




© 2022 Hammerström *et al.* This article follows the  Open Access policy of CC BY NC under Creative Commons attribution license v 4.0.



Taxonomy of an IIoT Device Based upon Production Functions

Lennart Hammerström^{1*}

Dirk Zwerenz²

Carsten Giebe³

¹Department of Director Operations Engineering Electronics,
Head of Corporate Competence Center Industry 4.0,
University Kaposvár, Hungary

²Department of Project Management Formwork Technology,
University Kaposvár, Hungary

³Department of Referent Data Analytics, University Kaposvár, Hungary

*Email: lennart.hammerstroem@icloud.com

DOI: 10.26417/ejes.v5i2.p6-22

Abstract

In this essay, we develop a decision model for the economic impact of Industry 4.0 technologies/IIoT devices on established business processes by testing two hypotheses concerning a decision model based on production functions. New methods to aid in the design and modelling of production systems that are able to rapidly reconfigure and that are self-adaptive in response to disruption (both by humans and for automated systems) are required (Sanderson, Chaplin, & Ratchev, 2019). Mass customization, shorter product lifecycles, smaller production batches and higher production variability lead to the requirement for manufacturing systems to be rapidly reconfigurable and self-adaptive in response to disruption, We propose to recover and apply available and established techniques to evaluate and assess the rationale of technologies before they are implemented to improve the decision process. We consider the investment into IIoT devices from a microeconomic perspective as a long-run problem for companies and therefore consider those problems to be reviewed with adequate methodologies to build a consistent decision model. Investing into a factor (such as an IIoT device) is only economically reasonable as long as this factor produces a benefit, otherwise the investment infringes upon economic feasibility (Fandel 2005).

Keywords: taxonomy, IIoT, device, production, functions

Introduction

A decision model is built upon objectives for the input factors and alternative decision options that depict different courses of action that are independent from one another and at the same time cannot be realized at the same time. The objectives define the factors for the alternatives as the optimal one (Schweitzer & Küpper, 1973). To encompass the alternatives and their consequences the theoretical model that we have tested and that we introduce below can be applied. In a standard case, applying IIoT technologies is going along with the execution of a digitalization strategy, a digital agenda or a digital roadmap within a company. This digitalization agenda is often based on strategic key performance indicators, such as growth, horizontal or vertical diversification and profitability. Contrary to the disruptive nature of the 4th industrial revolution, the calculation models to make an investment decision, stood the test of time and can be considered as traditional. Even though the 4th industrial revolution requires new ways of thinking and modified solutions we believe that existing calculation models are sufficient and can support the implementation process of IIoT devices within a company. We further feel certain that the calculation model that we apply for this essay is not only an industry specific methodology but also can be adopted for different industries such as automotive, banking and construction business. Nonetheless an industry specific adaptation is required, but due to the publicity and prevalent appearance of such calculation models they can be adopted fast to different industries and to different types of problem settings. We have chosen to investigate the *production function* of a specific IIoT device and to compare it with the well-established production functions; such as Leontjew.

Production functions are particularly suitable to solve practical management decision problems or to develop an authoritative forecast. In most cases they can be considered as user-friendly because they represent linear functions with terminable influencing factors and are easy-to-apply decision making tools. The production functions provide a good understanding of the input and output dependencies and allow a good approximation for the examined subject. The methodology of production functions can also be applied for research questions that exceed the sheer sector of investment decisions. It can be applied on research questions that go as far as the investigation of knowledge production functions (Pellegrino & Piva, 2019).

The IIoT device, that we applied has an expansive application spectrum. To make the final results even better comparable we decided to focus the use of the IIoT device on its capabilities in the area of training and support for all 3 investigated industries.

Motivation and Hypotheses

The 4th industrial revolution is affecting a wide range of industries. All of us are working in areas that are affected by the change that is driven by this revolution in a greater or lesser extent and we are required to deal with investment decisions in this field.

Making investment decisions and giving a substantial reasoning is a necessity in our daily business and we are confronted with this requisite constantly.

We developed two hypotheses to enhance the decision to invest into a certain technology or to be against an investment from a financial perspective while working together in a Corporate Social Responsibility engagement.

The first hypothesis emanates when discussing the different challenges and requirements of our industries within the IIoT. We believe that a comprehensive calculation model can be established based on long-time available models that have been tested numberless times.

Even though IIoT devices are considered often as “disruptive”, its impact on the return on investment can be calculated with established and tested calculation models. No new calculation model is required even though the impact of an IIoT device is unknown and considered as disruptive.

Our second hypothesis originates from the specific industries that we are working in and that we believe that one model can be used for different industries. It is not necessary to develop dedicated models to calculate the return on investment for each single industry.

The model to calculate the return of an investment that is based on hypothesis #1 is independent from the industry it is applied on.

The second hypothesis is evidently showing that we expect a concatenation of the 3 investigated industries and we expected, depending on the timelines, a production model that is alike.

Experimental Set-Up

At first, we defined an IIoT device that is applicable for the industries we are working in. The industries we considered are a.) Formwork Construction, b.) Banking and Finance and c.) Electronic Production. Within those industries we further specified the area of application of the IIoT device, such as maintenance in the Electronic Production.

The device has to carry one specific function that is has been built for; in our case the collaboration of two participants that are physically separated and that are not at the same place at the same time. The supporter is guiding or assisting the applicant within a certain field of application.

We then identified the experts in those specific areas of application worldwide and discussed with them our hypotheses and the terms and definitions that are the foundation of production functions. Furthermore, we explained the IIoT device that we had chosen to be applied on a theoretical basis and held some further information meetings to ensure that the device is understood and its impact is considered in the right way.

Then we asked those experts to rate the impact of the IIoT device on a standard production function scale with the device on the axis of abscissae and the return on the axis of ordinates. Those ratings were then used to precede with an illustration of the production function in a graphic form and to then deduce the mathematical function from the graph which is used as an auxiliary.

First field of investigation – Formwork Construction

For the part of the survey on the implementation of IIoT device in construction industry, we selected a worldwide operating company in the construction supply industry.

For a variety of reasons, the construction supply industry, like the construction industry, is under the constrain to digitize its working processes and project management processes.

Unfortunately, however, the construction industry has not yet succeeded in integrating innovative technologies within its processes in order to keep pace with other industries, such as automotive and mechanical engineering (Oesterreich & Teuteberg, 2016). Due to the high degree of individuality of construction projects, constantly changing framework conditions and value chains, which continue through many different subcontractors, the construction industry cannot call itself a leader in the digitalization and industrialization of its project management.

Often the professional experience within construction is regarded as irreplaceable; and this is justified and proven in many cases. David Autor describes the professional experience as the "cognitive abilities" of a human being which are to be rated higher than the knowledge of the human being about the associated physical laws (Autor, 2014). The author further describes that the increasing automation and substitution of jobs due to digitalization will primarily affect *routine medium-skilled* tasks that follow an exhaustive set of rules (Autor, 2014).

