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Application of Input Output Analysis to the Production of Services

An Overview

by

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Abstract

Input Output Analysis is a powerful tool to formally analyze the economics of service production in business terms. Through its methodology, it is able to integrate different approaches from other disciplines and address their shortcomings in terms of production theory.

This review paper provides at first an overview of which key areas of service production the Input Output Analysis has been successfully applied to. The digital transformation is a new challenge for the application of this analysis tool. So, secondly an overview of areas of service production follows in which the digital transformation places new demands on the application of Input Output Analysis.

1 Aims and issues of the paper

In the developed economies of the Western world, the contribution of service production to gross domestic product averages almost 70%. The study of the economic efficiency of the production of services as intangible goods is therefore of great importance. Input-output analysis, which has already proven itself in the form of activity analysis (Koopmans 1951) in the investigation of the economic efficiency of the production of material goods, is a suitable method for this purpose.

The article begins with a literature review, which shows that input output analysis has already been successfully applied in several areas of the economic production of services. However, many contributions also reveal that research on service production is still characterised by some inconsistencies and deficits (see Fandel 2022). The explanations show how activity analysis remedies this methodologically through its integrative properties. Its instruments prove to be broad enough to capture different directions of investigation of service production in a unified scientific concept. The discussion of the methodological aspects of applying activity analysis to service production and its limitations comments on this. Subsequently, important areas of future service production research are addressed. They pose challenges to

the future developments of an application of input output analysis to service production as an integral part of a comprehensive theory of production.

2 Literature analysis: Activity and input output analysis in different service areas

2.1 Functions of the firm

The tasks of planning, organization, and control are the outstanding activities of in-house service production, as they affect all other functional tasks of a company or shape their implementation. This raises the question of the applicability of the concept of input output and activity analysis to these dispositive tasks.

2.1.1 Planning

Very early on, Wild (1970a, 1970b) has developed an “input-, output- and process analysis of information systems” and an information cost calculation based on it. The types of information supplied by various sources at certain points in the information system are recorded in an input matrix with the frequency of their transmission for a period under consideration. Using a process matrix, the information inputs are processed into information outputs by the relevant bodies in the subsequent informational process analysis. The output matrix finally shows the frequency of communication of the information outputs to the information user as the receiving point of the information system. In this analysis, the use of resources for information management of certain types of information and their output quantities are the subject of the analysis, but not the origin of the information content itself nor its quality as results of the informational production process.

In this sense of semiotics, Bode (1993) made a very decisive contribution to the conception of an input-output model for information production. For the example of the production of lot size information, he explicitly shows what such an approach should look like. In addition to the usual use of computer power and human labor, this information production by the production point “original information” also includes as inputs the fixed costs, the periodic requirements, and the storage cost rate as object information, from which the numerical value of the optimal lot size is generated as a unit element of the output information.

This theoretical concept is also the basis for the work of Fandel / François (1994) and Fandel (1994). In a narrower sense, their work falls into the area of the application of activity analysis to planning, organization and control in their capacities as in-house service production. Specifically, it is initially about an activity analysis of data processing - applied to the module of dynamic lot size planning as part of production planning - and then, as an extension, about the analysis of production planning and control systems (PPS) as efficient combinations of information activities. In both cases, the efficient activities can finally be understood as information production, which supplements the classic production function with the factor information on the input and output side. For this it is necessary to derive terms such as information processing activity and information technology as well as various efficiency and dominance definitions for the area of data processing. Information about goods that are involved in the provision of services by a company are then themselves defined as input or output goods of the data processing process.

2.1.2 Organization

While the application of the input output analysis to the module of lot size planning describes a single-stage process of information production, PPS systems can be understood in their planning structures, sub-modules and the associated processes of information and data processing like systems of multi-stage multi-input production. In the arrangement of their modules, they map the decision-making competences in the hierarchical structure of the dispositive factor organization (Scheer 1990 and Scheer 1994). Assumptions for information technology and suitable efficiency criteria that are adapted to these cases and formulated analogously allow for the quality of data processing in PPS modules to be assessed and inefficient activities (modules; planning software) to be eliminated. For the module of dynamic lot size planning, for example, the methodological considerations are made usable in order to compare the planning quality of heuristic processes with that of an exact solution process in the context of a computer-aided sensitivity analysis (François 2000).

Bonney / Jaber (2013) presented what is probably the most extensive use of activity analysis in planning and organization. For the simultaneous holistic design of a manufacturing system and its embedding in a supply chain, they use an activity matrix that shows how the inputs of a company are transformed into the outputs. Inputs are the company's planning specifications and data about its resources such as material, energy and workplaces, which can be utilized to achieve the planning specifications. Outputs are information about the company's performance. They contain data on production, the quality of services as well as waste and environmental protection, which need to be coordinated with other objectives (technical or social) of the company. The cycle of such a system design comprises several successive stages, the object of which is initially the design of products, processes, workplaces and the entire production system with regard to market requirements. Subsequently, the implementation and operation of the system are considered at further stages and its performance is analyzed. For information processing, the authors suggest well-known concepts of decision support (PPS, CAD, CAP, CAQ). So far, the article has most consistently pursued the aim of depicting the production of services in operational planning in the literature.

2.1.3 Control

The work by Fließ et al. (2011) concerns the application of the activity analysis to all three dispositive tasks planning, organization and control at once. The combination of the activity analysis with the network planning technology offers the possibility to assess the profitability of a service production, the subject of which is the implementation of a large project. The critical path through the network plan shows the sequence of operations, the total execution time of which can no longer be reduced with a given use of resources, unless more resources are used for these operations. However, this approach does not necessarily have to represent efficient production because it does not have to be ensured that operations that are not time-critical are actually carried out with the minimal use of resources required for them. It is better visualized by mapping the project flow with the help of the totality of the resource consumption and the duration of its processes using an activity vector. In this way, the production of large-scale service projects can be checked for both their allocative and dispatch efficiency.

