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Results from the project work of IAB

Industry 4.0 and the consequences for labour market and economy

Scenario calculations in line with the BIBB-IAB qualifications and occupational field projections

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Abstract

This study focuses on the economic effects of the phenomenon of “Industry 4.0”, the digitalisation of the production processes. These developments involve considerable challenges for companies as well as on a political level. This five-step scenario analysis begins with the impacts of increased investments in equipment (1) by companies and in the network infrastructure (2) by the government on the overall economy and the labour market. On this basis, we continue to model the consequential personnel and material costs of the companies (3) and a changed pattern of demand according to occupations and skills (4). The cumulative effects of these four partial scenarios are compared to a baseline scenario, which does not contain an advanced developmental path to Industry 4.0. In another scenario, the effects on the labour market of a potentially increasing demand for goods (5) are taken into consideration and also contrasted with the baseline scenario.

The results show that Industry 4.0 will accelerate the structural change towards more services. In the process, labour force movements between sectors and occupations are significantly greater than the change of the number of employees overall. The turnover on the labour market is accompanied by an increasing added value, which not only leads to more economic assets but also – due to greater demands on the labour force – to higher aggregate wages.

The underlying assumptions have a positive effect on the economic development. However, that also means that, given a delayed implementation, the assumptions are turning against the business location Germany: We will export less and demand more “new” goods from abroad.

In order to continue to improve the economic findings on the effects of digitization, a further development of the QUBE-I4.0-project is planned.

Zusammenfassung

Mit diesem Forschungsbericht liegt die erste modellbasierte Wirkungsabschätzung von Industrie 4.0 auf Arbeitsmarkt und Wirtschaft in Deutschland vor. In einer 5-stufigen Szenario-Analyse werden zunächst die Auswirkungen von erhöhten Investitionen in Ausrüstungen (1) und Bau für ein schnelles Internet (2) auf die Gesamtwirtschaft und den Arbeitsmarkt dargestellt. Darauf aufbauend modellieren wir den daraus folgenden Personal- und Materialaufwand der Unternehmen (3) und eine veränderte Nachfragestruktur nach Berufen und Qualifikationen (4). Die kumulativen Effekte der vier Teil-Szenarien werden mit einem Referenz-Szenario, das keinen fortgeschrittenen Entwicklungspfad zu Industrie 4.0 enthält, verglichen. Darüber hinaus werden in einem weiteren Teil-Szenario Arbeitsmarkteffekte einer möglicherweise steigenden Nachfrage nach Gütern (5) in den Blick genommen und ebenfalls am Referenz-Szenario gespiegelt.

Im Ergebnis zeigt sich, dass Industrie 4.0 den Strukturwandel hin zu mehr Dienstleistungen beschleunigen wird. Dabei sind Arbeitskräftebewegungen zwischen Branchen und Berufen weitaus größer als die Veränderung der Anzahl der Erwerbstätigen insgesamt. Mit den Umwälzungen auf dem Arbeitsmarkt geht eine zunehmende Wertschöpfung einher, die nicht nur zu mehr volkswirtschaftlichen Gewinnen sondern – aufgrund höherer Anforderungen an die Arbeitskräfte – auch zu höheren Lohnsummen führt.

Die getroffenen Annahmen wirken zu Gunsten der ökonomischen Entwicklung. Das bedeutet aber auch, dass bei einer verzögerten oder gar verschleppten Umsetzung, die Annahmen sich gegen den Wirtschaftsstandort Deutschlands wenden: Wir werden weniger exportieren und mehr „neue" Güter im Ausland nachfragen.

Um ökonomische Erkenntnisse zu den Wirkungen der Digitalisierung weiter zu verbessern, ist eine Fortentwicklung des QuBe-I4.0-Projekts geplant.

Ein „Aktueller Bericht" fasst die wesentlichen Ergebnisse dieses Forschungsberichts zusammen. Sie finden ihn unter „Aktueller Bericht 16/2015".

1 Industry 4.0 leads to various changes

Economic development is always characterised by change. For instance, the pool of employees in the overall economy of the industries changes continuously in line with the economic structural change. The percentage of employees working in agriculture and the manufacturing sector is steadily declining but increasing in the service sector. This report examines whether improvements expected in connection with Industry 4.0 will accelerate this structural change and significantly affect the work environment with regard to the occupational and qualification structure. Which effects the transition to Industry 4.0 will have on the economic development and the number of employees collectively is also key.

We distinguish between the terms “Industry 4.0” and “Economy 4.0”; the latter having a much greater scope. While we interpret “Industry 4.0” as interactive interconnectedness between analogue production and the digital world, “Economy 4.0” defines the factor that digitisation not only results to a change in industrial production but all service sectors, and will therefore affect all spheres of life. Accordingly, the consequences of “digitising work” discussed publicly, like the Green Paper “Work 4.0” (BMAS - Federal Ministry of Labour and Social Affairs 2015), accordingly refer to Economy 4.0.

We identify determining factors (parameters) which will change in line with the transition to Industry 4.0. In line with a scenario analysis, which is based on the methods and results of the QuBe project (www.qube-projekt.de), the consequences the amended parameters have on qualifications, occupations, sectors and the macroeconomic development are identified. The overall scenario is worked out step-by-step through the following five partial scenarios:

(1) Consequences of increased equipment investments
(2) Consequences of increased building investments
(3) Results of the change in material and personnel costs
(4) Results of the change in the structure of occupational fields
(5) Consequences of an increasing demand for new goods

Due to the step-by-step structure of the scenarios, this report follows a chronological structure of investments and their results. The results of the individual scenarios are therefore always compared to the results of the preceding partial scenario. Furthermore, the impact the cumulative effects have on the partial scenarios 1 to 4 or 1 to 5 is also reflected in the baseline scenario of the 3rd phase of the QuBe project (Maier et al. 2014a).

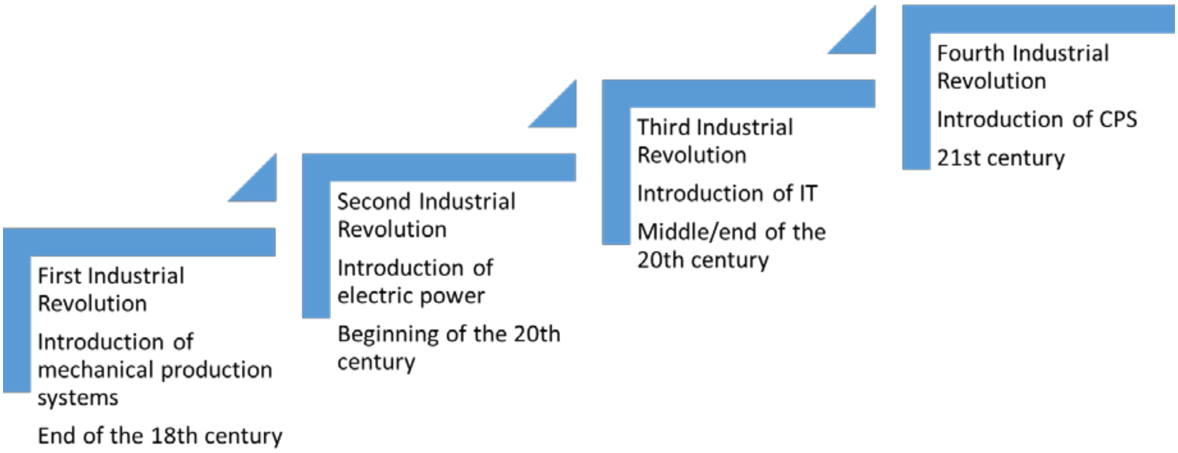
Key results of the study show that although the transition to Industry 4.0 can on one hand in fact yield an improvement in the economic development, on the other hand, however, based on the assumptions made in ten years there will be 60,000 fewer jobs than in the baseline scenario. At the same time, 490,000 jobs will be lost, particularly in the manufacturing sector, and approximately 430,000 new ones will be created. To a great extent, jobs “switch” between sectors, occupations and qualifications.