Characteristic for this are cognitive and manual activities such as bookkeeping, office work and repetitive production tasks, but not just yet mechanization in the construction industry. In 2017, Daniel Kiel and colleagues examined in many case studies how shortened technology and innovation cycles affect increasing individualization and increased the volatility of demands (Kiel, Müller, Arnold, & Voigt, 2017). They came to the conclusion that a sustainable value expected by manufacturers from an investment in IIoT must meet economic, social and ecological objectives in equal measure (Kiel et al., 2017). However, the construction industry primarily expects investments in IIoT to maintain and strengthen its future global competitiveness. Due to the many subcontractor relationships, social and partly ecological goals are regarded as rather secondary. Technological change in the construction industry necessarily follows the Pareto principle (Autor, 2014). The author describes 3 factors that mitigate or amplify this approach:

Employees benefit from automation

The elasticity of final demand can either dampen or reinforce the gains from automation

The changes in the labor supply may also reduce wage increases

In 1997 David J. Teece, Gary Pisano and Amy Shuen raised in their article *"Dynamic Skills and Strategic Management"* the questions whether strategic theory is connected with the analysis of strategies at company level to maintain and secure existing competitive advantages, and how and why certain companies can build up competitive advantages in systems of rapid change (Teece, Pisano, & Shuen, 1997). The approach is particularly relevant with regard to the cognitive skills described by Author (Author, 2014) in performing simple activities in the context of innovation-based competition, price-performance rivalry, rising returns, and the "creative destruction" of existing competencies (Teece et al., 1997). As a competitive advantage, David J. Teece and his corresponding authors describe the recording of the imputed rents of decisive competitive advantages in the third paradigm of their remarks (Teece et al., 1997) and thus partially prepare the basis for the theory described in 2005 by Robert Gibbons in the *Journal of Economic Behavior & Organization* (Gibbons, 2005).

Gibbons wanted to answer the question: Which transactions of a company are carried out more efficiently? It defines and compares elementary versions of 4 theories of the enterprise, the theory of the incentive system, the adaptation theory, the property right theory, the theory of rent search (Gibbons, 2005).

Especially with the theory of the incentive system, in addition to purely calculable economic facts, there are rich reasons (soft skills) why a construction company should invest in innovative technologies such as IIoT. The increasing shortage of junior staff in all sectors of the construction industry requires more attractive and innovative jobs. This is true both for commercial activities on construction sites and for activities in management positions in the construction industry.

In *Marketing and Management of Innovations*, Zwerenz describes his findings regarding the crucial importance of presenting a construction project as an innovative brand and the consequences for the performance of employees, their identification with the project and the commitment of employees in construction projects (Zwerenz, 2019). The effects of the introduction of IIoT devices on construction sites can thus not only be measured directly in monetary terms, but must also be assessed taking into account aspects of the attractiveness of projects.

The positive or negative influences are evaluated as an example of the introduction of a digital service of a worldwide leading manufacturer of concrete formwork, the Doka Group. Doka is one of the leading firms in respect of industrial casing and frameworks with a turnover of more than 1.5bn€ (www.doka.com).

The decisive factor for the evaluation of the number of IIoT devices to be invested here is the perspective of the manufacturer of concrete formwork (the service provider) in order to guarantee the service offered worldwide by the so called *Remote Instructor* (<https://www.doka.com/at/solutions/services/remote-instructor>).

In the Digital Services business unit, the Doka Group is developing digital services and applications for the construction industry today and in the future. Doing so, the Doka Group is optimizing existing processes and establishes new and more efficient ones.

In a co-development with its customers, the company can respond in an optimal manner to their needs and also strengthen customer relationships. The *Remote Instructor* is a powerful video collaboration software for the remote support of problems on construction sites. Full order books with an acute shortage of skilled workers - a major challenge that the industry is currently facing. Time and again, uncertainties and mistakes lead to expensive downtimes. The *Remote Instructor* takes on this challenge. As a software solution for real-time collaboration specially developed for the building industry, intelligent video telephony provides location-independent support for rapid problem solutions. The product video is available under the following link: <https://www.youtube.com/watch?v=Mya0mvYSB2o>

The smart glasses are therefore predestined to be applied for the *Remote Instructor* and to implement some of the digitalization issues that the Doka Group is working on.

Second field of investigation – Banking and Finance

The financial sector is one or even the most important instruments of the economic system. In phases of digital transformation, the sector is able to implement changes. The development shows investments in projects for the implementation of innovative technologies. In particular, we are talking about the formation of virtual regionalism (Pajak K. et al., 2016).

The use of VR and AR in the financial sector demonstrated its benefits for the transfer of information and knowledge. Here a concept was used which learns from the interaction with a 3D environment. Virtual Reality enables the creation of virtual environments with features that represent a real situation. For viewers, visualization and interaction with virtual objects is closer to reality than previous abstract representations (Maad, S. et al, 2010).

The characteristic of the banking sector in Germany is the three-pillar structure via a strict separation into three columns, Cooperative banks (e.g. DZ Bank), Private commercial banks (e.g. Deutsche Bank, Commerzbank) and Public-law institutions (e.g. Savings banks). In our research work we will focus on the German saving banks. The savings banks are independent commercial enterprises in municipal ownership. Their task is to strengthen competition on the basis of market and competition requirements, primarily in their business area. Furthermore, their role is to ensure adequate and sufficient supply of all population groups, the economy, in particular of the middle class, and the public hand with monetary and credit-economic

achievements also in the area (regional aspects). Saving banks support the task fulfillment of the municipalities in the economic, regional political, social and cultural area. At least savings banks promote the economy of savings and the accumulation of wealth of broad sections of the population and the economic education of the youth.

Many savings banks in Germany could miss the connection in the age of digital transformation. On the one hand, external influences such as customer behavior, customer expectations, technological change, willingness to pay and product life cycles are gaining in importance. On the other hand, the internal expectations of the employees, e.g. the acceptance of new technological solutions, the adaptation of new processes, are constantly increased. Due to low returns, savings banks are forced to digitize processes. In the future, we will experience a working world characterized by automation and digitization. As a technical revolution, this also encompasses many areas of the saving banks. Digitization has priority in order to be able to catch up the backlog for "digital capabilities". This forces the savings banks to modernize. To realize their ambitions, savings banks are well advised to create the necessary internal conditions. Innovative banking services must be tested for feasibility and then embedded in processes and appropriate technical architectures. It is an open secret that costs can be reduced through a higher degree of automation. The current and planned activities in the saving banks financial group, which deal with new processes and digital tools, are correspondingly diverse. Examples of chatbots are the possibility of data analytics or the use of virtual reality (Giebe, 2019).

For our research, an example of the saving bank *Göppingen* shall be considered (<http://ksk-gp.future-banking.digital/de/>). The *saving bank* has a balance sheet total of approx. 6 billion euros, 1,080 employees and 67 branches. As early as 2015, the saving bank launched a comprehensive digitization project with the aim of strengthening digital competence within the company. A so-called "digital playground" was created in the customer center of the saving bank. Among other things, Holo-Lens were installed for customers and employees explained the digital transformation. In this 60 square meter innovation branch, customers will be able to experience the technical innovations together with the employees. Interested people can try out virtual reality glasses there and ride a roller coaster with them, for example. 3-D glasses make it possible to virtually view a property without having to take a step outside the door. In another section, screens and smartphones are available. There, customers can have online banking, the use of saving bank apps, mobile payment and photo transfers explained to them on the basis of test accounts. The digital playground is managed by ten saving bank employees. They act as important ambassadors of digitalization to customers and into their own company. The concept plans the regular exchange of gadgets (Müller, 2018).

