5 = 20	2,500 : 200 = 12.5

This calculation shows the following changes in wage prices:

Product A: a drop from 10 to 5 hourly wages per unit product (index: 0,5)

Product B: a drop from 20 to 12.5 hourly wages per unit product (index : 0.625).

The assumed index of the integral productivity of labour has already been shown to be 1.75; the reciprocal of this index (0.57) is substantially the same as the mean of the wage-price indices for the two products (0.5 and 0.625).

This is not surprising since the methods used for calculating both the integral productivity of labour and wage-prices are based on the same principle.

Conclusions

The changes observed in the various productivity indices from period 1 to period 2, can now be summarised in ascending order :

Specific productivity (gross) of equipment:		- 56%
Specific productivity (gross) of raw material		+ 10%
Overall productivity of factors:	At period 1 prices:	+ 30%
	At period 2 prices:	+ 50%
Integral productivity of labour (assumed):		+ 75%
Net productivity		
(specific) of labour :	At period 1 prices:	+ 125%
(visible)	At period 2 prices:	+ 135%
Specific productivity (gross) of visible labour:		+ 175%

This spread suggests two main comments:

1. In measuring the increase in productivity for a particular type of operations from one period to another, a choice can be made between several formulae which give very different results. Consequently, extreme care must be exercised in the choice of method and in the interpretation of results.
In many cases, the specific productivity of labour is increased by large additions of equipment; in such cases, the productivity of equipment may show only a slight increase or may even decline; if that is so, net productivity of labour will increase less than gross productivity of labour and the overall productivity of production factors will increase even less. In the example used, an increase of 175 per cent in gross productivity of labour is combined with a slight increase in the productivity of raw materials (10 per cent) and a decline in the productivity of equipment (-56 per cent), the latter being due to large additions to capital, leading not to a proportionate increase in production but to an economy in labour per unit product, i.e. an increase in the productivity of labour: under these circumstances, it is not surprising that the net productivity of labour (which by deduction comprises added capital in the numerator) increased by only 125 to 135 per cent whereas gross productivity of labour increased by 175 per cent; equally, it is not surprising that the overall productivity of production factors (which by addition comprises added capital in the denominator) increased by only 30 to 50 per cent.
It will be observed that the integral productivity of labour increased more (75 per cent); this was to be expected since this index includes not only economies in factor consumption per unit-product, due to the industry under review, but also economies in labour used in the production of these factors, due to industries earlier in the production cycle.

2. Wherever productivity is measured in values, as becomes inevitable once some synthetic concept such as net productivity or overall productivity is involved, the indices obtained depend on the price structure used for reference purposes. In the example used, the increase in the overall productivity of production factors from period 1 to period 2 rises from 30 to 50 per cent when the price structure is changed; the corresponding figures for net productivity of labour are 125 and 135 per cent.
These discrepancies are fairly small but in the example used this is due to the fact that price distortions are relatively limited. Much wider differences are sometimes observed when comparing widely differing techniques applied in countries with very dissimilar price structures. This means that with the existing national price structure the introduction of a foreign production technique to any country (both the most backward and the most advanced) may lead to a decline in the overall productivity of the

factors of production, i.e. costs may increase. Frequent comparisons between French agriculture and industry and American agriculture and industry have confirmed this disturbing fact.

This means that price and wage structures, which reflect out-of-date production techniques in an under-developed economy, may be one of the main obstacles, if not, the main obstacle to the technical improvement on which increased productivity, higher real wages, and the adaptation of the price structure to technical advances, all depend.

SECOND NUMERICAL EXAMPLE

(Dependence of productivity index on price structure)

The point made at the end of the previous section can be illustrated by a further numerical example, in which American and French farms are compared.

This example is based on two mixed farms, the first in Bresse (France) and the second in Illinois (U.S.A.). It is assumed that both farms produce the same items (e.g. maize and pigs) and have the same gross product per hectare (both in volume and value); on the other hand, it is assumed that the factors of production (labour and machinery) are combined in very different proportions and that the prices paid for these factors are equally disproportionate.

The main items in the two operating accounts are as follows (dollars being converted to francs at the market rate):

BRESSE	
Labour 300 hours fr. 75	= 22,500 fr.
Machinery: 9 units at fr. 2,000	= 18,000 fr.
Other expenditure	= 29,500 fr.
Total expenditure equal to gross product	= 70,000 fr.

ILLINOIS	
100 hours at fr. 200	= 20,000 fr.
20 units at fr. 1,000	= 20,000 fr.
Other expenditure	= 30,000 fr.
	70,000 fr.