As a basic principle, the results from the scenario analyses depend on the assumptions made. The project partners will therefore continue to refine this study in the future. This will then focus on the modelling type and additional information, e. g. from company surveys. We will also pursue broadening it from “Industry 4.0” to “Economy 4.0” to gain further insight into the consequences digitisation has on the labour market and the economy.

2 The path to Industry 4.0

The term Industry 4.0 is a result on the history of the industrial revolutions, which so far is perceived in three stages (Figure 1). At the end of the 18th century, the introduction of hydropower and steam power brought on the change from an agricultural to an industrial society. The use of mechanical energy allowed production to be accelerated significantly compared to tasks formerly performed manually (e. g. mechanical weaving looms). The simultaneous increasing prevalence of steamboats and railway trains made transport and logistics considerably easier. Wage labour was born. The prevailing energy resource was coal. The second Industrial Revolution is chronologically attached to the beginning of the 20th century and ushered in the new era of industrialisation. The electrification of production by introducing electric power – crude oil replaced coal as the leading energy source – resulting in an expansion of mass production (assembly line work). Fordist mass production with taylorist production processes triggered an increase in productivity which also facilitated a social middle class and the beginning of a welfare government. The third Industrial Revolution is chronologically attached to the 1970s and is also referred to as the digital revolution. The increased use of computers ushered in the change from an industrial to an information society. The introduction of electronics and information technologies allowed for further automation of production. A great extent of the control and coordination of machines, processes and the global integration of suppliers are performed with the help of computers. Microelectronics, new materials and bioengineering introduced new production methods, applications and the development of new products and services.

Figure 1
The four stages of the Industrial Revolution



Source: based on BITKOM 2014 – diagram by author.

The fourth stage of the Industrial Revolution can be perceived as a continuation or rigorous implementation of the ideas and technologies from the third Industrial Revolution. In addition to fundamentally rethinking the functionality of production facilities, it will also lead to changes in the work environment.

Changes in the economy and society, which can already be observed today, will accelerate the trend towards Industry 4.0: So far, the powerful, export-oriented sectors of machine building, automotive and chemicals industry have been able to sustain their position internationally, mainly due to high product quality. Globalisation improves the comparability of services and increases competitive pressure. Companies must constantly defend their competitive advantage. Hence, product and process innovations are vital, particularly because the value chains continue to be more detailed and more complex. Not only must national limits be overcome but the interaction of a variety of different, in part highly specialised suppliers must also be coordinated. Aspects of industrial production processes already highly developed today becomes more and more relevant for sectors such as commercial companies and the shipping industry or agriculture due to the urbanisation and the continued (worldwide) population growth. On one hand, more and more foods must be produced with limited space and more efficiently, and on the other hand, urbanisation poses new challenges for trade and transportation in terms of prompt and continuous provision of products and services. Furthermore, the demand for customised products will increase with the individualisation of society. Ultimately, the shortage of re-sources will also have to result in optimising production process.

All in all, in the future, continuous innovative activities must be aligned with an increasing complexity and dynamic in the value chains, which must result in rethinking the entire production control system across all economic sectors. This rethinking is defined using the keyword “Industry 4.0”.

However, to date there still is no standard and distinct definition of how exactly to interpret the term Industry 4.0 (DBR 2014). This not only becomes clear in the few German studies which have dealt with this topic (BITKOM 2014; PWC 2014; DBR 2014). A survey conducted on behalf of WELT (2014) also confirms that 64 per cent of companies surveyed were not familiar with the term Industry 4.0. Nevertheless, Industry 4.0 is an idea which not only large industrial concerns and associations are committed to. The motto at the 2015 Industrial Trade Fair's in Hannover was Industry 4.0; many big corporations (e. g. Bosch, Audi (Reflex Verlag 2015; Die WELT 2014) are already investing in Industry 4.0 technologies. The large industrial associations Bundesverband Informationswirtschaft, Telekommunikation and neue Medien e. V. (Federal Association for Information Technology, Telecommunications and New Media - BITKOM), Verband Deutscher Maschinen- und Anlagenbau (VDMA - German Engineering Federation) and Zentralverband Elektrotechnik- und Elektronikindustrie e. V. (ZVEI - German Electrical and Electronic Manufacturers' Association) have initiated a website[1] on Industry 4.0 together with the Federal Ministry for Economic Affairs and Technology (BMWI) and the Federal Ministry of Education and Research (BMBF). It is part of the BMBF's high-tech strategy (2014) and the Federal Ministry of Labour and Social Affairs has also addressed this topic in the Green Paper "Work 4.0" (BMAS 2015).

Despite the many studies and forums it's usually unclear what Industry 4.0 actually means. It is more than "just-in-time production" and more than "lean production"[2] – keywords from the 90s. "Digital sub-projects" are often "referred to as Industry 4.0" (Professor Schuh of RWTH Aachen in DIE WELT 2014). However, it is in fact about an "industrial domino effect" (DIE ZEIT 2014) where parts exchange data fully automatically across all industrial and production boundaries. At least awareness of Industry 4.0 should be higher now than it was in 2014.

Industry 4.0 stands for an interactive networking between analogue production and the digital world. This transformation includes elements such as big data, autonomously operating systems, Cloud computing, social media, mobile and self-learning systems. This development is more of an evolutionary process than a revolution. The following provides a standardised definition based on available (German) literature. Forschungsunion Wirtschaft und Wissenschaft (German Science-Industry Research Union 2013) provides the following definition:

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1 www.plattform-i40.de

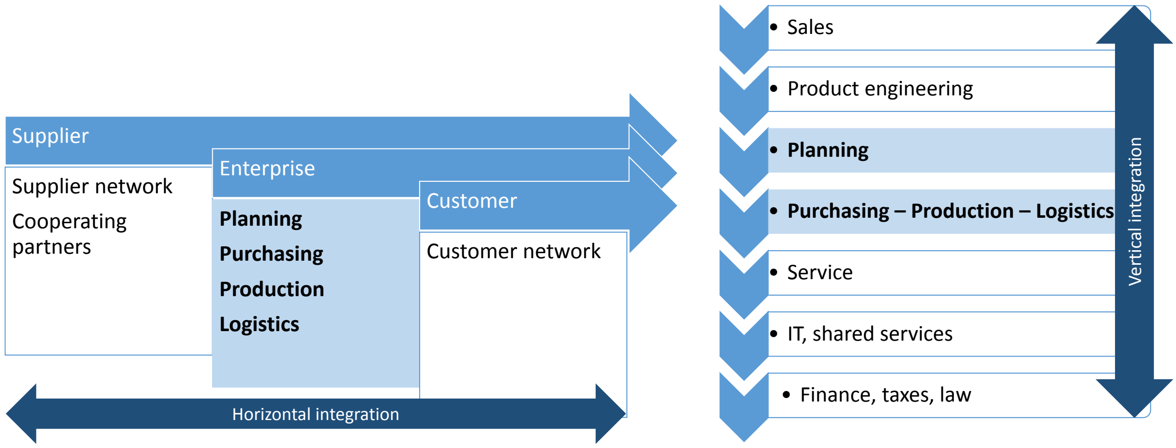
2 Lean production traces back to the Toyota production system, which aims at avoiding or optimising any kind of "waste" (reworking, warehousing, overproduction, transport,...). It is controlled via the Kanban method and a milk run concept. The milk run concept requires the one-time provision of lot sizes based on demand. The Kanban method communicates the demand using electronic signal cards.

Industry 4.0 essentially refers to the technical integration of CPS[3] *into production and logistics as well as applying the Internet of things and services*[4] *in industrial processes – including the resulting impacts on the value chain, business models, as well as downstream services and work organisation.*
(Forschungsunion & acatech 2013)

Developing and implementing new cyber-physical systems innovative paths in production. Even today, there are discussions about individual serial production, improved production planning using near real time data and the resulting increase in production flexibility or businesses being better fit to respond to market fluctuations. The high degree of volatility of “on demand” production leads to a more a flexible utilisation of production facilities as well as company employees (Spath et al. 2013).

However, Industry 4.0 not only means an intelligent control and planning of production within a company (vertical integration), but also beyond the company (horizontal integration). The interface between horizontal and vertical integration lies in planning, purchasing, production and logistics (Figure 2).