The expert assessment is based on the described example "Digital playground" of the *saving bank Göppingen*. Beside a station with VR glasses there are further gadgets of digitalization. Customers have already been able to steer drones through the customer hall. In addition, a 3D printer was installed to produce edible chocolate

figures. Since 2018 there have been so-called theme islands dealing with banking topics such as apps, online banking or online brokerage. Since ten employees work in this innovation branch and different stations can be visited, there is a decreasing benefit within the scope of the assessment. The top box value was not awarded, as the benefit is more likely to serve the understanding of technological innovations and the image. This means, for example, that no additional revenue or cost reduction is generated. The use of the glasses used is intended for the assigned station. This means that the glasses do not perform any other function and are not used elsewhere. If ten employees had ten glasses in use, the other stations could not be manned. This means that customers' requirements cannot be met holistically. A high impact was achieved with 1-3 glasses, a medium impact with 4 glasses. 5 glasses have a little impact, 6 and 7 glasses have a very little impact. Having 8-10 in use has no impact.

With regard to the effectiveness of the contents provided, it is known from studies that these were assessed as realistic. The participants could be given the feeling of being present in the respective environment. These conditions created a positive sympathy level as the participants could feel part of the content provided. The results also showed that the content provided could support the concrete learning experiences of the individual. When preparing VR environments, however, the study results include the possibility of long-term use of these technologies and a higher effectiveness of realistic contents (Yildirim, Elban & Yildirim, 2018).

The 386 individual saving banks each have their own market area and are separate from each other. The regional principle, for example, makes personal communication possible without problems. Till August 2019, there was no centrally defined use of VR glasses in the Savings Banks Finance Group. If savings banks use VR glasses, they do so on their own initiatives. The case study of saving bank Göppingen was used as best practice part of this research because the background for using VR glasses is transparent.

However, the conditions described for the *saving bank Göppingen* show that the content provided has a playful character in order to explain digitization technologies using the example of virtual reality. In our opinion, this also holds potential for future use.

Third field of application - Maintenance

The automotive supplier industry is often organized in a decentralized manner and competencies are unevenly distributed worldwide.

Different kind of very specific systems are produced within selected locations in one part of the world and shipped to many other locations worldwide to fulfill their purposes for a specific product at the production site. This is done due to cost competitive reasons and to benefit from local advantages in certain regions.

This approach confronts the automotive supplier industry with the problem of specific requirements to maintain and to repair this specific equipment. To do so,

special knowledge and special training is in many cases required to keep the systems capable of running. The situation is aggravated by the just in time and just in sequence approach of the automotive industry. The equipment is not allowed to be idle or out of use for a certain length of time, often only hours or a very short period of days.

The automotive supplier sector introduced different measures to react to this challenge, such as hotlines, service contracts, training and education for the own employees or went to such length to have a backup of systems on site.

With the development of smart glasses, the potential to support locations remotely improved dramatically. Now the specialist is enabled to interact with the employee on site and to give guidance and support in a more efficient manner.

Therefore, it was decided to examine the impact of the introduction of smart glasses into the maintenance systematic in this industry.

The maintenance teams consist of different experts and have an uneven need for support of the experts from other regions. The team is connected to experts that can be located at different locations worldwide.

We talked to a number of maintenance experts and asked them how they rate the impact of smart glasses on their special field of accountability after they were taught about the systematic of our survey. Their feedback was then compared to the other industries.

The production functions

A production function depicts the relation between input and quantitative output by representing the aggregate output depending on the given amount of production factors (Lenk, 2017). The formula for the production function is the following:

$$Y = f(K, L, P, H)$$

The factors of production are:

***K* = Physical capital [capital, tangible assets (mobile and immobile)]**

***L* = Labor (skilled and unskilled human workers)**

***P* = Land (surface, subsoil and conjoined raw materials such as coal)**

***H* = Entrepreneurship (the business intelligence and its quality)**

The input factors of a production function can be reduced, for example to labor (*L*) and capital (*K*).

$$Y = f(K, L)$$

In respect of the variety of types of production many different production functions exist.

The model that we developed is an isomorphic mapping of the (real) observation state; the model is idealized but can be repeatedly applied at different industries in

the type of embodiment that we have chosen. It facilitates the scientist or the engineer to understand and to chart the elements of the de facto application and its principles. This is true for the different industries that we investigated. Modeling an appropriate measurement, we provide the theoretical background that can be transferred for the further application of similar devices in different areas of application in different industries. The model is both, an explication of the well-defined and finite area of application and a tool to prognosticate the effect of the IIoT device.

Production functions, such as those that Wassily Leontjew developed while investigating the in- and outputs in the American economy, provide a reasonable model to recognize the right investment into a certain IIoT technology. The proverb “a lot helps a lot” was proven to be wrong in the beginning of the development of the production functions. “As much investment as necessary” from an economic perspective is the target, but it depends on the financed technology.

The investigation of a production function reduces uncertainty and helps the entrepreneur to improve her investment decisions, based on facts and figures.

Production functions have some well-known and thoroughly examined weaknesses in the long run; nevertheless, they work well in the short run and can be applied as a model to determine the effect and influence within a certain field of application in a confined environment.

We adopt the production function for a microeconomic practice to calculate the economic effect of a *supportive* IIoT device. This device is not changing the nature of production or the kind of organization; we set those factors as fixed. The device is clearly an IIoT device, but it is extending the way of working and is not disrupting it. From an innovational point of view, it can be seen as an *architectural innovation* due to the set-up of the single components.

For other devices, that enable a new way of working from an organizational perspective or change the nature of production (disruptive innovation) the application of our approach needs to be further investigated.

In our research we investigated the kind of production function we are dealing with; we expected it to be neither a substitutional production function nor a fixed proportion production function but a fuzzy production function because the device is applicable in several different sets of working. We decided to ostracize the fuzzy influence by restricting the field of application to avoid a misinterpretation at the end of the analysis. We further ostracized functions by the exclusion principle, based on their definitions in the economic literature. We ostracized the following types of production function: type B (after Erich Gutenberg and Wassili Wassiljewitsch Leontjew), type C (after Edmund Heinen), type D (after Josef Klook), type E (after Pichler) and production functions that are dynamic ones (after Matthes).

A *type B production function*, the Gutenberg, Leontjew or Kilger production function, investigates the aftermath of changes in the labor market situation with the

accompany of the adjustments of producer's goods for a given amount of capital goods and no change of the technical parameters (Albach 1989, Gutenberg 1952). Variables are the output per unit of time, the period of application and the number of the applied aggregates (Gutenberg 1952). For a type B function it is assumed that two transformation functions are valid, for one part of the used goods it is assumed that their amount is immediate with the output quantity. In many cases they represent Leontjew-functions, but their characteristic is that for some input factors the output depends only indirectly.

A *type C production function* (Heinen) is distinguished by the stratification of the production process in rudimentary combinations, the consumption of output related, indirect material depends on the intensity of the means of production. Because there is no indirect material in our model, we neglect the type C.