In this context, network planning technology is closely related to the concept of service blueprinting that is often used in the economy of service production (Fließ / Völker-Albert 2002, Fließ et al. 2011). This concept represents the chronological sequence of all processes within the network plan of a service process horizontally and groups the processes vertically according to their distance from the customer. By simultaneously tracking and checking the planning results for their technical and organizational efficiency, the task of control is also done at the same time.

2.2 Profit and non-profit sectors

The following sketches for the applications of input output and activity analysis to service production are arranged according to business sectors (Fandel 2022). As a tribute to Koopmans / Reiter (1951), they begin with applications in the field of transport planning. With their contribution to the development of the concept of activity analysis, these authors were the first to show how this analytical instrument can be applied to service production in a highly innovative way.

2.2.1 Transportation planning

The subject of Koopmans / Reiter (1951) is a static model for the efficient use of a transportation system. A given month's transport program among several ports should be managed by using ships of the same type. In the technology matrix, the basic activities, which can be proportionally increased and added, are defined by production coefficients. By assigning zero-one values for each port, a distinction is made between two activities (loading or unloading of a ship) and two activities (shipping with freight or without freight) for each route between two ports. Outputs are the ship freights, calculated in shiploads per month, which are transported among the various ports and unloaded there. As intermediate products, the authors formulate the occurrence of loaded ships to and from the various ports as well as the occurrence of empty ships in these ports - both calculated net in the number of ships per month. After the transportation program has been carried out, the intermediate product quantities are zero. Inputs are the total number of ships available for dispatches, the times for loading and unloading in the ports and for driving between two ports with or without freight, as well as the port capacities calculated in the number of berths, which are temporarily used for loading and unloading. The technology of the service production includes all the activities that, at their performed levels, allow the implementation of the specified transportation program. Among them, the efficient production point is characterized by requiring the minimum number of ships. For the route map of empty ships derived from this, it is not important to avoid empty ships and the circulation of ships without cargo, but rather to minimize the number of circulating empty ships that are required for transportation in other ports. In the efficient production point, under resource restrictions, no flow of goods between ports can be increased without reducing another flow of goods in the route plan.

In a practical case, Koopmans / Reiter (1951) apply the activity analysis to a transportation program planning for 14 ports and determine the cost-minimal solution of the problem by evaluating the routes by their distances between the ports. It goes without saying that this approach can also be applied directly to transportation program planning for planes, trains, buses, and trucks. The efficiency of activity analysis for the economic design of service

production is evident. It is all the more astonishing that this concept did not find its way much earlier into the dealings with service production by business administration.

Transportation activities as services often go hand in hand with activities in the production of goods. To combine both activities and to simultaneously include environmental protection through the additional consideration of ecologically effective activities, Freire et al. (2001) formulated a remarkable decision model on the basis of mathematical programming, which combines considerations on the cost-minimal allocation of resources and on the effects on the environment during the life cycle of reusable or recyclable glass water bottles. The methodological bases of their formal descriptions are the activity analysis by Koopmans (1951) and the input-output analysis by Leontief (1951, 1970). Both concepts allow for including production, transportation, and environmental activities in a decision-making process and to visualize the volume and energy flows in the transitions between the activities. Empty water bottles are picked up at the collection points after consumption and sent for cleaning. Glass shards from broken water bottles are collected in the environment and are used in glass production and thus in the manufacture of new glass bottles. Newly filled glass bottles are then returned to the places of demand. The optimal design of the activities takes place with the aim of minimizing costs and under the constraints that the demand is covered, the environmental pollution from production and transportation does not exceed certain (political) requirements, and the net quantities of the intermediate products are zero (no storage of intermediate products). Intermediate products are collected broken glass, melted glass for bottle production, empty bottles after consumption, reused bottles after return transport, new bottles and filled bottles before and after distribution. The application studies the optimal solutions under five different environmental scenarios (e.g. no environmental requirements and different percentages of bottles returned, refilled and disposed of in landfills as constraints).

It is very pleasing that Souren / Richter (2015) take up the considerations of Koopmans / Reiter (1951) in their contribution and expand the activity analysis in the formal description of the production of services to include interaction features and show how the activity analysis can be applied to household waste collection. The basics are the input-output graph and the associated technology matrix of a multi-level service process. The basic activities compiled in the technology matrix are carried out either by the customer or the waste disposal provider. The customer makes the full waste container ready for emptying and then returns the empty waste container. The disposal company drives the garbage truck empty from the landfill to the customer, fills the disposal vehicle with the customer's garbage and then drives back to the landfill to empty the garbage truck. The full rubbish bin and the customer with their interaction times may be understood as external factors of this service production, but this delimitation in the resources is not mandatory, as the two above-described applications in transportation planning have shown. At the same time, the handling of full and empty rubbish bins is also an output of the interaction of the consumer. The efficiency considerations are analogous to the contribution by Koopmans / Reiter (1951).

2.2.2 Theater performance

The example of a theatrical performance subsequently discussed by Souren / Richter (2015) is also interesting. In addition to the theatrical performance as the main activity, upstream,

simultaneous, or downstream processes of cloakroom storage and distribution as well as activities of program booklet issuing embedded therein are also components of the technology matrix. The view of the theatergoer as an external factor can certainly make sense here, since one and the same theater performance may affect the experience of every theatergoer differently. So even after the theatrical performance, they would have to be seen as an independent output type.

What is innovative about the authors' explanations is that in their input-output oriented modeling of the theater performance service, they explicitly address the fact that it contains both collective and individual sub-activities that require different analytical handling in the form of a numerical separation in the technology matrix. For example, the performance and the storage of the wardrobe are independent of the number of demanders, since they are provided collectively for all theatergoers. Receiving and returning the checkroom and issuing program booklets, on the other hand, are demand-number dependent, since they must be performed individually for each visitor to the theater event. Thus, if one were to attempt to describe the theater performance service by a single aggregate total activity, it would be important to note in further analysis that this activity cannot be performed at any level because of the subprocesses that are not demand-dependent.