Figure 2
Horizontal and vertical integration



Source: PWC 2014: 21 – diagram by author.

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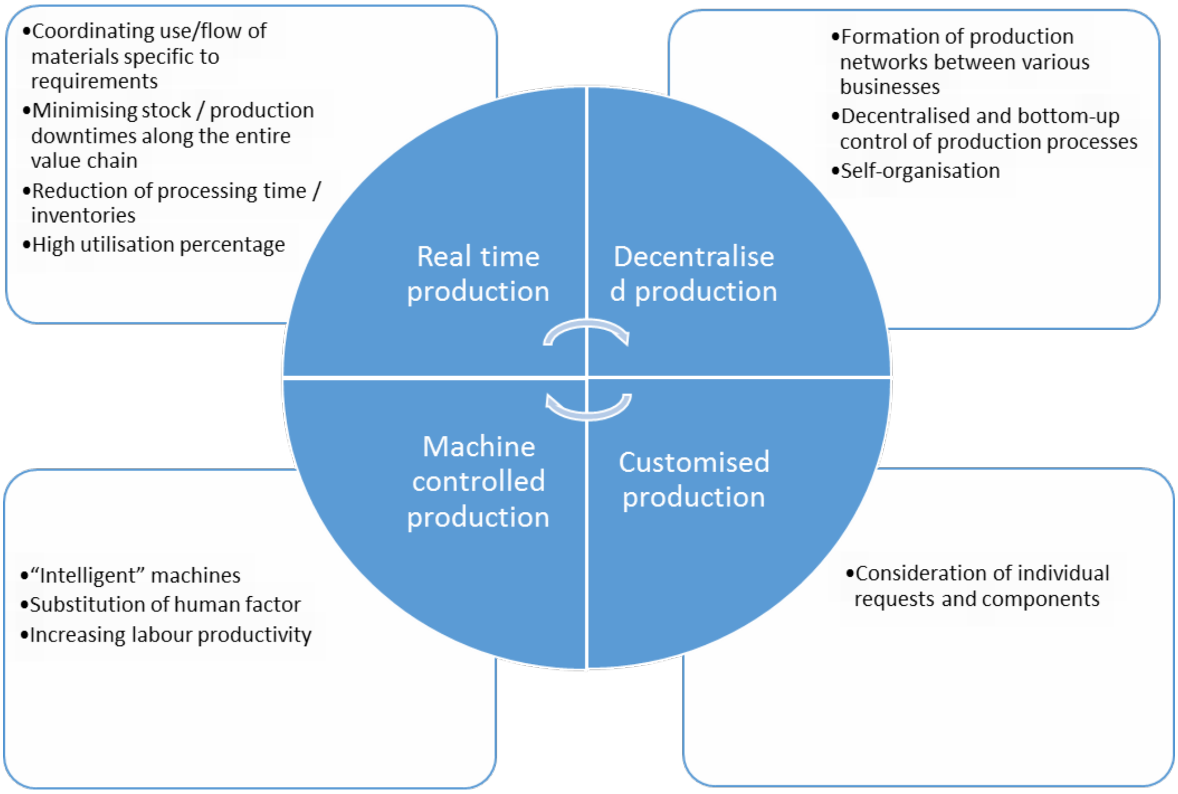
3 CPS – Cyber-Physical Systems – designates a link between physical elements and the virtual world. That is, linking between humans, machines, products, objects and ICT systems. Tools, containers and other aids are designated as objects, which mutate from passive to active resources in production through bar codes, sensors and actuators. In addition to communicating with the operator (= human) and other machines, machines can also communicate with the objects and products, creating a steady streams of information, e.g. via order status, material or maintenance requirements.

4 Refers to merging the Internet with the object or service. The computer is no longer an “auxiliary” device but an integral component (“embedded system”). Products are linked with additional information via bar codes, radio frequency identification (RFID), sensors or actuators. Online parcel tracking is an example.

Horizontal integration refers to the cross-industry linking of production processes. The work required from the machines is assigned via hubs. They autonomously calculate the requirements for basic materials, tools and personnel, identify utilisation and autonomously reorder materials from upstream entities. The objective is to optimise the flow of goods and information within the value chain. Vertical integration on the other hand defines optimising the flow of in-house goods and data with the objective of increasing quality and flexibility. For both aspects of Industry 4.0 it's crucial information can be processed in real time, all processes along the value chain to be linked, communicating, and furthermore to be able to take self-organised action. Self-organisation in particular shows Industry 4.0 will not have hierarchically and centralistically planned production management, but rather the product knows how it is to be processed, what it is needed for and where it needs to be transported. In summary, this results in the following four key characteristics for the term Industry 4.0 (Figure 3):

Figure 3
Characteristics of the term Industry 4.0



Source: diagram by author.

During the transition to Industry 4.0, the change in production structure will surely have consequences. With regard to the working and professional world, according to the assumptions, work will become more challenging and have more informal qualification requirements such as the ability to act independently, self-organisation, abstract thinking-skills (Forschungsunion & acatech 2013). In line with qualitative preliminary studies BIBB and IAB conducted with companies which have already intensively involved with the implementation of Industry 4.0[5], results show there will particularly be less need for simple, repetitive tasks and special knowledge applied.

According to the individuals interviewed, start-up companies utilising the potentials digitisation has to offer are able to manufacture more flexible and individualised products, will form and occupy new market niches. They in particular require their specialists to hold special professional skills, which must be accompanied by expertise in dealing with digital media and networks, as well as distinctive soft skills in communication and especially in teamwork. Expertise in problem solving, which is coordinated within the processes among the team but also implemented independently, is vital for the companies.

Though according to these companies, fundamentally new skills or activities which would result in new job descriptions, are not expected. In fact, the previous occupations are sufficiently established. However, it is emphasised require even greater and virtually end-to-end IT skills are required here.

According to these companies, a decline in the demand for specialists in the area of intermediate skills is not inevitable. Although the requirements placed on employees are increasing, particularly in the development phase of new processes and products, this can only result in a short-term shift towards requiring academic degrees. This shift would settle down again during the implementation phase since more people with training qualifications would then be in demand again. On the other hand, the employment situation for low-skilled workers remains problematic in the long run.

However, manpower may not be the only thing reduced or restructured over the course of Industry 4.0. Material, inventory and movement sequences will also become replaceable by real time production (BITKOM 2014). Increased efficiency can be attributed to labour- as well as material productivity. Internal operating costs are reduced by digitising the value chains (Forschungsunion & acatech 2013). The assumption is, inventory can be reduced; in extreme cases, even be completely eliminated. Increased energy efficiency can also be achieved due to coordinated activation and deactivation of machine components (Forschungsunion & acatech 2013). In addition to cost savings, a greater sales volume is expected “due to addressing a wider market and an increase in customer satisfaction” (Forschungsunion & acatech 2013). Furthermore, the production location Germany can benefit as a whole because production also remains appealing in high-wage countries.

The positive effects (avoiding costs, improving sales potential) are accompanied by various additional expenses. The need to invest is great and poses challenges for

[5] To date, BIBB and IAB have interviewed a total of six companies as well as two trade resp. professional associations in the field of software, electrical engineering, electronics, logistics and vehicle construction in line with qualitative guided interviews.

companies where safety, disclosure and standardisation are concerned. The need for high employee qualifications is also seen (VDE 2013). The introduction of Industry 4.0 will therefore be a long and gradual process. According to a VDE study (2013), the companies interviewed do not expect a complete realisation before 2025.

Particularly younger companies and start-ups will turn to this development. The more specialised a company, the more difficult it will be to further automate the value chain (Heng 2014). Transitioning existing machinery and production facilities will therefore play an important part for established companies. Automation through Industry 4.0 will be very flexible and can be implemented specifically depending on the sector and company. For example, the introduction of new innovative processes will more likely ensue in the automotive industry with its high degree of individualisation, according to Heng (2014), whereas pure process industries, e. g. the pharmaceutical industry, will not implement these innovations as quickly. Areas such as machine building (automation, process engineering, production engineering) and information and communications technology (ICT) and the associated services will particularly be affected, given that these will be primarily responsible for developing the infrastructure for Industry 4.0 (VDE 2013).