In the 1950s Pichler framed a specific Leontjew production function, the type D. In type D production functions command variables represent the variables, such as throughput or in-company constraints. Pichler production functions can be one- or multi-level production functions and he formulated those with a focus on chemical industries. The in-company constraints we were able to exclude from our model and therefore exclude the Pichler production function.

The characteristic of a *production function of the type E* (Kloock) are complex production structures with cyclical interdependencies and, contrary to the other types, are not static. They rest upon the technical progress within a production process, e.g. a product on a higher production stage can only be produced when a product on a lower level (the input for the higher level) has been produced already and is available.

Further interdependencies are the technological progress, newly created materials and/or improved production processes and machines. Also, the learning of the employees is considered as an interdependency in this production function.

The transformation functions are formulated in a general way, all other production functions can be deduced from this type by reducing or excluding the impact of the mentioned constrains, for instance by taking only a very small time period into account to reduce the timely correlation to a minimum.

Investigating our model and comparing it with the different production functions we set up the hypothesis that our production function is either a function of the standard profit law production function or a special case of the CES-production functions, a Cobb-Douglas production function.

At this point we were unclear if we can reduce the law of diminishing returns in our case to the argument that *a.)* from a certain amount of the variable factor (the IIoT device) an under proportional increase of the return is effectuated or *b.)* if there is no maximum for the variable factor (the IIoT device), with a non-linear correlation to the

factor. We had to investigate the *standard profit law production function* and a special case of the CES-production functions, the *Cobb-Douglas production function*.

The characteristic of the *standard profit law production function* is that at first the output quantity x increases over proportional, then proportional and eventually under proportional.

A *Cobb-Douglas production function* (a special case of the CES-functions) is a commonly used substitutional production function within the macroeconomics and the national economy. The calculation model can be carried over to the microeconomics, too. The variable factor is increasing the profit, but not in a linear manner. Increasing the factor will always increase the profit, but not proportionally.

The Cobb-Douglas-function predicated on the findings of Johann Heinrich von Thünen, the founder of the scientific agricultural economics. Thünen searched for a natural and equitable income distribution and can be assigned to the classic economy. In the beginning of the 19th century he examined how to calculate the maximum profit of agricultural products, using the method of abstraction. The maximum profit depends on an optimal utilization of the land surface and the cost for transportation. The price for the land decreases with the distance to the nearest market place and the transportation cost are directly proportional to the distance to the market place and the weight of the goods. He was able to test and to verify his findings on his own estate near Teterow which he bought in 1810 (Linß, 2014).

Paul H. Douglas was lecturing at Amherst College when he consulted Charles W. Cobb, a mathematician. Cobb suggested to adopt a simple homogeneous function that had been used by Wicksteed and Wicksell before.

$$P = bL^k C^{1-k}$$

Douglas (1976) explicates that with an influential article of David Durand (Durand, 1937) and the facilitation of Grace Gunn, a change of the formula was made.

The formula was changed to make the exponent of C independently determined instead of treating it as the residual in a homogenous linear equation.

$$P = bL^k C^j$$

Douglas and his team applied the new formula to their precedent and actual data that they compiled from different industries; their findings strongly supported the formula. But the formula was criticized by prominent economists, such as Horst Mendershausen and Ragnar Frisch and from other senior American economists at the University of Chicago (Douglas, 1976). Scientists have tested the formula in almost every industry and have found that it can be misleading and has to be adapted to the special field of application (Assaf & Josiassen, 2016) (Costa, Lopes & Matos, 2015) (Okolo & Attaham, 2017).

Assumptions of the mathematical model

When testing our hypotheses, we based our assumption on the “traditional model” of a Cobb-Douglas production function, assuming that firms operate on a non-stochastic production function and maximize profit. Zellner, Kmenta and Dréze (1966) introduced a model of a Cobb-Douglas production function that left aside random disturbance terms of the econometrician which would make the model stochastic. Zellner et al (1966) argument that entrepreneurs are aware of the stochastic nature of the production process. We argument that the random disturbance of the model has to refrain from our model to expose the effect of the IIoT device by itself.

Assumptions of the IIoT device

We set limitations to the application of the IIoT device that were necessary to generate an abstract model to enable the model to be tested under factual conditions.

The IIoT device is the same for all use cases, there is no technological disparity between the devices

The level of training and the level of know-how of the applicants is inalterable, the learning curve is neglected

The number of utilizations for the device is constant and unchanging

The fundamental idea is that with the introduction of the IIoT device the quotidian expenses are reduced according to the theoretical yield curve.

Generalized graphical representment of the hypotheses

Our hypotheses are that we are either concerned with a Cobb-Douglas production function or with a standard profit law production function. Both graphs look quite different and are easily to be distinguished from one and another.

A discernible cachet of the Cobb-Douglas production function is its indefinite growth, it does not have a maximum and will further increase when the variable is increased. Our limiting factor is here the user of the device, it is perspicuous that one employee cannot handle more than one of the above outlined devices at a time.