2.2.3 Healthcare

Prasiswa (1979) uses the activity analysis of linear-limitational production processes of the Leontief type to determine the cost-minimal organizational structure and equipment of a medical practice and to concretize those examinations for a specialty ophthalmology practice. Outputs are services that have been carried out and can be billed for ophthalmology using tariff codes for the treatment of doctors; inputs are the services provided by the medical staff and the equipment used. A special feature is that certain outputs can also be produced through alternative linear limitational activities (result-oriented processes; choice of procedures). If some aggregates are used at full capacity, the advantage is that their scarcity does not immediately limit the service generation in the practice, since less cost-effective operating resources can then be used. In addition, with increasing patient numbers the formulated model makes it possible to decide in view of the cost-minimal organizational structure of the practice, whether it should continue to run as an individual practice or to expand into a group practice by adding more doctors. The practical relevance of this application of activity analysis is evident; and the publication found a great response at that time and was a stimulus for improvements in the economic design of the organizational units in private medical health care in Germany (Clemens / Prasiswa 1980).

The queueing theory approach by Hegemann (1986) to optimal capacity management in the clinical diagnostics of a hospital resorts also to activity analysis. Here, it is in particular the transition probabilities from one to the other examination room of diagnostics compiled in the routing matrices that express the dynamic input-output character of the migration movements. The parameters of the arrival processes of outpatients and inpatients before the diagnostic service points and the time distributions in the service stations have to be determined as important quantities. Outputs are the diagnoses made individually for each patient at the end of a run through the diagnostic system. Preliminary diagnostic findings after

passing through a service station (equipment and medical staff) represent intermediate products of further diagnostics, which are recorded in the medical records, insofar as they are not zero after completion of diagnostics. When applied to the diagnostic system of a 650-bed hospital, it was shown that simple organizational measures of regrouping and merging diagnostic service units could reduce average patient waiting times and increase the average utilization rate of the overall diagnostic system.

2.2.4 University planning

The first considerations of business administration to transfer structural models of the input-output analysis to university planning date back to Albach et al. (1971) and Albach et al. (1978). Exemplary activity-analytical formulations for a department of economics are given in Albach et al. (1978) and Fandel (1977). For the production period of one year, several outputs may be considered with the integration of teaching, research and self-administration. The output components include the number of students - differentiated according to the quality of successfully completed academic years (at that time there were only diploma courses without intermediate examinations) -, the number of doctoral positions created, the creation of a number of specified research projects according to subject and resource qualification, as well as the performance of the department self-administration. Inputs are office spaces, conference rooms, lecture halls, general administrative services, computing time, as well as different budget types for salary payments to scientific and non-scientific staff, and certain types of material expenditure. The latter two input types are not calculated in monetary terms (quantity-oriented activity analysis!), but in the number of available positions in salary levels and equipment packages. Since at that time masses of willing students poured into the German university system without the necessary resource capacities being increased accordingly, the efficiency in this activity analysis was considered to be output-oriented, i.e. to generate as many students of the various academic year qualities as possible with the available resources, but to specify certain minimum quantities for other outputs.

Stimulated by the research results of Albach et al. (1971) and Albach et al. (1978) on university planning and methodologically based on it, Paff (1998) added with her work using activity analysis to the political discussion about the economic viability of universities in general, and the one of distance teaching universities in particular. For the production-theoretical foundation of a university's cost accounting, she has formulated a very extensive structural model in which the services of all departments are included with their inputs, intermediate and main services, and outputs. The outputs of teaching are not the successfully trained graduates, but rather the support services such as lectures, exercises, seminars, theses, that are provided for the students. According to Engelhardt et al. (1993) these outputs can be understood as a bundle of services which, as sales objects, consist of services and benefits in kind. Research outputs are sub-units of basic research and project research. In teaching, for example, the model can be used directly to show how one department (a discipline) with efficient production can only offer more teaching services for students at the expense of teaching services in other subject areas (disciplines), whereby resources are redistributed within the university between the departments (or within a department between the various chairs and disciplines). In addition, it becomes immediately evident which resources have to be increased and to what extent if the university - as is often politically desired - is to cope

with even more students by expanding the range of teaching services or to generate successful graduates.

Clermont / Richter (2016) have graphically sketched an extension of the activity analysis to refine the modeling of the input-output relationships of the service of university knowledge transfer for the teaching form of a lecture. They are based on a constructivist model of integrative co-production in teaching, namely that the transfer of knowledge in a lecture does not come about through the activities of the lecturer alone, but rather through the interaction between the activities of the lecturer and student. For both the lecturer and the student, the lecture consists of a uniform, multi-stage process with the sub-processes “preparation” (collection of teaching materials by the lecturer; reading the learning materials by the student), “course” (providing or receiving specialist information after the Uno-Actu principle (Maleri 1973) of the provision of services), and “follow-up” (sorting of teaching materials by the lecturer; individual acquirement of knowledge by the student). The actual course lecture integrates the spheres of the lecturer (noting, explaining) and the student (adding, listening) as a sub-process. This fine structure of the teaching form “lecture” prepares the basis to enable adequate curriculum design. The authors do not propose a quantitative formulation of the activities that goes beyond the graphical sketch of the refined extension of the activity analysis.

If paying equal attention to the input- and output-oriented views of students in university planning, it is expected from an educational policy that a university will accept as many students as possible with the existing capacities and bring as many as possible to graduate successfully. It is assumed that the training university influences the quality of the graduates through the quality of its teaching. The question that remains unanswered is the extent to which the success of universities in teaching, measured by the quality level of their graduates, depends on the quality of the students as an external factor in this service production itself and how this quality develops over the course of the academic studies up to and including graduation. As a possible answer to this, Fandel / Blaga (2004b) used input-output analysis and the migration matrices derived from it to quantify and to stratify 272 graduates of economics at the Distance Teaching University in Hagen according to certain qualities to be able to study the quantitative relationships. Graduates who had completed their full-time studies in the years 2000-2002 were included. Stratification occurred according to their qualities on entry into the course (grade average of the first four compulsory exams in the basic course), according to the preliminary diploma (preliminary diploma mark as an intermediate qualification), and upon graduation (diploma mark) in terms of goods in the sense of a multi-stage production process (inputs, intermediate products, and outputs). The migration matrices depict specific realized production processes based on activity analysis, whereby it is assumed that the technology remained unchanged over the academic years of these 272 graduates. Following the individual migrations of the students, it shows that with regard to the quality of goods of individually identifiable students in the training process hardly ever improvement or deterioration of grades occurs. The vast majority of students achieve the same grades at the various levels of qualification. Shorter study periods went hand in hand with both a better entry qualification and a better diploma grade.