3 Methods, factors and assumptions

3.1 Methods: Scenario technique and model application

The scenario technique is applied to illustrate the consequences of a transition to Industry 4.0. For this purpose at least two scenarios are assessed, which are e. g. compared absolutely or relatively for a selected future period. This requires a baseline scenario, which describes a currently plausible and consistent future trend and an alternative scenario which documents a different trend. Both scenarios can differ in regard to their assumptions on exogenous parameters (e. g. population trend) or endogenous behaviour (e. g. production methods). In order to be able to quantify the effects of the assumptions on economic parameters, this also requires a model which can assess the baseline as well as the alternative scenario.

The BIBB-IAB qualifications and occupational field projections, published in line with the 3rd phase of the QuBe projections (Maier et al. 2014a, method box 1), serve as a baseline scenario. The trend described in said projections of course contains technological advancement, however, this rate of progress is geared toward the normal development apparent from the empiricism. For Germany to assume a worldwide pioneering role in the transition to Industry 4.0, as assumed in this report, additional efforts or investments are also required, which are shown in an extensive scenario specification.

The Q-INFORGE model used to compile the baseline scenario will also be used to calculate the Industry 4.0 scenario. The Q-INFORGE model is based on the IAB/INFORGE model (Schnur/Zika 2009; Distelkamp et al. 2003; method box 2), which was significantly extended in the area of the labour market (method box 1) in line with the QuBe project. The QuBe project's mission is to regularly project qualifications and occupations and in doing so, continue to develop methods and analyses (Helmrich/Zika (ed.) 2010; Zika/Maier (ed.) 2015).

The detailed modelling of the sectors with their cost structures based on the input-output calculation by the Federal Statistical Office and the finely structured illustration of the 54 occupational fields (Tiemann et al. 2008) according to 63 industrial sectors based on microcensus data are valuable for the following scenario analysis, as it allows for changes in production methods in agriculture and the manufacturing sector as well as the occupational structure by sectors to be illustrated.

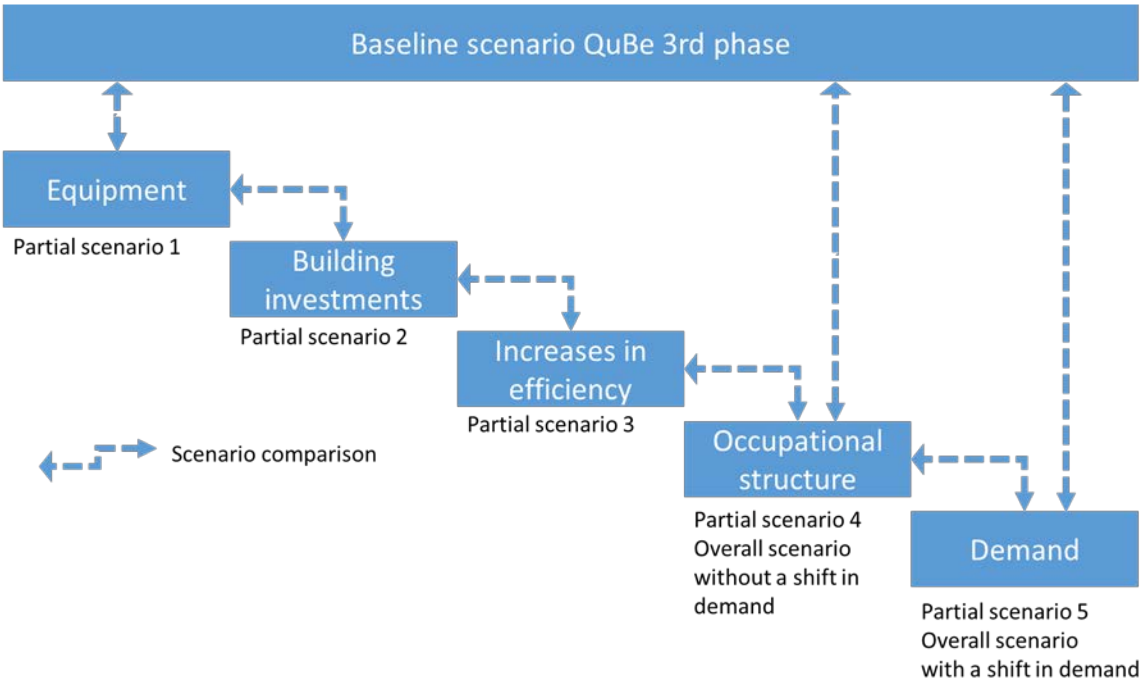
The operationalisation of the Industry 4.0 scenario is based on assumptions and quantitative approaches, which, in addition to the required investments, concern components on the consumer demand end, the cost structure of individual sectors, as well as the type and extent of the labour market. The complexity of this scenario therefore requires a multitude of interventions, the macroenomic effects of which are overall hard to quantify by "contemplating" without a theoretical background on the model. When the parameters are set, the complex modelling approach of the QuBe project allows for a concurrent, dynamic assessment of the effects on the overall economy and the labour market.

Here, we must again emphasise that the consequences of Industry 4.0 are estimated, not the "digitisation of work", which goes beyond that, which would be synonymous with Economy 4.0.

The parameters and their quantification are the result of an extensive foundation, intended to deal with the current uncertainty as best possible. First, literature on studies dealing with Industry 4.0 and its effect on the national economy and individual sectors was studied. Unlike the existing scenario, all studies uses are based on the results of surveys. Moreover, BIBB and IAB conducted qualitative interviews and in-depth discussions with companies based on a questionnaire developed mutually. Furthermore, information events, e. g. in line with the Hannover Trade Fair, were used get into conversation with companies of all sizes.

Five partial scenarios were assessed, which are based on each other, due to the high level of complexity of an Industry 4.0 scenario. Each is compared with the preceding partial scenario (Figure 4). The partial scenarios describe the changes in equipment investments and building investments, the resulting material and personnel costs, the adaptations to the occupational field structure of branches of production in the manufacturing sector and agriculture, and lastly the effects on the remaining demand components. The adaptations of the cost and occupational field structure also include material and labour costs as well as changes in occupational field structures within the investing sector. Given that the effects on demand are extremely uncertain, the overall scenario is compared to the baseline scenario with and without this shift in demand.