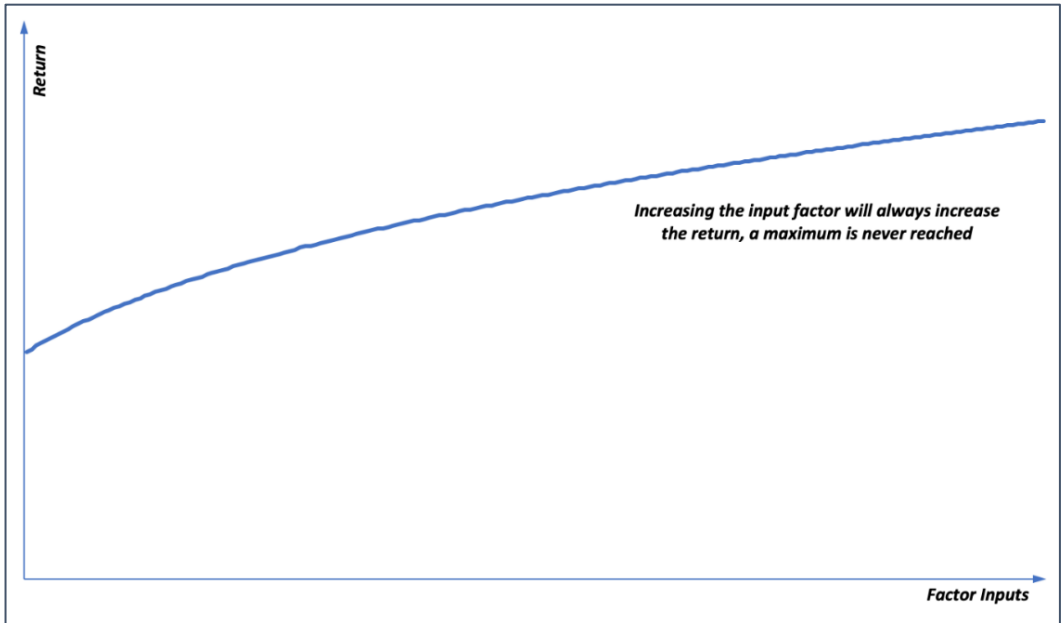


Figure 1 - Cobb-Douglas Production Function

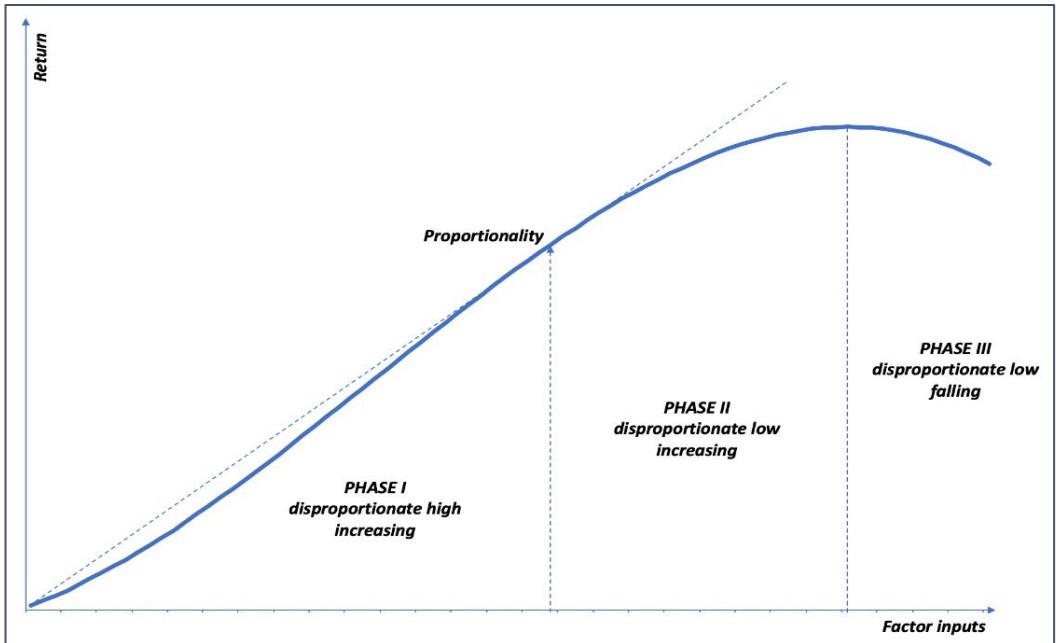


Figure 2 - Standard Profit Law Production Function

Contrary to the Cobb-Douglas production function the standard profit law production function does have a maximum and it will be reached at a certain time when a certain number of input factors are implemented.

Implementing the IIoT device increases the return in a disproportionate high manner. The first IIoT devices deliver a high return rate according to the standard model of the yield curve (figure 2, PHASE I). According to the standard yield curve the return reaches the proportionality and enters PHASE II, in which the increase becomes disproportionate low. The third phase is the phase in which the return starts falling (PHASE III) due to the missing contribution of the device to the return.

The IIoT device is the factor that can be bought with money; therefore, it is the capital in the standard equation.

The Marginal Return

The marginal return is inextricably combined with the type of the production function. The marginal return of a Cobb-Douglas production function will fall, but will never be negative. In opposite to the Cobb-Douglas production function the standard profit law production function does fall and will discernibly lead to a negative marginal return at a certain point.

To find out which progress the function is taking over time is of immediate utility before investing into an IIoT device and is

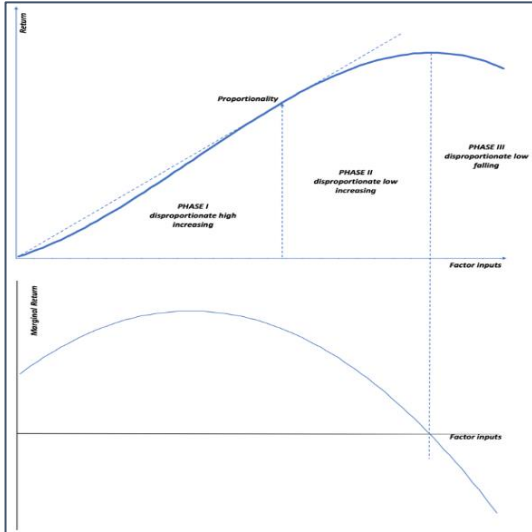


Figure 3 - Marginal Return of a Cobb-Douglas PF of a Standard Profit Law PF

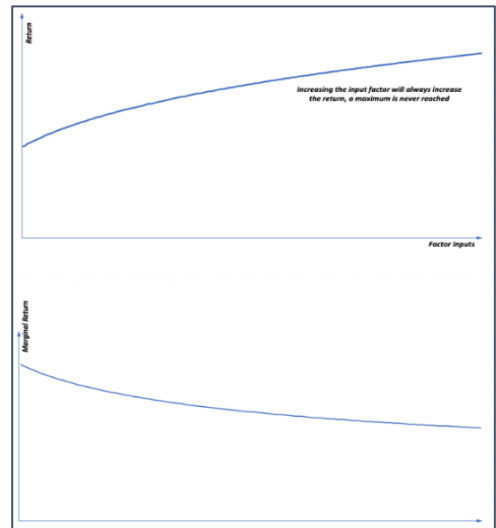


Figure 4 - Marginal Return of a Standard Profit Law PF

The IIoT device

The IIoT device is viewed in this case as the *means of production* that supports the transformation process of the working habits within a locally limited production center. It *cannot* be seen as an intrusion of a new state of industrial form of production, but as a completely new support device that can be considered as a production device or an expansion of the means of production.

The segregated field of application with a direct impact on the output of the process allows us to *factor in* the IIoT device and to *singularize its discrete impact* on the production function.

We have chosen to implement smart glasses as a relatively easy-to-apply IIoT device within existing service- and production environments.

There is a wide range of applications regarding augmented and/or virtual reality respective mixed realities. We intentionally reduced the range of the technological capabilities and the technological specifications (such as the CPU, the resolution per degree, connectivity, ergonomics, field of view, etc.) of the device for this survey to avoid a technical discussion with the interviewees.

The technological capabilities were reduced to particular features that are common for most of the devices:

Realtime connectivity

Ability to communicate with the applicant and the ability of interventions

Video demonstration capabilities

The device does not require a long-time training or asks for dexterity from the applicant. The software for the device is both installed in the local network of the applicant and in the network of the assistant.

The hardware needs to be on-site of the applicant; the applicant is the one who is supported by the person that has a deeper understanding and a wider range of knowledge of the supported technology.

When the applicant takes note of a problem, she is accountable for and that she cannot solve, she can contact with the supporter with the IIoT device. The IIoT device enables the supporter to gain a better overview of the on-site situation and to give more specific advices and is enabled to solve a problematic situation that in other case only would be solvable with an on-site appearance of an expert.

An inscrutable situation can be made clearer and the solution process can be accelerated, the dependencies of the input and the output can be deducted empirically.

There are certain production functions for different technologies, we go as far as to assert that even within a certain cluster of technologies the production functions differ from one and another slightly.

The Survey

When we decided to uncouple our survey from other factors and to exclude certain ones, we also obtained the possibility to create a very specific questionnaire that focused on the chosen IIoT device.