2.2.5 Banking and Finance

In the business field of banking and finance, there has by no means been a lack of attempts to use the idea of activity analysis to analyze the profitability of banking operations (Santomero 1984, Elyasiani / Mehdian 1992, Färe / Primont 1993). Even though some of these works mention the term activity analysis in the title, monetary values are here also listed under the inputs and / or outputs, and the Data Envelopment Analysis (DEA) is typically utilized to compare the profitability of different banks with one another or of branches of the same bank, because these companies or branches are decision-making units with different technologies. The exact procedure in the sense of the activity analysis by Koopmans (1951) would be obvious. Inputs are the bank's employees and resources; Outputs are executed transfers as well as executed investment activities and executed lending of certain specification classes. The transformation of accepted amounts of money in different types of investments or issued loan amounts of different types can be represented by budget constraints similar to those in production program planning, which act as secondary conditions but not as objects of the actual input-output transformation. It is surprising that this path has not yet been taken in the literature, whereas the banks' risk reports follow this pattern (Hull 2014, Fingerlos et al. 2020). For example, it is checked how the number of loans of different credit ratings has changed in a reporting period. With sufficient detail, all banking services activities can be described in terms of pure quantities.

2.3 Inconsistencies and deficiencies in the literature

2.3.1 Methodological inconsistencies

Based on the solution of a biform game (Brandenburg/ Stuart Jr. (2007)), Chatain/Zemsky (2007) determined in their work in a first step how to distribute two one-time, different types of orders to two specialists – one specialist for each order – and a generalist, depending on the added value resulting from the specific supplier-customer-relationship for these services. All three providers can handle both types of orders – albeit on different terms. An extension of this model to repeatable orders as well as to several demanders and suppliers of the same type takes place in subsequent steps.

In Chatain / Zemsky (2007), several determinants are decisive for the significant added value for the assignment of orders: organizational trade-offs of the providers in the processing of both orders, their customer-specific economies of scope, market entry barriers, the heterogeneity of the order-specific requirements, and the bargaining power of the providers with respect to the customer. The evaluation of the influencing components determining the added value is expressed in the payouts of the game solely by the willingness of the customer to pay, without reference being made to explicit production-theoretical determinants of the performance of the orders. Chatain (2010) applied the methodological considerations in a large-scale study to legal advice for British law firms. These considerations then lead to the surprising result that assignments of orders may arise as solutions of the biform game, in which a single order is awarded to the generalist, for whose creation actually the other – neglected specialist – is the expert. Fandel / Trockel (2020) use an approach of non-cooperative game theory (Nash 1951) and show that - among other assumptions - there cannot exist such a division of jobs between a specialist and a generalist under the usual activity-analytical considerations.

2.3.2 Added value theory of service production

The contributions by Chatain / Zemsky (2007) and Chatain (2010) are embedded in an extensive, simultaneously published literature that deals with the question of what may create added value in service production and how it affects supplier-customer relationships, or in particular have an impact on the willingness of consumers to pay. Grönroos (2008, 2011) points out in his publications that possibilities of increasing profits are of great importance for the creation of supplier-buyer relationships and that it is important to determine how these profit increases affect the behavior of the players. Grönroos / Ravald (2011) also show that the customers only create added value through the increased willingness to pay by allocating their orders to the providers. Brandenburger / Stuart Jr. (1996, 2007) analyzed in their work the extent to which such added values can be influenced by the competitive behavior of providers, how providers and consumers can acquire parts of them through various strategies, and how the introduction of a trademark for a product can increase the buyer's willingness to pay for this product. Adner / Zemsky (2006) and Schmidt et al. (2016) have formulated models in which the relationships between the customers' willingness to pay and the suppliers' production costs are examined. While the buyers' willingness to pay depends on their assessment of the quality in which the orders are likely to be executed, the sellers' profit results from the difference between their added value, which they only generate by producing the orders for the buyer, and their costs.

2.3.3 Elimination of deficits through activity and input output analysis concepts

In all of the aforementioned work, the production-theoretical assumptions of the service producing orders are disregarded. They are considered to either already be valued in terms of a cost figure, of which it remains unclear which specific resource consumption is assumed, or they are thought to already be implicitly recorded by a net willingness to pay on the part of the customer, by which all determining components of the added value should already be taken into account with their valuation.

These methodological deficits in the formulation and solution of decision-making problems in service production make it clear that considerations of production theory need to be given more attention than previously. Fandel / Blaga (2004a) as well as Richter / Souren (2009) and Souren / Richter (2015) have already referred to this deficit and therefore they advocate the application of activity analysis to service production, whereby for particular applications, methodical adjustments or extensions of this instrument with regard to the specific characteristics of service production may be required. So, these references are the starting point for further considerations on methodological aspects and developments in the application of activity analysis to service production.

3 Methodological aspects of the application of activity analysis to service production and delimitation of content

3.1 Integrative properties of activity analysis

Activity analysis has been developed to investigate and design efficient production, a powerful instrument that has proven itself in the analysis of the profitability of material goods production (Wittmann 1968, Fandel 1987, Dyckhoff 1993a). Activities are permissible

quantitative input-output combinations of real goods, which are also referred to as processes or production points. They are collected for a production process in the underlying technology, which expresses the technical knowledge and ability of a company and for which formally certain assumptions are assumed that must be fulfilled (Fandel 1987). With the determination of all efficient activities, one has the production function associated with this technology.

With regard to the properties of such technologies, certain basic forms can be distinguished for practical investigations of manufacturing processes in production, depending on which operations the activities collected in them can be subjected to. The level of activities may be reducible at will (degression in size), multipliable at will (progression in size), or both at the same time (proportionality in size). If they can be added up (summation of the quantities of goods with simultaneous or sequential execution of activities) and if they also follow the proportionality of size, one speaks of linear technologies. They create a very important connection to Operations Research, as they form the basis for the use of linear programming for optimal production program planning in practice.