Figure 4
Scenario results

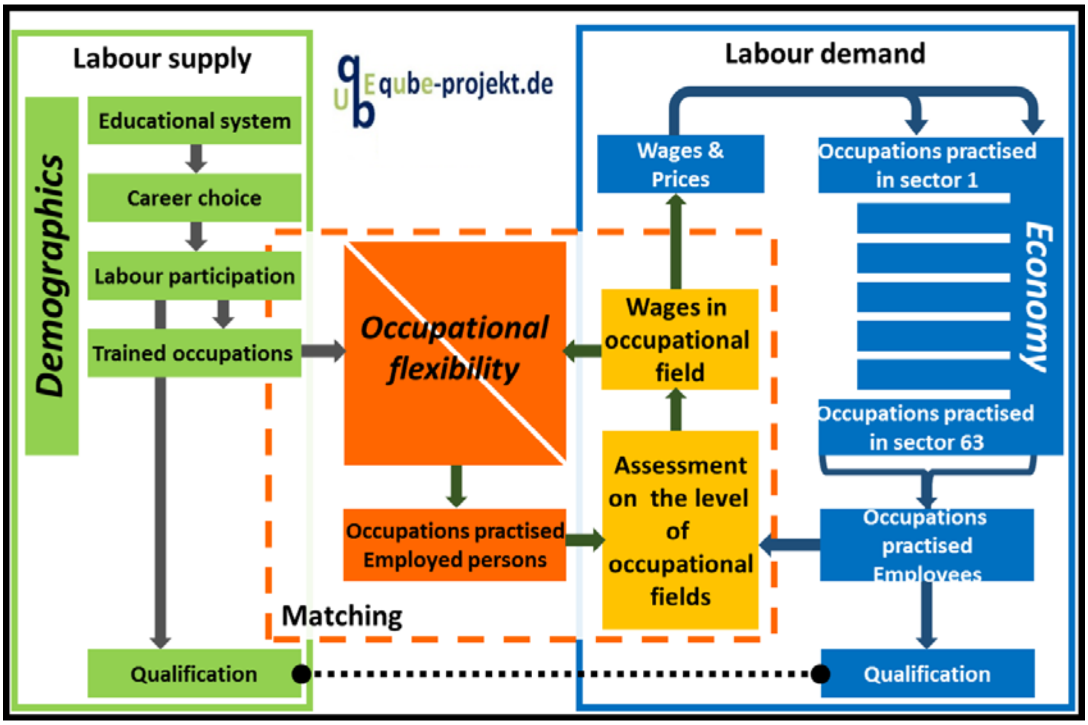


Source: diagram by author

Method box 1: QuBe project

The BIBB-IAB qualifications and occupational field projections (QuBe project), developed in collaboration between the Institute of Economic Structures Research (GWS) and the Fraunhofer Institute for Applied Information Technology (FIT), show how supply and demand for qualifications and occupations can develop on a long-term basis using model calculations. This case is based on data from the microcensus (in the available projection up to 2011): official representative statistics from the Federal Statistical Office on the population and the labour market, in which one per cent of all German households participate each year, adapted to the parameters of national accounts (in the available projection up to 2012). Wage information originates from the employee history of the employees subject to social insurance contribution (in the available projection up to 2011). A standard occupational field system for distinguishing occupations was developed by BIBB, which groups occupations at a three-digit classification level of occupations according to activities (Tiemann et al. 2008). For illustration purposes, these 54 occupational fields are aggregated into 12 primary occupational fields (MOF) (see chart 4 in Maier et al. 2014b).

Figure 5
QuBe project at a glance



Source: diagram by author

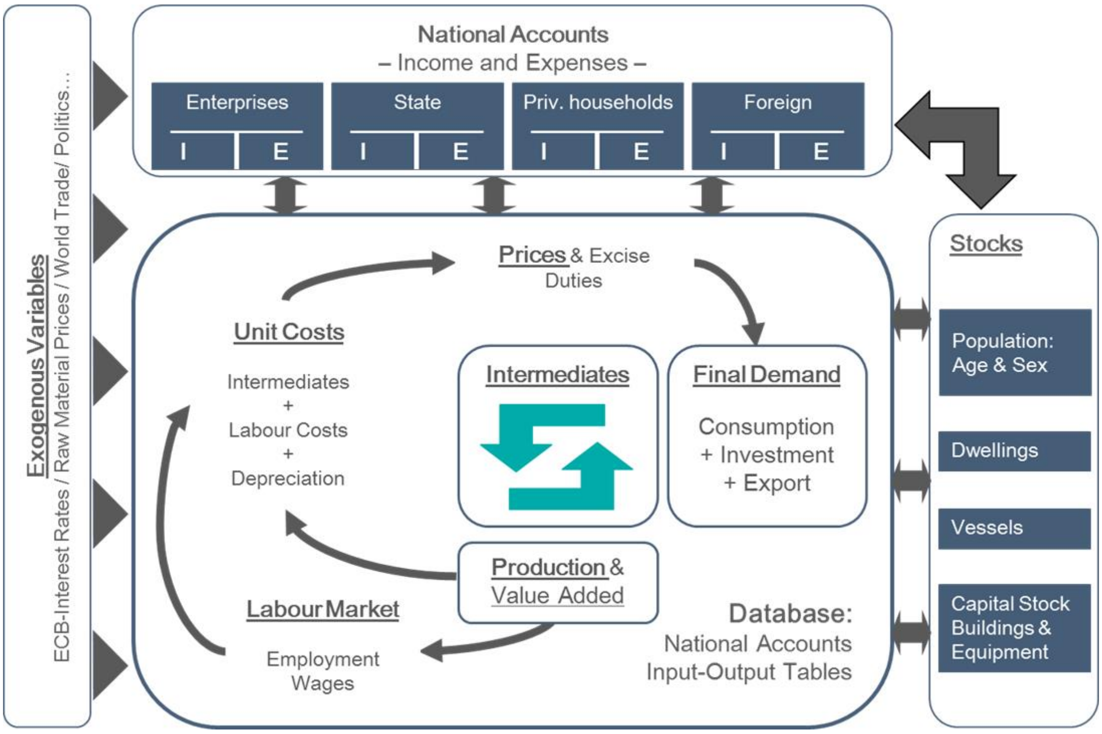
These results are based on the baseline projection (baseline scenario) of the third projection phase. These are based on the methods of the first (Helmrich/Zika 2010b) and the second phase (Helmrich et al. 2012; Zika et al. 2012) and also includes other innovations. Therefore, the previous IAB/INFORGE model (Hummel et al. 2010; Schnur/Zika 2009) is expanded on the demand side by including the available job-related labour supply in numbers and hours in determining wages for the occupational fields. On the supply side, the advantages of both previous supply models BIBB-FIT (Kalinowksi/Quinke 2010) and BIBB-DEMOS (Drosdowski/Wolter 2010) are combined into one supply model while modelling wages depending on occupational flexibilities, which allows the labour supply to respond to the changing wages in the occupational fields. However, the QuBe project pursues an empiricism-based concept in the baseline projection: only the previously proven behavioural patterns are projected to the future. Consequently, past unascertainable behavioural changes are not part of the baseline projection. This also applies to the modelled market adaptation mechanisms. All innovations in the modelling are detailed in Maier et al. 2014b. Figure 5 provides a rough overview of the functionality of the model.

Further information at www.QuBe-Projekt.de.

Method box 2: The IAB/INFORGE model

The IAB/INFORGE model is an extremely disaggregated and econometric forecast and simulation model for Germany by branches of production and categories of goods, which was developed by the Institute of Economic Structures Research (GWS) and has been continuously pursued and updated since 1996 (Schnur/Zirka 2009). This model is based on the “bottom-up” and “complete integration” design principles.

Figure 6
IAB/INFORGE at a glance



Source: diagram by author

“Bottom-up” implies that the individual sectors in the national economy are modelled in great detail and the macroeconomic variables are formed through aggregation in the model context. This enables a complete depiction of the individual sectors in a macroeconomic context and in the intersectoral integration, as well as an explanation of macroeconomic correlations, which the national economy conceives as the sum of its sectors. “Complete integration” refers to a model structure with the illustration of inter-industry integration and an explanation of how private households use income generated by the individual sectors (Figure 6). Export demand is determined through Germany’s foreign trade relations with the rest of the world. The forecasted import demand from 60 countries and regions determines the goods specific exports from Germany via bilateral trade matrixes.

Although the IAB/INFORGE model does indicate a very high degree of endogenisation, it cannot do without an exogenous setting: In addition to the instrument variables in fiscal policy such as tax rates, this includes the central bank interest rates of the European Central Bank, the exchange rate, as well as the price trend of raw materials. The development in other countries represents an exogenous parameter for determining German exports just as the demographic development and its age structure does for labour demand.

3.2 Possible parameters and assumptions

In line with the effects and correlations discussed above, the parameters in the Q-INFORGE model of the QuBe project for implementing Industry 4.0 in agriculture and the manufacturing sector in Germany are described below. The parameters discussed below refer to the national accounts of the Federal Statistical Office, which the model is based on.

Interventions are addressed alongside the input-output chart in Figure 7. The respective interventions in the input-output chart are explained below and can be located using the respective numbers in the input-output chart. The input-output chart serves as an orientation grid, given that only this chart can provide an industry-specific image of demand, intermediate input and production, and the structural consequences of Industry 4.0 can only be explicitly addressed and classified in a macroeconomic context here.

Introducing Industry 4.0 into the national economy has an impact on the indicated areas. On one hand, building investments ❶ are affected. Among others, these include underground engineering, which includes expanding the line network ("high-speed Internet service"). Equipment investments ❷ not only provide information on machine purchases in the machine building industry but also on required IT and information services. Both parameters will change in connection with the introduction of Industry 4.0. The changes in inventory represent another part of the gross fixed capital formation ❸: They provide information on the change in inventory: negative values represent a reduction in stock. In the course of applying new technologies, a change in inventory is basically conceivable.