# of IIoT Devices	No Impact	Positive Impact				
		Very little Impact	Little Impact	Medium Impact	High Impact	Extreme positive Impact
1	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
9	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
10	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Figure 5 - Rating of the Impact

The interviewed person was informed about the content and the background of the survey and received an easy to fill out spread sheet. The spread sheet asked for the impact of a single IIoT device and for a then following aggregation of the devices till the number of 10 devices (1 device, 1+1 device, 2+1 device, 3+1 device, ..., 9+1 device). To indemnify that we will have in any cases a sufficient number of devices we decided to set the maximum up to 10 devices; we made the assumption that in no single case a number of 10 devices will have an impact that is higher than what we labeled as *little impact*.

To express that a further input does not have any further positive impact on the output we labeled this point with *no impact*. This point would correspond with either the reversal point in the graph of a standard production function or would not be chosen by the interviewee when there is no reversal point as it is true for the Cobb-Douglas production function.

Results of the Survey

The graphs we received after the analysis reveal that the production function is following the standard law production function and by no means at all the Cobb-Douglas production function.

Therefore, we are in a position to determine that investments into the analyzed IIoT device is behaving according to the function of the standard production law and that investment decisions can be based upon those findings.

The process of elaboration was to collect the answers, converted those into the main database and create a general.

To display the result a X/Y plot was chosen and the dots were connected for each point.

The axis of abscissae displays the number of devices that are implemented in the described scenarios and the axis of ordinates displays the impact. For each graph an approximation was generated, too.

Results of the Construction Industry

For the construction industry we received a graph that evidently appears to fall straight from a very high level to the zero-impact level in a nearly straight line. The investigated implementation area of the IIoT device has for the construction industry the highest impact, two devices improve the situation extremely positive. The third device comes with a retrogression but still has a high impact. The number of devices for the implementation area within the construction industry can be pointed out to be at 5 to 6 devices. A fast return on investment can be expected with 3 to 4 devices, which is a high number compared to the other investigated industries.

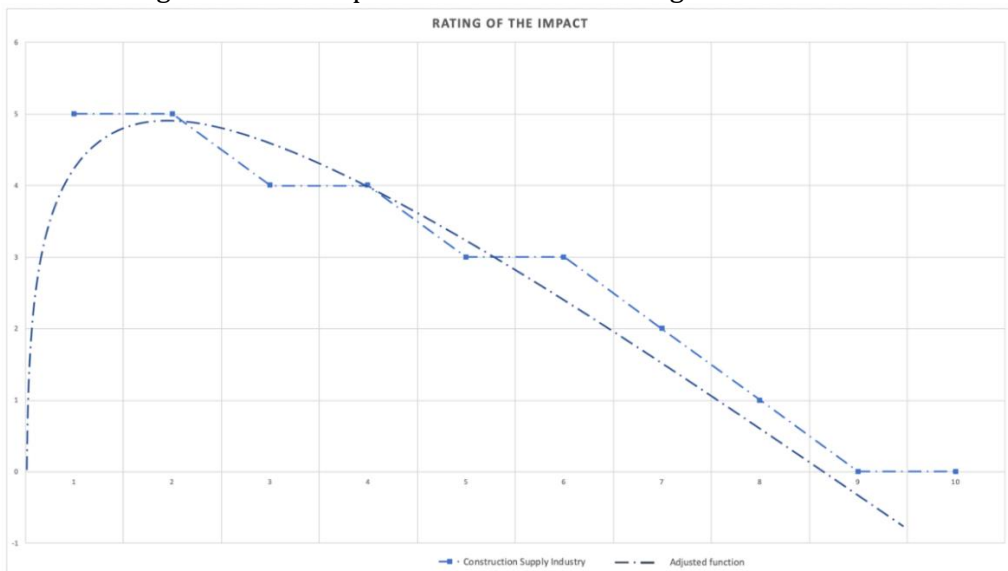


Figure 6 – Rating of the impact for the Construction Industry

Results of Banking and Finance

The investigated area of the saving bank shows a constant high impact, but never an extremely positive impact. The device seems to have a flat top level for the first 3 devices but then the impact starts to downfall continuously. An investment strategy could be to start with 2 devices and to validate the impact again. A third device seems to be a low-risk asset, the fourth device has to be observed closely.

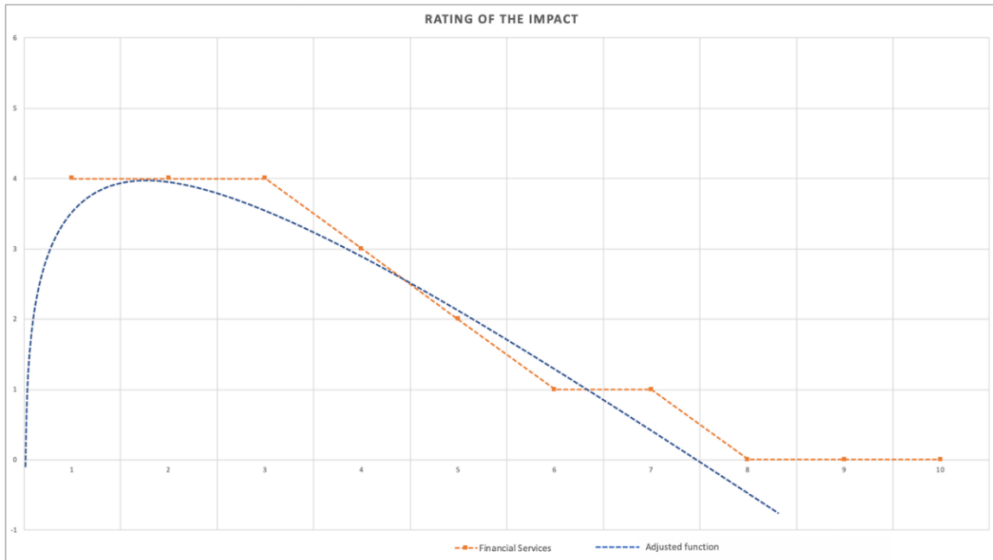


Figure 7 – Rating of the Impact in the Savings Bank

Results of the Automotive Supplier Sector

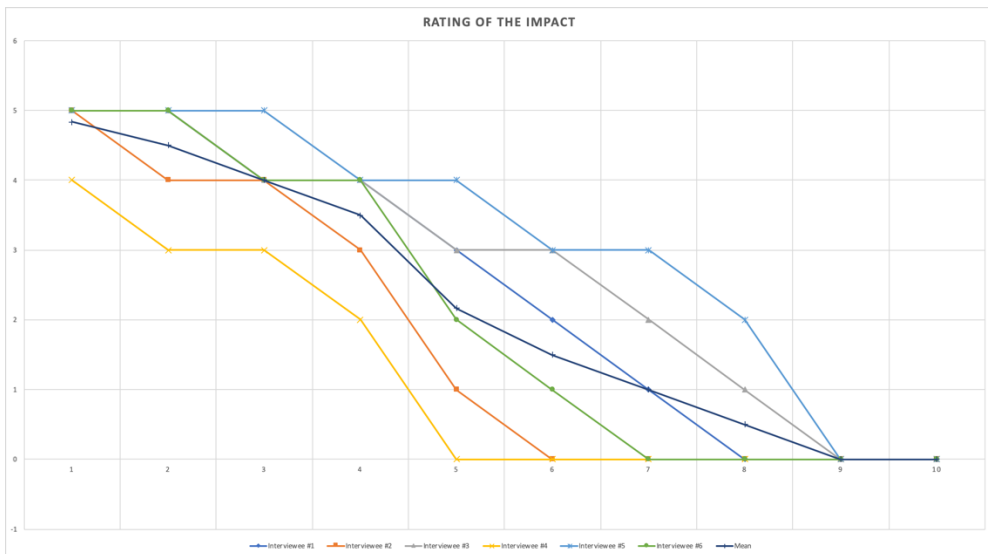


Figure 8 – Detailed Results of the Survey for Maintenance

Unlike the investigation within the construction industry and the saving bank sector the investigation within the automotive supplier maintenance area was conducted on a global basis. Therefore, the dataset had to be adjusted to the number of employees working in each area. After cleaning the data, we came to a presentment of the following:

Each graph represents an individual from a different region. Not surprisingly the graphs have different levels where they start from, but they all follow a very similar course.

The results were combined and a mean of the functions calculated. The adjusted function shows that the device has also a high impact right from the beginning on the maintenance but is declining in a similar way to the construction industry.

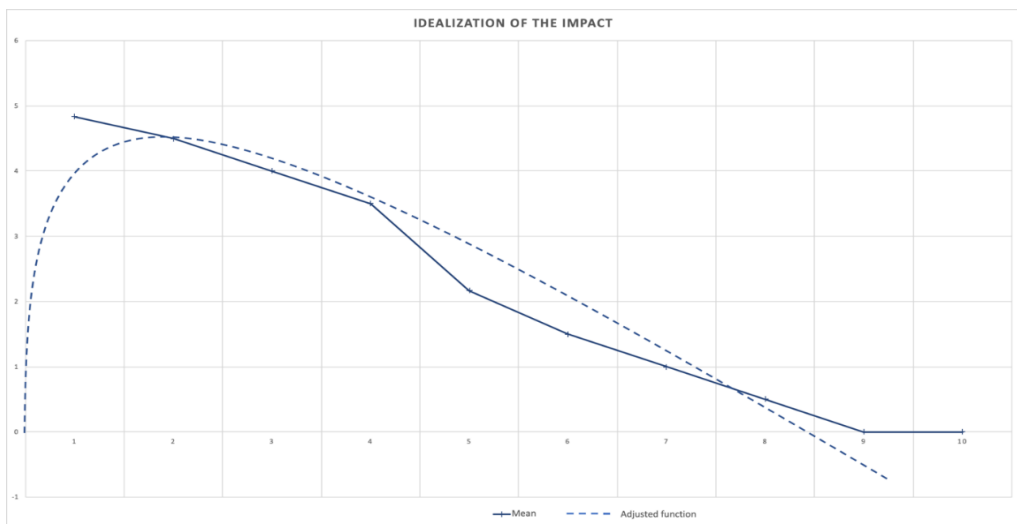


Figure 9 – Rating of the Impact of Maintenance in Automotive Supplier Industry
Subsumption of the 3 industries

Our main finding is, that all three industries show the behavior of a standard production function but that the investigated industries do have different adjusted progressions.

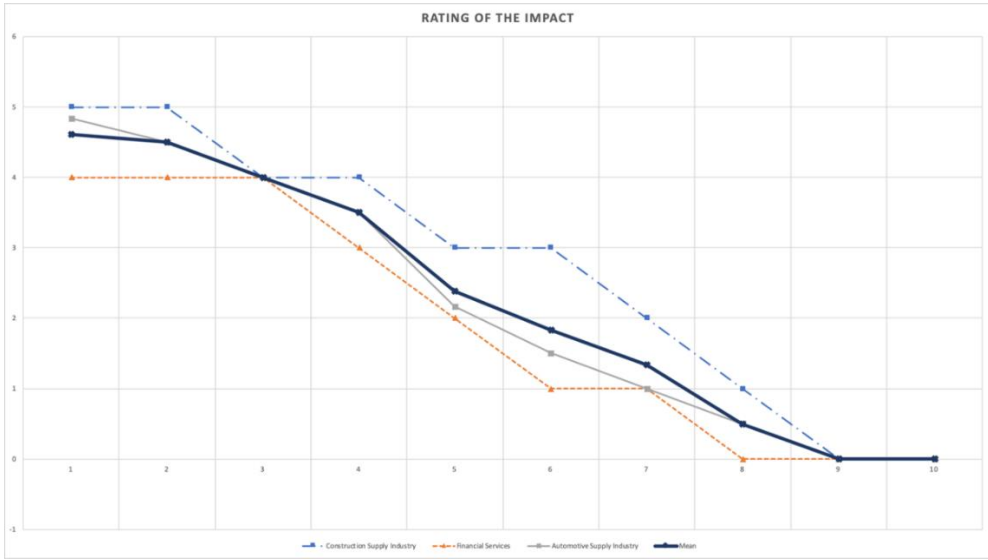


Figure 10 – Comparison of the Industries

The type of production functions of the different industries is akin with each other regarding its overall shape, but differs regarding the impact of the number of devices.

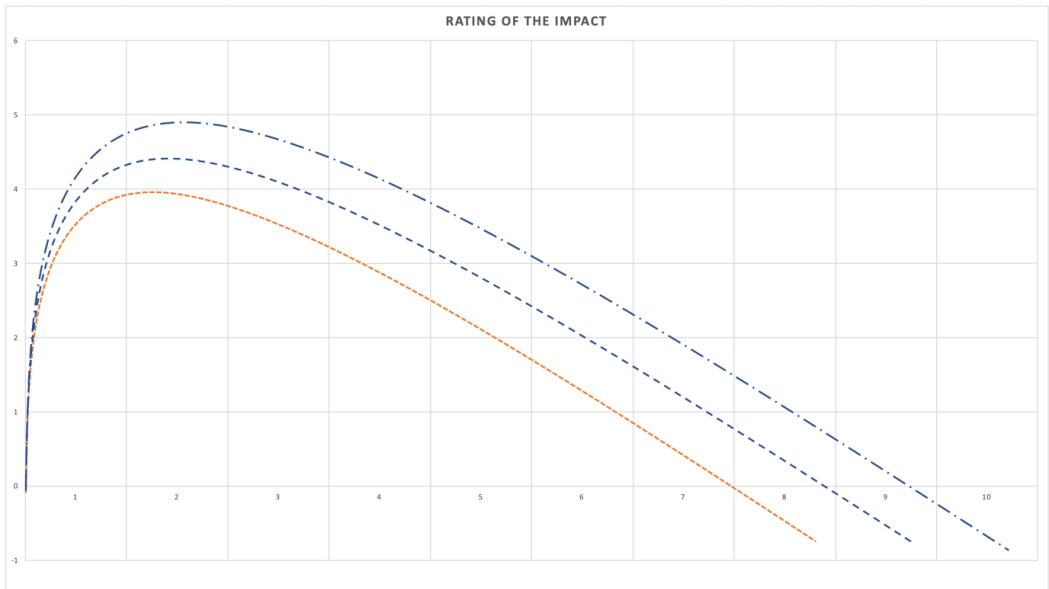


Figure 11 – Adjusted Rating of the Impact for the Industries

The adjusted functions draw an even clearer picture of the progression and the superordinated form of the behavior of the function.