The translation of the activity analysis to the production of services is obvious, since Koopmans / Reiter (1951) had already shown in their approach how it can be used for the efficient and cost-minimal use of ships in transport planning when the total freight needs to be fulfilled among a large number of ports. This result-oriented view (Maleri 1973, Gerhardt 1987) on the production of services defining services as intangible economic goods that are generated as outputs (products) – produced services, not producing of the services – through the combination of production factors (inputs, resources) corresponds to the methodology of activity analysis, describing productions using vectors of quantities of goods. The following explanations are based on this: Services are intangible products that have been produced by producers for customers through the commercial services performed. The result-oriented perspective is supplemented and enriched by different perspectives (potential-oriented (Meyer 1987), process-oriented (Berekoven 1974) and phase-oriented (Corsten 1985, 1990)). As opposite as the perspectives appear to be, they are actually not, because they can be integrated into the methodology of activity analysis. The result-oriented view corresponds to the output, the potential-oriented view to the input combination, the process-oriented view to the activity or technology, and the phase-oriented view to the multi-stage production. However, the result-oriented definition of services is indispensable because the profitability of service production can only be checked on the result. After all, the aim is to generate a service or certain quantities of it with as little input as possible. This requires to precisely specify the output service in each individual case and not to describe it using other perspectives as a substitute. This rationale is compelling, because prices for the result of service production must be determined on the market. Lancaster (1972) argued in a neat way that the market evaluates goods and not their useful properties. For the possibilities of specifying the output concretely in certain practical problems and for related individual aspects, reference is made to Fandel / Blaga (2004a).

3.2 Types of goods and production processes

When handling the inputs, with slight modifications, the scheme for classifying production factors according to Gutenberg (1975, 1994) can be used (Fandel / Blaga 2004a). The mere necessity of including external factors in the system of productive resources (Maleri 1973) makes a corresponding modification necessary. External factors are input types whose

occurrence and involvement in the combination process of service production are not subject to the disposition power of the service producer in terms of time, type, quantity and location, but are rather brought in by the customer of the service and are therefore determined in their quality. They can be people (the customer), objects (workpieces to be manufactured by others) or services themselves. Different qualities of an external factor either lead to different qualities of the output under otherwise identical production conditions - and thus, strictly speaking, due to its properties to a different end product (Lancaster 1972) - or, if possible, can only be compensated through additional expenditure of other resources with regard to the desired quality. Examples can easily be found for the external factor "students" in publications on university planning (Fandel / Blaga 2004b).

Fliess et al. (2011) have shown that the content-related expansion of an activity analysis of service production to include personnel, marketing and management aspects does not raise any fundamental methodological obstacles. The blueprinting used for service management (Shostack 1982, Kleinaltenkamp 1999, Allert / Fließ 1999, Fließ / Völker-Albert 2002) makes use of network planning technology, which can be integrated into activity analysis and the examination of correspondences to record organizational processes. New compared to previous approaches is that, in addition to the technical efficiency, the organizational efficiency of the service provision can also be checked with the help of the expanded activities. An extension are the methodologically fundamentally oriented considerations by Souren / Richter (2015) on the activity-analytical modeling of standardized services. To describe the technology of service generation, they use a technology matrix of supplier and customer activities, which is expanded to include activities of both actors through which interactive exchange processes are recorded. When formalizing interactive transformations as basic activities, a distinction is made according to whether it is about object-immanent services (material change of the external factor, e.g. performed haircut) or process-immanent services (added value through a process, e.g. movie showing) services, how long the contact time is, and whether it is about demand- number-independent or demand-number-dependent property types. In the context of the application of activity analysis to service production, the authors again emphasize the methodology of Koopmans / Reiter (1951), whose implementation in the field of production theory seemed long forgotten.

3.3 Methodological basis of the concepts

The aforementioned discussions have made it clear that input-output combinations can be described quantitatively as activities of service production and thus the activity analysis can be made useful as an instrument for examining their economic viability in these cases.

In doing so, Koopmans' concept is followed to count output quantities as positive and input quantities as negative results of the production processes - regardless of whether they are desirable or undesirable goods, as is the case with activities that have an impact on the environment. The background to this argument is that every activity, as a flow variable in production, affects two stocks of goods before and after production and, in this respect, first allows the changes in these goods balances to be recorded; this need applies even more to pollutant balances. Further efficiency considerations of course implicitly include evaluation processes to what extent the changes in quantities in the goods stocks were desirable or not (Dyckhoff 1993b). The peculiarities of the analysis resulting from this are not detailed here.

In the activity analysis, the production function is defined on the basis of a given technology, which one ultimately wants to determine from the investigation, in that it depicts the efficient productions. No special function type is assumed for this representation. In this respect, there is no need to discuss whether the production function of service production is limitational or substitutional (Gerhardt 1987). This question has already been answered by the properties of the activities collected and the resulting characteristics of the technology (Fandel 1987). The possible compensation of unsatisfactory levels of activity of the external factor in the provision of services, in which its interaction is important, through the increased use of the set of internal factors suggests the assumption of substitutional principles. It is also supported by the greater labor intensity in service production compared to industrial material goods production. The possibilities of substitution can of course be restricted due to the qualifications required.

4 Important areas for the future development to apply activity and input output analysis to service production

4.1 Central challenges

The existence of a diverse body of literature considering the possibilities of using activity analysis in service production is reassuring. At the same time, it also becomes clear that the transfer of this concept is often only made fruitful when it is supplemented by other perspectives on the description of service production. In this respect, the integrative character of the activity analysis is definitely a methodological recommendation for its future application in this area of business administration.

However, there will be a considerable need for research in some aspects of the application of activity analysis to service production, especially considering the current importance of service production for the added value of developed economies. Modern planning and decision tools like Digital Transformation, Decision Support Systems, Supply Chain Management, Production Planning and Control, and "Industry 4.0" have in common that they integrate complex information systems and decision-making processes and, as a result, require considerable volumes of internal and external services to be provided and coordinated in their practical implementation. This poses the challenge for companies to strive for goal-oriented optimization of their decisions and thus ultimately efficient production, provision and use of these services with regard to the superior goals of corporate management.