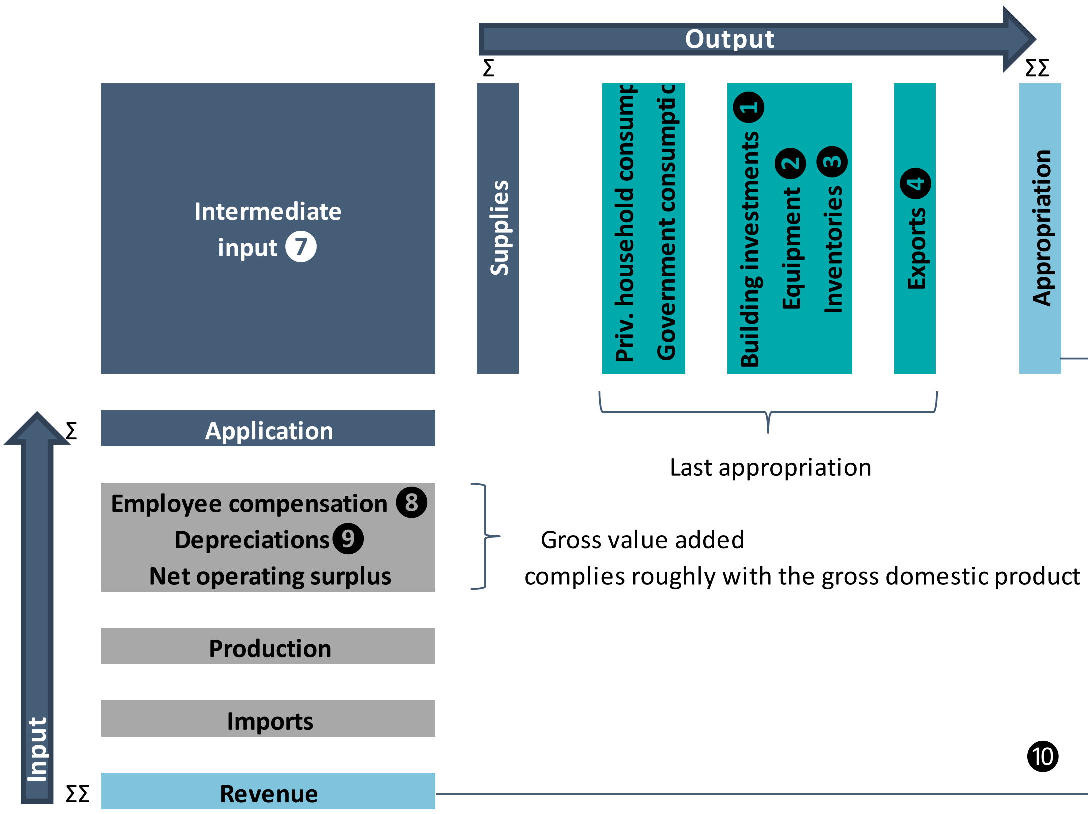
While items ❶ to ❸ primarily describe the required investments, the following items revolve around a change in the demand for goods. This can be caused by a change in pricing: Products can become less expensive. Furthermore, new products or a change in quality can generate additional demand. In conclusion, there is "collateral" demand, which is for example expressed in a greater demand for continuing education.

Germany's exports ❹ are, simply put, characterised by the trend of other countries' import demand and the competitiveness of prices for German products. There are also long-term relationships between supplier and consignee, and differences in the quality of German products. The latter becomes clear in the goods structure of German exports, which are mainly in the chemical, machine building and automotive industries. This concentration cannot solely be attributed to cost-based competitive advantages.

There can be direct and indirect impacts on exports in line with transitioning to Industry 4.0. On the one hand, changes in demand can arise due to new qualities or products, and on the other hand, the production process is also modified, so export prices are subject to change.

The same applies to private household demand ❺: New demand can arise or consequences based on new price trends can result. There also are self-motivated costs for continuing education in private households to keep up with technological advances. Government spending ❻ includes costs for education, among other things. This also includes the activities of the Federal Employment Agency, which the government considers part of social insurances in line with national accounts. Increased initiatives for continuing education are also conceivable here.

Figure 7
Schematic diagram of the input-output chart



Source: diagram by author.

The intermediate input ❼ among branches of production provides information about the supplies (“Which goods are supplied to which branch of production?”) (line) and the cost structure (column). The latter indicates the amount of goods and services, which must be used to facilitate production. Industry 4.0 will bring a lasting change to these supply structures. We must therefore assume that to some extent, less (raw materials, semi-finished products) and/or other (electronic products) goods will need to be used. At the same time, there may be more demand for services (ICT). Since by definition, production minus intermediate input equals the added value, changes in the cost structure have an immediate effect on it. From a company's microeconomic perspective, decreasing material costs, which also include acquired services, results in an increase in gross profit for an unchanged sales volume.

For the purpose of simplification, the added value itself is split into employee compensation ❽ (personnel costs), depreciations ❽ and net operating surplus (similar to profit). Employee compensation is affected by several factors. If production is reduced, less employees will be required for the same production methods. This situation can arise if there is less demand for own goods due to the change in cost structures of other branches of production. However, there can also be changes in labour productivity; Industry 4.0 may require less employees without a change in production.

Depreciations ❾ are directly affected by investments ❶&❷: For instance, expenditures for new machinery are depreciated over the useful economic life and recorded in the form of depreciations on the cost side. At the same time, technological progress can lead to machinery no longer being used because it is no longer profitable for production to use it or the goods produced with the machinery are no longer in demand. In both cases, extraordinary depreciations due to a reduction in the useful economic life can occur.

The remaining parameters not mentioned above are usually affected indirectly. This applies to e. g. imports. Production is the result of supply (price setting) and demand (❶ to ❻). Prices can be set by calculating the unit costs, which is a result of the ratio between the intermediate input plus wage and depreciation relative to price adjusted production.

Due to the abundance of impacts Industry 4.0 has on the economic process, no conclusion can be drawn on the overall result, i. e. the change in gross domestic product and the number and structure of employees, a priori. All consequences of Industry 4.0 addressed ultimately have an effect on the overall appropriation or the total revenue. After all, revenue and appropriation of each produced commodity must be the same due to the double-entry bookkeeping behind the input-output chart ❿. Consequently, changes in demand as well as supply will lead to a new result.

The illustration selected is a simplified version. Thus, wage and profit are changed by the interventions discussed. This results in consequences for the government budget (direct and indirect taxes) and the budget of private households (discretionary income). At the same time, the labour market changes. The number and compensation of employees are subject to change, which results in impacts on unemployment and the financial provisions of social insurances. Even if these and other correlations are not illustrated, they are indicated in the applied Q-INFORGE model (Maier et al. 2014b).

3.3 Assumptions – general assessments

As in the publications available on the topic of Industry 4.0, the scenario illustrated here also assumes that Industry 4.0 will not be introduced ad-hoc but that the transition will be a long-term process, which will take until 2025.[6] Industry 4.0 is regarded fully implemented at such time and will persist until the end of the projection horizon – 2030.

Industry 4.0 will not only be relevant to industrial companies but also to service companies – though perhaps to varying degrees. Consequently, a complete implementation of the fourth Industrial Revolution would signify structural changes for all sectors of the national economy. In view of a lack of available baseline calculations and in view of the special relevance Industry 4.0 holds for companies in the manufacturing sector, the scenario focuses on sectors in the manufacturing industry and agriculture. These sectors are, on the one hand, usually characterised by a high reliance on export and a large workforce, and/or will be manufacturing many of the components or machinery required for Industry 4.0. The cost structures and therefore the supply relationships between sectors are explicitly changed for these sectors.

Creating of new business models, products and services for final demand are regularly mentioned in literature with regard to the opportunities and potential of Industry 4.0. The possibilities applying Industry 4.0 technologies have to offer are beyond dispute. However, whether the demand will also be created for the new business models and to which it extent, is uncertain. Therefore, the effect on the demand side due to new supplies (so not based on a change in demand due to a price setting) usually illustrated quite abstract in the aforementioned studies, is therefore not realised in this scenario through assumed trends until the last partial scenario.