All industries show that the use of smart glasses have a steep rise of the impact for the first glasses that are introduced. The decline is also similar in each of the industries and eventually results in a negative impact of the device, i.e. a further device cannot be applied lucrative.

Conclusions and recommendations

Production functions are significant for the functioning of economics and business management systems. To understand at what extend an investment is affecting the business environment can be an important success factor resp. can be developed to an advantage in competition.

Using the example of a disruptive device, we have shown that the disruptive effect of innovative processes, technologies, methods and devices on established industries can be integrated into the strategy process of such different industries as the banking sector, the automotive- and the construction-industry. Established models, that were applied in the second resp. third industrial revolution are powerful tools even today when applied on technologies that are considered being part of the fourth industrial revolution.

We therefore consider our first hypothesis as confirmed in the sense how we verbalized it in the beginning of this work.

For the industries that we examined we also consider our second hypothesis to be correct; the graphs in the 3 investigated industries have a very similar progression and, but a difference within the heights of the impact, it is industry specific.

The limitation of the explanatory power of the work is the methodology of using structured interviews go gain insights into the impact. The graphs and their progression have to be tested within the industries to strengthen the findings.

In addition to test the progression within the investigated industries, it is worthwhile to enlarge the survey to other industries, to examine the behavior of the IIoT device in those and to be able to build clusters for different industries as a model for prediction.

The know-how to develop technology specific graphs, as we have done it in this survey, is in most cases available in the companies and can become part of the preparation of a decision process.

We recommend to use the approach of a structured interview, considering the production function before investing into a technology as an internal exercise to improve the decision process.

References

- [1] Albach, H. (Ed.) (1989). *Zur Theorie der Unternehmung*. Schriften und Reden von Erich Gutenberg. Aus dem Nachlaß. Springer. DOI: 10.1007/9978-3-642-61539-9

- [2] Assaf, A. G., & Josiassen, A. (2016). Frontier Analysis: A State-of-the-Art Review and Meta-Analysis. *Journal of Travel Research*. DOI: 10.1177/0047287515569776
- [3] Autor, D. (2014). Polanyi's Paradox and the Shape of Employment Growth. *National Bureau of Economic Research*, 20485
- [4] Costa, M. A., Lopes, A. L. M., & Matos, de Pinho, G. B. B. (2015). Statistical Evaluation of Data Envelopment Analysis versus Cols Cobb-Douglas Benchmarking Models for the 2011 Brazilian Tariff Revision. *Socio-Economic Planning Sciences*, pp. 47 - 60
- [5] Douglas, P. H. (1976). *Journal of Political Economy*, Vol. 84, No. 5, pp. 903 - 915
- [6] Durand, D. (1937). Some Thoughts on Marginal Productivity with Special Reference to Professor Douglas. *Journal of Political Economy*, Vol. 45, No. 6, pp. 740-58
- [7] Fandel, G. (2005). *Produktions- und Kostentheorie*. Chapter 3, Substitutionale Produktionsfunktionen Springer Berlin Heidelberg. Print ISBN: 978-3-540-25023-4
- [8] Gibbons, R., 2005. Four formal(izable) theories of the firm? *Journal of Economic Behavior & Organization* Vol. 58: 200–245
- [9] Giebe, C. (2019). The Chief Digital Officer - Savior for the Digitalization in German Banks? *Journal of Economic Development, Environment and People*, 8(3), 6-15
- [10] Gutenberg, E. (1952). Zur neueren Entwicklung der Wirtschaftlichkeitsrechnung. *Zeitschrift für die gesamte Staatswirtschaft / Journal of Institutional and Theoretical Economics*. Volume 108, pp. 630 – 645
- [11] Kiel, D., Müller, J. M., Arnold, C., & Voigt, K. I. (2017). Sustainable industrial value creation: Benefits and challenges of industry 4.0. *International Journal of Innovation Management*, 21(08), 1740015
- [12] Lenk, T. (2017). *Volkswirtschaftslehre; 6. Edition*. Produktions- und Kostentheorie. Springer Fachmedien Wiesbaden
- [13] Linß, V. (2014). *Die wichtigsten Wirtschaftsdenker*. Matrixverlag. ISBN: 978-3-86539-922-9
- [14] Maad, S., Garbaya, S., Mccarthy, J. B., Beynon, M., Bouakaz, S., & Nagarajan, R. (2010). Virtual and augmented reality in finance: State visibility of events and risk. *InTech*
- [15] Müller, S., (2018). Digitaler „Spielplatz“ für Kunden und Mitarbeiter - Wie die Kreissparkasse Göppingen Digitalisierung voranbringt <https://www.der-bank-blog.de/digitaler-spielplatz-kunden/digital-banking/31090/> [Accessed July 2019]
- [16] Oesterreich, T. D., & Teuteberg, F. (2016). Understanding the implications of digitisation and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry. *Computers in Industry*, 83, 121-139
- [17] Okolo, C. V., & Attaham, N. (2017). Comparative Analysis of the Effectiveness of Coub-Douglas, Real Business Cycle, and Keynesian Growth Models in

Determining Economic Growth in Nigeria. *Journal of Empirical Studies*, Vol. 4, No. 1, pp. 1 – 14

- [18] Pająk, K., Kamińska, B., & Kvilinskyi, O. (2016). Modern trends of financial sector development under the virtual regionalization conditions. *Financial and credit activity: problems of theory and practice*, 2(21), 204-217
- [19] Pellegrino, G., Piva, M., 2019. Innovation, industry and firm age: are there new knowledge production functions? *Eurasian Business Review*. <https://doi.org/10.1007/s40821-019-00129-6>
- [20] Sanderson, D., Chaplin, J. C., Ratchev, S. (2019). A Function-Behaviour-Structure design methodology for adaptive production systems. *The International Journal of Advanced Manufacturing Technology*. <https://doi.org/10.1007/s00170-019-03823-x>
- [21] Schweitzer, M., & Küpper, H.-U. (1973). *Produktions- und Kostentheorie. Grundlagen – Anwendungen*, Vol. 2, Gabler
- [22] Teece, D. J., Pisano, G. & Shuen, A. (1997). Dynamic Capabilities and Strategic Management. *Strategic Management Journal*, Vol. 18, No. 7, pp. 509-533
- [23] Yildirim, G., Elban, M., & Yildirim, S. (2018). Analysis of Use of Virtual Reality Technologies in History Education: A Case Study. *Asian Journal of Education and Training*, 4(2), 62-69
- [24] Zellner, J., Kmenta, J., & Dréze, J. (1966). Specification and estimation of Cobb-Douglas Production Function Models. *Econometrica*, Vol. 34, No. 4, pp. 784 – 796
- [25] Zwerenz, D. (2019). Brand Management: Organizational Changes in Project Management. *Marketing and Management of Innovations*, 6718(2), 253–265. <https://doi.org/http://doi.org/10.21272/mmi.2019.2-22>