In addition, environmental aspects such as electricity consumption, CO₂ emissions, and lost work hours due to internet surfing would need to be included in the activity analysis in a corresponding input-output analysis. Also, information can be subject to expiration dates and would then have to be disposed of as data garbage consuming human resources.

Many people, especially young adults, order a large part of their consumer goods through online stores. As convenient and as beneficial as it may be in times of a pandemic, the deliveries associated with shipping the goods and the generation of packaging waste with the need for disposal point to a significant impact of the service production on the environment, which needs to be included in an adequate activity analysis. With the shift in the focus of

modern economies from material goods to service production, attention to aspects of environmental protection will shift in this direction.

4.2 Digital transformation

Hausberg et al. (2019) point out in their broad literature review on digital transformation that there is still plenty of need for research in the analytical description of dispositive functions as internal services of industrial producers of tangible goods if one wants to make an in-house assessment of the introduction of new technologies. Many authors see great opportunities for significant reductions in overhead costs in the areas of production-related scheduling, administration and distribution. Rogozhin et al. (2010), for example, consider overhead cost reductions in these areas of 40% possible among the world's largest automobile manufacturers. De Backer et al. (2019) report a potential of 20% reduction in these overhead costs for semiconductor production, and Gyurjyan et al. (2017) estimate the corresponding reduction potential for the pharmaceutical industry at 30%. What all contributions have in common is that they consider an allocation of cost savings to specific functions in the aforementioned dispositive areas to be possible only if the intra-company services behind the overhead costs can be specifically named, formally-analytically recorded and evaluated. However, this also presupposes here that the input-output structures of these activities can be recorded in detail.

Now there is no reason to capitulate scientifically and practically to this operational challenge. If Business Process Modeling (Scheer et al. 1995) is combined with the idea of Activity-Based Costing (Cooper / Kaplan 1991), an extensive activity-analytical formal description of the company's internal services can be achieved. In this context, Scheer et al. (1995) pointed out very early on how to integrate digital tools into the corporate organization to support and improve dispositive tasks in a company, i.e. to structure internal services more effectively. Finally, the certifications of firms according to ISO 9000 have followed up on these structurings. A further detailing useful for production-theoretical considerations can be made within these structures then by following the idea of Activity Based Costing. By differentiating between activity-quantity-induced and activity-quantity-neutral activities, this approach makes it possible to break down the original overhead costs of a company to such an extent that a large part of them are also visible as direct costs and can be shaped by recording the real (non-monetary) activities behind them. This comes very close to a production-theoretical treatment of internal services.

When reading articles on "Industry 4.0" or its characterization as the fourth industrial revolution, one would like to learn something about how industrial enterprises – according to the usual understanding of those producing material goods – can improve the efficiency and productivity of manufacturing by digitizing production systems with the help of information and communication technologies. Rather, however, one learns that the concept of "Industry 4.0" dissolves the traditional hierarchical forms of automated material goods production toward a model of connected services (Goudarzi et al. 2021). Linear production sequences of tangible goods are being replaced by new ecosystems consisting of relationships between customers, suppliers and manufacturers, in which demand-driven products and services are provided. The accelerated exchange of data in e-business is expected to lead to more cost-effective internal and external services; internally, for example, through cost savings of e-

procurement and e-marketing, and externally, through cost reductions resulting from increased rates of resource utilization (Bock et al. 2000, Rogozhin et al. 2010).

The paradigm for "Industry 4.0" is considered to be the Cloud Manufacturing System (CMS), in which end products are assembled from services according to customer needs (Fatahi Valilai / Housmand 2015). It is assumed that the external services are only created through the interaction of a manufacturing cloud service provider. This approach is similar to the Added Value Theory of marketing and eventually goes so far that all activities of a cloud manufacturing system are seen only as services. This means in particular that tangible goods contained in the end products are inputs of these end products. The cloud service broker acts as an actor between the consumer and the supplier, replacing the omitted stages of intermediary trade as a cybermediary (Chen et al. 2016). Tao et al. (2015) and Aghamohammadzadeh / Valilai (2020) see the biggest problems of Manufacturing Service Management in the optimal selection and combination of services and their quality levels that mark the final product. Because of the combinatorics involved, this is a search for the solution of an NP-hard problem from an Operations Research perspective. Liu et al. (2019) regret that no satisfactory decision models are available to assess cloud manufacturing.

These findings in the literature on "Industry 4.0" show quite clearly that there is still plenty of research needed in the analytical description of cloud manufacturing products. The determination of their revenues and costs for their valuation, as well as the formulation of the payoffs associated with their creation, require that the input-output structures of these services be clearly worked out in terms of production theory. As far as this concerns external services for customers, we can refer here to the general scientific discussion on the production-theoretical treatment of services as end products.

It is encouraging, however, that a number of papers have recently been presented that deal with questions of how the digital transformation or concepts of Industry 4.0 influence the dispositive functions of industrial production and thus the in-house services of planning, organization and control. Matthiesen (2022) generally examines the requirements that must be placed on Industrie 4.0 or digital transformation concepts in order for them to contribute to the efficiency and improvement of production. Semprini et al. (2022), Evangelista / Hallikas (2022), and de Oliveira-Dias et al. (2022) analyze the links between Industrie 4.0 and the designs of lean management and an efficient supply chain. In particular, Evangelista / Hallikas (2022) contribute an extensive literature review on the topic of how to assess the relationship between digital technologies and the management of a sustainable supply chain. Csiki et al. (2022) and Dióssy et al. (2022) examine impacts of digital transformation on specific dispositive operational functions of manufacturing companies. While Csiki et al. (2022) present a systematic literature review on the interplay between Industry 4.0 and human resource management tasks, Dióssy et al. (2022) focus on the impact of digital transformation on firm's operational and financial performance.