One consequence of the cost reduction resulting from Industry 4.0 technologies is a relative cost advantage of products produced in Germany. This can infer a repatriation of production processes relocated abroad, which would be expressed in a reduction of the intermediate input imports. This scenario does not act on the assumption that production sites will return to Germany because there was no indication of a trend in the above mentioned in-depth discussions.

Furthermore, this scenario assumes that Germany will begin introducing and implementing Industry 4.0 very early compared to all other countries. That is the only way to successfully generate “temporary monopoly profits” when dealing with foreign competitors. In principle one must assume, as established by international studies (Berger 2014), that Germany is not the only country pursuing the fourth Industrial Revolution. Efforts to realise the productivity potential of Industry 4.0 technologies can also be observed in the USA and China. One possible consequence of a quick

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[6] Later points in time are also given for a complete implementation.

implementation of Industry 4.0 abroad could be that Germany's import structure would need to change. This assumption can therefore lead to an overestimating the actual consequences.

4 Scenario calculations and results

A series of assumptions based on the depicted correlations are used in the QuBe model (Q-INFORGE; Maier et al. 2014a) below. For clarity purposes, the assumptions are listed in Chart 1 and allocated to the individual partial scenarios (PSC) and overall scenarios, described and the results of which are addressed below. The detailed description of the assumptions is provided in the respective partial scenario. Here the respective assumptions refer to the corresponding number in Table 1.

Table 1
List of assumptions

Assumptions		Partial scenarios	Overall scenario 1	Overall scenario 2
Equipment investments				
10	Additional investments	PSC 1	without a shift in demand	with a shift in demand
10	Conversion of capital stock sensor technology			
3	Conversion of capital stock IT services			
Building investments				
3	Capital expenditure "high-speed Internet"	PSC2		
3	... and distribution			
3	Balanced Government budget			
Material and personnel costs				
3	... Continuing education	PSC3		
3	... consulting services			
3	... digitisation			
10	... proportional decrease in raw materials and supplies as well as purchased services			
10	... increasing labour productivity			
Change in the structures of occupational fields				
10	Adjustment in occupational structure with industrial sectors considering routine	PSC4		
10	Adjustment in labour productivity			
Increases in demand				
10	... increases in export	PSC5		
10	... additional demand from Private households			
Comparison with the baseline scenario (baseline projection) QuBe project				

Source: diagram by author.

4.1 Equipment investments (partial scenario 1)

One deciding factor for economic development is how many additional investments in equipment will be needed and over which time, when transitioning to Industry 4.0. This question cannot be answered conclusively since newly purchased equipment may already have the required features but may have been purchased again in line with general replacement processes. We can therefore only attempt to make assumptions on the additional investments, taking plausibility into consideration.

(Assumptions ❶ and ❷) Part of the existing equipment is retrofitted or upgraded by replacing the control units and procuring the IT services required for this purpose.

Measured relative to the capital stock for equipment, equipment investments have an approx. 10 per cent stake. That means, the capital stock is normally replaced every ten years. It is assumed that of the last ten model years invested in, only the five more recent years will be equipped with Industry 4.0 compatible control instruments in the coming years. It is no longer profitable with older equipment, since it will be replaced in the next five years as scheduled. It is further assumed that not only control instruments, but IT services are also required to integrate the respective machinery into the new production process.

According to the input-output table 2010[7], of the € 193 billion invested in equipment, a total of € 7.7 billion will be spent on "measuring/control instrument among other instruments and equipment, electro-medical devices as well as data carriers". Another € 21.1 billion account for "IT and information services". The combined amount to approximately 15 per cent of the total equipment investments.

Since the production statistics do not provide any information on how many percent of the € 7.7 billion apply to measuring and control instruments required for data exchange with the machine, we are assuming a volume of 25 per cent. The same percentage is assumed for IT services (total of € 21.1 billion). Therefore, approximately € 7.25 billion, or 3.75 %, are allocated to required sensor technology and IT services for a "normal" investment year of 193 billion.

It is further presumed only 50 per cent of the machines in question will actually be retrofitted. That results in an annual investment amount of approx. € 3.6 billion, which would then have to additionally be invested. It is further assumed that today's five year old machines will be retrofitted in the next five years. This also applies to the four following years, but respectively moved back by one year. The investments required for retrofitting in the amount of approx. € 18 billion adjusted for price are therefore extended to nine years. Consequently, retrofitting costs apply to the years 2016 to 2024 (Figure 8).

Figure 8
Vintage years of retrofitting investments

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Investment year 2010	X	X	X	X	X					
Investment year 2011		X	X	X	X	X				
Investment year 2012			X	X	X	X	X			
Investment year 2013				X	X	X	X	X		
Investment year 2014					X	X	X	X	X	

Source: diagram by author.

(Assumption ❸) In addition to investments required to upgrade existing equipment, the current investments totalling approx. € 300 billion annually adjusted for price are being increased by an additional 0.5 per cent for Industry 4.0 retrofitting measures. In the course of the baseline, the investments increase until 2025, adding an aver-

7 Input-output chart 2010 prior to the revision of the national accounts.

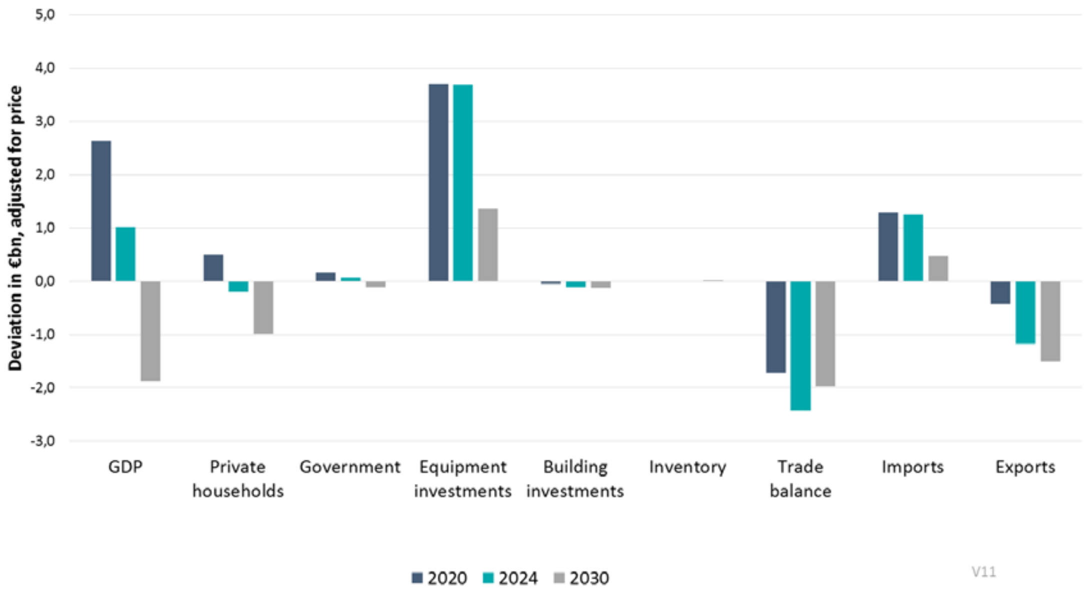
age of another € 15 billion adjusted for price over the years, i. e. € 1.5 billion per year.

This corresponds to additional investments amounting to € 22.5 billion over the course of the entire projection period (2016-2030). The investing industrial sectors (simplified: sectors) are in the manufacturing sector and in agriculture. For the purpose of allocating investments of the sectors to the assets invested, it is presumed that only categories of goods (CG) are affected, which actually guarantee Industry 4.0 competence. These include the following categories of goods:

(1) CG 27 - electrical equipment
(2) CG 28 - machinery
(3) CG 33 - repair, maintenance and installation of machinery and equipment
(4) CG 62-63 - IT and information services

A total of (assumption ❶ - ❸) approximately € 33 billion adjusted for price more will be invested in 2016 to 2025 than in the baseline scenario. This value consists of a price adjusted investment volume of €18 billion in sensor technology and IT services as well as an additional € 15 billion (adjusted for price) through additional investments amounting to € 1.5 billion annually. During the period 2026 to 2030 the general additional annual investments continue, so that the total investment volume increases by another € 7.5 billion to € 39.5 billion by 2030. Furthermore, additional investments caused indirectly ensue in the model context. The investments are financed via depreciations, which either reduce the profit of the companies or result in shifting to ex-factory prices.