Here we have two methods of farming which provide the same gross product (fr.70,000 per hectare) with a very different distribution of the factors of production. The French farm uses 300 hours of labour per hectare as against only 100 hours in Illinois (i.e. one third as much); on the other hand the American farm uses twice as much machinery per hectare (20 units as compared with 9).

These differences in the distribution of factors are due to differences in the structure of prices. At current exchange rates, the cost of labour (wages) is three times as high in the United States as in France whereas the cost of mechanical units (price of machinery and fuel) is only half the French figure.

The two farms have the same figures for expenditure and income; in each case costs are just covered. The problem is to decide which of the two has the higher overall productivity for the factors of production used.

The answer to this question depends on the price structure selected as a basis of calculation. As there is no prior reason for selecting either the French or the American structure each will be tried in turn.

1. French price structure. With this system the overall productivity of the factors used on the Bresse farm is clearly unity:

$$\frac{\text{Gross product}}{\text{Cost of production}} = \frac{70,000}{70,000} = 1$$

Recalculating costs on the Illinois farm at French prices, the following figures are obtained :

Labour:
100 hours at fr. 75 = fr. 7,500 as compared with fr. 20,000

Machinery:
20 units at fr. 2,000 = fr. 40,000 as compared with fr. 20,000

Other expenditure:	fr. 30,000 as compared with	fr. 30,000
Total expenditure :	fr. 77,500	fr. 70,000

On the basis of French prices therefore the Bresse farm would lose by conversion to the Illinois production technique and its overall productivity would fall from 1 to:

$$\frac{70,000}{77,500} = 0.9 \text{ approximately}$$

This is due to the fact that at French prices, the saving per hectare of 200 hours of labour costing only fr. 75 per hour, represents a total saving of only fr. 15,000 whereas expenditure is increased by fr. 22,000 by the substitution of 11 machinery units costing fr. 2,000 each.

2. American price structure. Naturally, the overall productivity of the Illinois farm is unity:

$$\frac{70,000}{70,000} = 1$$

At American prices the expenditure of the Bresse farm would be:

Labour :		
300 hours at 200 fr.	= 60,000 fr. as compared with	22,500 fr.
Machinery:		
9 units at 1,000 fr.	= 9,000 fr. as compared with	18,000 fr.
Other expenditure:	29,500 fr. as compared with	29,500 fr.
Total expenditure	98,500 fr.	70,000 fr.

These figures prove that at American prices the Illinois farm would derive no benefit from introducing the Bresse technique because by so doing it would lose more in increased expenditure on dear labour than it would gain in savings on cheap machinery. Overall productivity would fall from one to:

$$\frac{70,000}{98,500} = 0.7 \text{ approximately}$$

These results are summarised below:

	OVERALL PRODUCTIVITY OF FACTORS CALCULATED	
	WITH FRENCH PRICE STRUCTURE	WITH AMERICAN PRICE STRUCTURE
Bresse farm	1	0.7
Illinois farm	0.9	1
Illinois / Bresse	0.9	1.4

These figures show that the productivity of the Illinois farm is 40 per cent greater than that of the Bresse farm with the American price structure but is 10 per cent lower with the French price structure.

This example clearly demonstrates that no absolute comparison can be made between the overall productivities of two systems of production based on different price structures. The relationship between two such productivities depends on the price structure used for purposes of comparison. If, as in the foregoing example, the price structures used are very different, one of the systems may appear better or worse than the other according to the price structure selected.

Two further points should be noted:

a) This reversal of relationships is only found under exceptional circumstances, when the comparison relates to two systems that are widely separated either by an economic

frontier (Europe - United States) or by a long period of time (18th century - 20th century). When the problem is that of measuring either differences in productivity between several firms in the same country or variations in the productivity of a particular firm over a relatively short period of time (e. g. 20 years), differences in price structure are either non-existent or sufficiently small not to have any appreciable effect on the productivity of the relationship. *

b) Even when differences in price structure do affect these calculations, the economist can still draw a number of conclusions.

Returning to our example of two farms, we find that the Illinois/Bresse relationship would be 0.9 with French prices and 1.4 with American prices. It is possible to take the mean of these two figures (1.15), which is in favour of Illinois, but this method is empirical.