4.3 Information production functions

Digital goods consist 100% of information. However, despite their considerable importance for the economy, there is as yet no industry-segment-specific or industry-oriented structuring of these goods on which one could base a production-theoretical analysis of the economic efficiency of their production and use. However, if we look at the internal planning and

decision-making processes in companies producing industrial goods and ask how they are structured in terms of process organization, it is obvious to pick out the Production Planning and Control Systems (PPC; Scheer 1987) used there as representative examples of the production of information and digital goods and to subject them to a production theoretical analysis. The insights gained can then be applied analogously to production of general information services (Fandel 1994).

Production Planning and Control Systems with their planning structures, submodules and the information and data processing show similarities with the structures of multistage multi-product manufacturing. This suggests to model production planning itself, with its subtasks of program planning, choice of procedure, procurement planning and process planning, as well as the multitude of information interdependences existing between these subtasks, by the concept of Activity Analysis. Along with the production relationships between input and output, the planning structures in the form of the information flows connected with these and the availability of data are also included as input-output relationships. So, by analogy with the integration of the technical characteristics of the goods in Engineering Production Functions (Bréguet 1927, Ferguson 1950, Chenery 1953) the attempt can be made to integrate the information characteristics of these goods with regard to the requirements of production planning in the input-output relationships and to represent them in the form of so-called "informational production functions". In this way information as relevant data concerning the production goods would - at least partly - be brought in explicitly as the fourth production factor in the production function.

The PPC system joins up the theory of production with production planning on the basis of data processing, as the production technology is implicitly contained in the data. Accordingly, a PPC system can be understood as a connection of information processing activities which have to be carried out in order to solve the subtasks in production planning. Thereby the information processing activities consist of components which show data inputs, embody data outputs and input quantities for data processing to generate data outputs out of data inputs. This basic connection has already been formally described by Wild (1970a, 1970b) and can immediately be integrated into the analytical considerations. Data inputs and outputs are information in the sense of task-oriented knowledge about the goods taking part in production. Input quantities are necessary for carrying out data processing and to execute the planning tasks respectively. Data values are for instance:

- quantity values of goods to be utilized and manufactured in production,
- time values (e.g. procurement times, processing times, lead times),
- monetary quantities (e.g. profit rates, fixed lot costs, inventory costs),
- any objectives of the planning (e.g. social and environmental criteria).

Differences can be made among data inputs and data outputs as well as among the goods of material production between long-lived data (analogously to utilization factors and consumer durables) and short-lived data (analogously to consumption factors and consumer disposables). Long-lived data are the parent production planning data such as, for example, structured bills of materials and technologically determined machine sequences for the jobs. Short-lived data on the other hand would be, for example, capacity utilization and batch sizes. On these foundations an information technology of production planning for a manufacturing company can be formulated. It consists of the set of all possible total information processing

activities which result from the repeated run-through of the submodules for solving production planning and control in the company and which can be realized on the basis of the technical knowledge of production of the company and the accompanying technique of data processing (Fandel 1994).

An efficiency assessment of information processing activities can be made according to various objectives; in this case, decisions can be conducted by applying multicriteria decision making. Examples may be calculating times to obtain the data or scores to assess their quality under organizational aspects. By these approaches the information processing activities show explicitly for the first time how the dispositive factor effects the quality of production by information (e.g. Völker / Mönch 2022, Gössinger / Plitt 2022, Persson / Kylinger 2022). The explicit formulation of “informational production functions” on this basis is an interesting field for further interdisciplinary research in the area of operational production and data and information processing. To develop such functions empirically for specific cases in practice would bring information-oriented production economics a decisive step further. Practical limitations on the information technology can result by additionally including in the considerations the relevance of data inputs and outputs respectively as well as the realizability of information processing activities. For examples of activity-analytic evaluation of PPC modules for optimal lot-sizing planning under dynamic demand and for the impact of their erroneous decision on the coordination of a just-in-time delivery, see Fandel / François (1994), and Fandel / Trockel (2016).

4.4 Ecology and sociology in production theory

Researchers in the field of Production Economics can justifiably point to the fact that in the past they have directly picked up on the social movements in the political and economic discussions in the world and therefore, quite early on, questions of the necessary inclusion of environmental protection in the theory and planning of industrial production of material goods were topics of scientific papers and are integral parts of university teaching for some time now (Dyckhoff 1992). Today, however, when the production of services and the strongly promoting and rapidly growing e-commerce that accompanies them have become the far predominant pillar of the gross domestic product of industrial economies, the question arises in a new guise as to what ecological consequences are associated with them and how they can be economically controlled by appropriate planning and decision-making models of service production.

The literature often diagnoses opposing trends when estimating the ecological consequences of e-commerce. For example, on the one hand, great potential for reducing resource and energy consumption is claimed through demand-driven production and the digitization of physical products, while on the other hand, an increase in small-scale delivery traffic is expected as a result of the reduction in storage capacities.

Studies on the material- and energy-related effects of e-commerce show an unclear picture, so that there is a considerable need for research in this area, the remedy of which could be more strongly addressed by the research field of Production Economics in the future. Further discussion will be preceded by some current data.

For the year 2020, it is reported (enviam-gruppe.de 2020, Plöger 2020) that 4.6 billion people worldwide, which is about 60% of the world's population, are connected online. On the Internet, 50 billion devices are used online, 4.2 billion are social media users, and 5.2 billion are mobile users. There are 550 hyperscale data centers operating worldwide, consuming 150 terawatt hours of electricity per year alone. The Internet is the third largest consumer of electricity in the world after China and the US, consuming 560 terawatt hours annually. 40% of this electricity consumption is used to cool computers. The CO₂ emissions of the Internet-country amount to about 800 million tons per year. In this level of environmental impact, it ranks 6th in the world with Germany, and at 3.7% of greenhouse gas emissions, is higher than global air travel.

B2B e-commerce handles US\$ 12.5 trillion in sales annually and B2C e-commerce around US\$ 4.2 trillion via the Internet. Just for comparison, the global gross domestic product of all countries was US\$ 82 trillion in the year 2020. Information and communication technologies are of fundamental importance for the functioning of the two e-commerce sectors listed above. They are said to consume 1% of the world's annual electricity consumption per year, which is currently 225 terawatt hours. Other lists from the Internet can be added endlessly. They very drastically demonstrate the need for research in Production Economics in the field of the theory of service productions and the expectations for the further development of our discipline, just as Behrendt et al. (2002) put it forward years ago:

From a methodological point of view, there is a need to develop models that go beyond the usual life cycle assessment techniques to include socio-economic parameters. The aim should be to address the interactions between e-commerce and changed economic structures, lifestyles and consumption patterns, forms of use of new media and the associated material and energy flows, to record them empirically and to derive ecological impact hypotheses.