A more scientific method is to try and identify the price structure typical of the most developed economy. It can reasonably be argued that these conditions are fulfilled by the economy which without artificial measures and solely by means of technical progress, provides the highest reward for labour in relation to the product of such labour. Here, this applies to the American type. In case of doubt, it would therefore appear reasonable to take the American price structure in preference to the French; on this basis it may be concluded that the overall productivity of the Illinois farm is in fact superior and not inferior to that of the Bresse farm. On the other hand it must be remembered that this conclusion involves an assumption implicitly based on an assessment of value.

THIRD NUMERICAL EXAMPLE

(Influence of integration on measures of productivity)

A problem which often arises in connection with measures of productivity is that of comparing unequally integrated units. For example, one motor-car factory is engaged solely on assembly work; it buys chassis, bodies, engines and all accessories from other firms. A second plant both manufactures the main components (chassis, engines and bodies) and assembles complete vehicles; finally, a third plant also produces a whole range of accessories (tyres, shock absorbers, etc.).

Clearly, these three factories cannot be compared directly and only departments engaged in the same operations must be

* It should be noted that even very wide fluctuations in the general level of prices - as a result of inflation (e.g. France from 1914 to 1952) - do not affect the results of these calculations to any great extent provided the various individual prices change in substantially the same proportion.

set against each other : in some cases this distinction is very hard to make.

It is interesting to observe, for example, how far productivity indices can be influenced by variations in the degree of integration.

The example selected relates to a product for which manufacturing costs are made up as follows:

1. During the final stage one unit product costs (at constant prices for the semi-finished product)

	Before		After
in man-hours			
20 hrs. at 300 fr.	= 6,000	10 hrs. at 300 fr.	= 3,000
in semi-finished products			
4 kg. at 1,000 fr.	= 4,000	3 kg. at 1,000 fr.	= 3,000
	10,000		6,000

2. At the previous stage one semi-finished unit costs:

in man-hours			
2 hrs. at 300 fr.	= 600	1.3 hrs at 300 fr.	= 390
in raw materials			
1 kg. at 400 fr.	= 400	0.9 kg. at 400 fr.	= 360
	1,000		750

3. Integrating both stages, one unit product costs:

in man-hours*			
28 hrs. at 300 fr.	= 8,400	13,9 hrs. at 300 fr.	= 4,170
in raw materials**			
4 kg. at 400 fr.	= 1,600	2.7 kg. at 400 fr.	= 1,080
	10,000		5,250

It will be observed that one unit produced by the new technique in an integrated system costs less (fr. 5,250) than the same product manufactured by the same technique but costed at the last stage (fr. 6,000). This difference is due to the fact that in calculating the new cost at the final stage, no allowance is made for savings in the manufacture of the semi-finished product (from 1,000 to 750 fr. per unit).

---

* Before 20 hrs. +4 kg. of semi-finished product each requiring 2 hrs. = 28 hrs. total
After: 10 hrs. + 3 kg. of semi-finished product each requiring 1.3 hrs. = 13.9 hrs. total

** Before: 4 kg. of semi-finished product each requiring 1 kg. of raw material = 4 kg.
After: 3 kg. of semi-finished product each requiring 0.9 kg. or raw material = 2.7 kg.

This point is most important as it explains differences which will appear in the productivity indices according to whether they are calculated from each stage separately or on the basis of two integrated stages.

It is now possible to calculate an overall productivity index for the new technique as compared with the old. These indices are inversely proportionate to production costs (at constant factor prices) as follows:

for the last stage : $\frac{10,000}{6,000} = 1.67$

for the previous stage : $\frac{1,000}{750} = 1.33$

for both stages taken together : $\frac{10,000}{5,250} = 1.90$

From this it can be seen that the index of overall productivity for the two integrated stages is not the mean of the indices for the two stages taken separately, but is higher than both.

This noteworthy characteristic is general and is due to the fact that the terms which represent economies during the successive stages of manufacture are not added together but multiplied. *

For the purposes of this argument k_1 and k_2 are taken to represent the indices of overall productivity at stages 1 and 2 α to represent the part of the cost of production at stage 2 attributable to the semi-finished product manufactured in stage 1. Analysis shows that the indices of overall productivity for the two integrated stages is given by the formula:

$$\frac{k_2}{(1-\alpha)+\frac{\alpha}{k_1}}$$

This index always exceeds k_2 when k_1 is greater than unity. For the example used this gives the following results :

$k_1 = 1.33$

$k_2 = 1.67$

$\alpha = \frac{3,000}{6,000} = 0.5$

The index of overall productivity for the two integrated stages is therefore :

$$\frac{1.67}{0.5+\frac{0.5}{1.33}} = 1.90$$

which corresponds with the value already found.

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* A general formula can be worked out for the single case under review.

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