Building on the modeling, existing instruments of ecological assessment would have to be applied and further developed. An important task is to consider central parameters in the life cycle of e-commerce applications. These include not only primary energy consumption, but also other indicators such as CO₂ emissions, waste volumes, pollutants, problem substances or electrosmog.

5 Perspectives of a comprehensive theory of production

5.1 General aspects of service production

The developments of the contributions of different economic sectors to gross domestic products of the most developed national economies prove that the theory of service production deserves a firm place in Production Economics and that concepts of the analysis of the economic efficiency require an intensive scientific elaboration. The economic data of the Federal Republic of Germany shall be cited here as an example for the evidence of this importance (Statistisches Jahrbuch 2019).

In 1980, 40% of a total of 0.79 trillion Euros (DM converted into Euro!) of the gross domestic product of the Federal Republic of Germany was accounted for by services. They were provided by 53.8% of the then total workforce of 27.4 million. In 2019, the contribution of the tertiary sector is 70% of the country's total performance of 3.47 trillion Euros and produced

by 74.5% of all 27.4 million workers that year (de.statista.com, 08.02.2022). So, both in monetary and real terms, the increase in the importance of service production for developed economies is very high. The four most valuable companies in the world in terms of their current market capitalization (in EUR) are service platforms for information and communication technology or trade (Apple, Amazon, Microsoft and Google; finanzen100.de, 10.04.2022). A corresponding place will also have to be taken by the theory of service production within the theory of Production Economics in the future, if the results of our empirical research are to be taken up by economic practice.

The literature is by no means lacking in approaches to a theory of service production (Maleri 1973, Corsten 1985, Fandel / Blaga 2004a, Sampson / Froehle 2006, Souren / Richter 2015). However, there is a lack of a consistent implementation of the structural elements of service production considered relevant in an input-output structure, which can then form the basis of a production-theoretical efficiency analysis and cost and profit considerations based on it. Thus, some authors complain that there are deficits in the information on cost structure data for all service industries, so that individual value added components cannot be calculated precisely. This is particularly true for financial services. In addition, it is criticized that there are inhibiting factors of further development in the e-commerce of consulting services, which are betrayed in the lack of competence of machine-based consulting and call centers (Riehm et al. 2003). The approach of added value must then be judged correspondingly critically.

In addition, the digital transformations in the economy necessitate corrections to the traditional defining characteristics of service production. For example, it is no longer generally possible to maintain the characteristics that services cannot be stored and that customers and providers must always come together at the same place in order to create the services. Network-based services and telecommunications services are no longer necessarily subject to this requirement. Furthermore, it must be remembered that digital goods consist one hundred percent of information and thus require a modified approach to the analysis of input-output structures of such services.

If one starts from the output-oriented definition of services in order to be able to use input-output analysis to assess their economic efficiency, then essentially the treatment of the external factor seems to pose the greatest difficulties. These input goods occur according to the Customer Contact Theory of marketing possibly also again after the service production as outputs, whose characteristics can be changed now however. Goods are defined by their characteristics (Marshall 1961, Lancaster 1972). This applies likewise to inputs and outputs. Thus, in order to describe the production-theoretical connection between these properties of the final product and the inputs in the service process, the approach of goal-programming (Ijiri 1965) from the theory multicriteria decision making (Fandel 1972) is a suitable one (e.g. Berti et al. 2022). The execution of a service is then under the postulate to design the production process (input-output combination) in such a way that one comes as close as possible to a spectrum of desired properties of the external factor after the treatment or even exceed them. For this purpose, different goal programming approaches based on distance functions can be used as solution approaches. In this way, it is also possible to take into account the customer's preferences with regard to the result of the service process. The properties achieved after the performance of the service then define its end product.

5.2 Need for a comprehensive theory of production

Efficiency analyses of service production presuppose that their input-output structures can be made visible, formally described and operationalized, and thus finally used for a decision-oriented analysis. Just as our discipline has succeeded in stringently examining the economic efficiency of the production of material goods in companies in a tried and tested form (Koopmans 1951) and in developing analytical models on which goal-oriented decision models can be based, the same questions also arise for the production of services and information. The goal to expand the traditional approach of the production function by including services and information as input and output goods into a modern form of an organization or information production function has been formulated in our research discipline for more than 50 years (Wild 1970a, 1970b, Noeske 1999).

If this production-theoretical task is not addressed more strongly in a future expansion and enrichment of Production Economics by a micro-theory of service and information production, one should not be surprised if approaches of marketing are combined with the solution concept of game theory, resulting in solutions that do not stand up to a production-theoretical examination. This happens, for example, when innovations of the digital age in companies or manufacturing systems are attributed added values to their advantageousness, willingness to pay is defined on this basis, and the added values are distributed among the players as a result, without their occurrence being described in concrete terms.

6 Conclusion

The explanations have made it clear that a goal-oriented corporate management can only be rationally justified by analyzing the underlying input-output relationships in terms of production theory. This also applies in particular to the production of services, information and ecological consequences. For this purpose, the literature already offers a variety of approaches that make it possible to form the basis for economic planning in a company. To want to control a company monetarily without concretely referring to the real relations of its production is a misconception and becomes dangerous when there are sudden changes in the price structure of goods. However, if one can formally describe the input-output relationships of a service production, then with the activity analysis a powerful investigation instrument is available to arrange the service production efficiently.

Studies of resource productivity through e-commerce are recommended. Detailed studies and model calculations on the effects on materials and emissions should be carried out along the entire value chain with a view to saving resources and reducing transport. Furthermore, it would be important to investigate the potential of the Internet to support environmentally oriented procurement by companies and the public sector. These are all appealing tasks for Production Economics.

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