Figure 9
Partial scenario 1 – Change in gross domestic product and its components in comparison with the baseline scenario

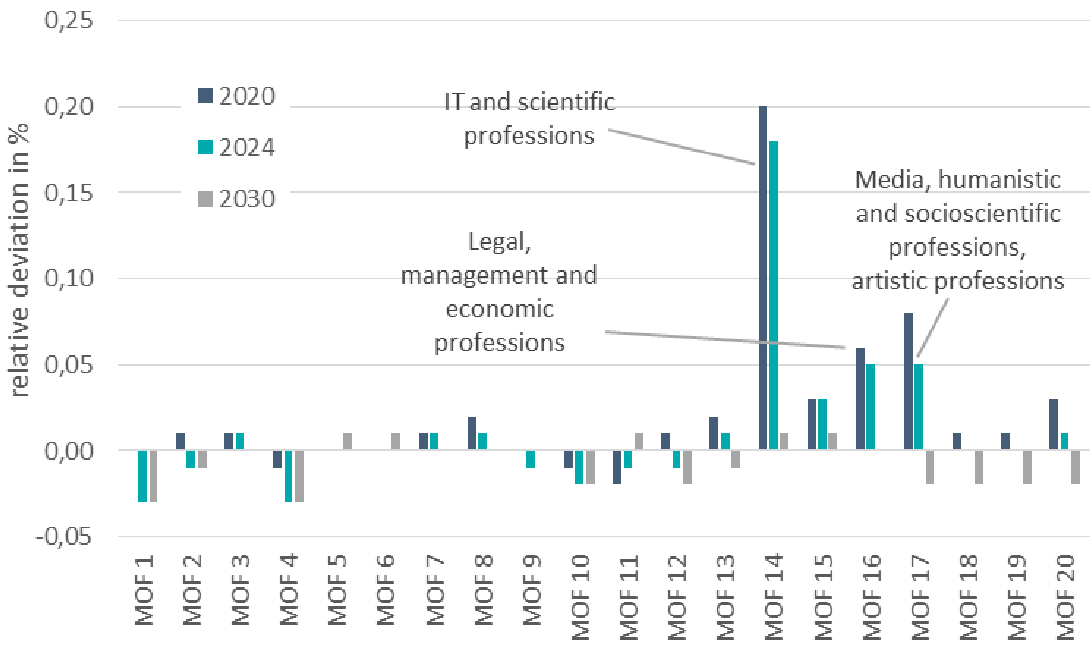


Source: diagram by author.

A look at the components of the gross domestic product (Figure 9) shows the equipment investments are in fact still higher than in the baseline scenario after completing the retrofitting phase in 2024, but the gap is smaller. The gross domestic product in 2030 is even lower than in the baseline scenario because the additional investments for 2016 to 2024 still lead to costs in form of depreciations. Export also suffers because of production prices increasing due to depreciations in comparison to the baseline scenario.

The result is not surprising given that partial scenario 1 by itself is incomplete: To date, the model only includes costs, no revenues. Nevertheless, initial changes in the occupational field structure can be seen (Figure 10). With the increase in investments and the overall higher rate of growth things brings, in the beginning, particularly IT & scientific professions (MOF 14) and professions in media science/ humanities (MOF 17) (incl. design) as well as management professions (MOF 16) will be in higher demand. The increase in MOF 14 will be primarily initiated by the specific IT services addressed.

Figure 10
Partial scenario 1 – Number of employees by primary occupational fields in comparison with the baseline study



Source: diagram by author.

4.2 Building investments (partial scenario 2)

Although this study focuses on the effects of Industry 4.0 and not Economy 4.0, for industrial companies, upgrading to a “high-speed Internet” is also key for implementing a digital economy. According to a study conducted by TÜVRheinland on behalf of BMWi (TÜVRheinland 2013), the costs for the upgrade amount to approx. € 20 billion to ensure 100 per cent of households have a 50 Mbit/s connection. The costs amount to € 12 billion for a supply goal of 95 per cent.

(Assumption ❹) The upgrade requires € 4 billion to be invested annually for the next three years in order for approximately 95 per cent of all households to have a 50 Mbit/s connection by 2018.

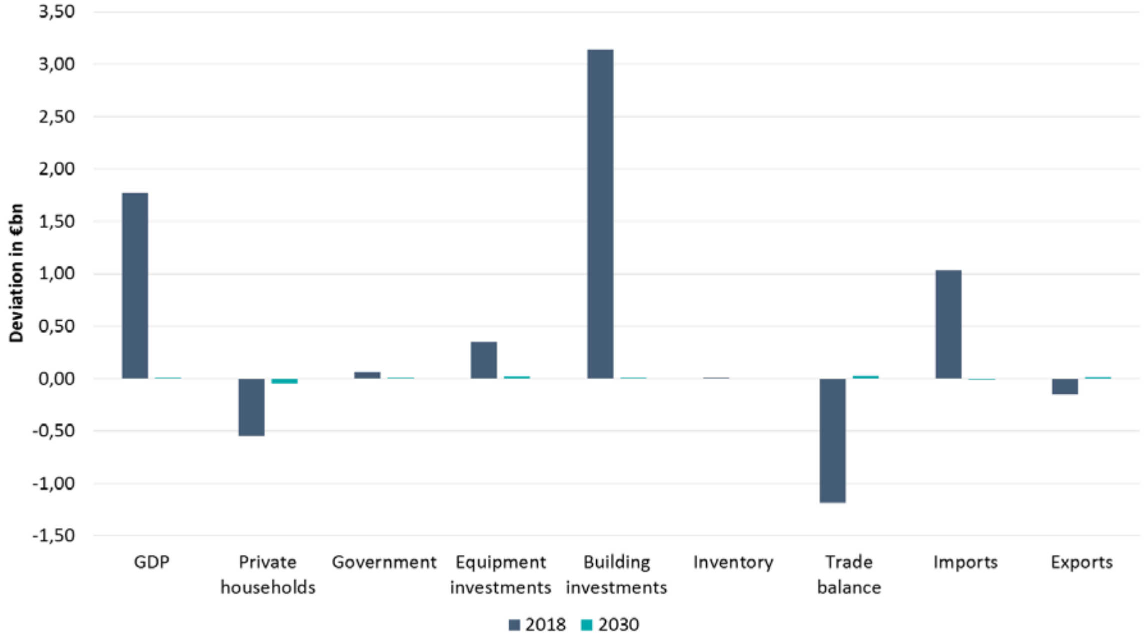
According to the study, the goal of to provide a nationwide network (i. e. 100 per cent) is to be achieved by 2018. Assuming that hardly any additional investments were made in 2014 and 2015, this leaves only 2016, 2017 and 2018. Due to the time constraints and the high demand for investments, a 95 per cent development will probably only be achieved by the end of 2018, so that an additional 4 billion Euros annually will have to be invested for the next three years.

(Assumption ❺) Normally, cable-based technologies (TÜVRheinland 2013) will be used. Consequently, civil engineering work and the application of electronic equipment (cables among others) will be affected. The electronic equipment only represents a small percentage of the building investments: According to the input-output calculation by the Federal Statistical Office, approximately 1 per cent. Therefore, it is assumed that a large part of this portion investments was already previously used for network upgrades and will now increase by 100 per cent (i. e. approx. € 1 billion annually). The remaining € 3 billion will be spent for civil engineering work. The offsetting entry is fully recognised in the government's investments.

(Assumption ❻) The government will not finance the required investments by incurring additional debts. On the contrary, it is assumed that the government's budget will remain balanced.

For example, additional tax revenue accrued over time could be used for financing. However, if sufficient additional tax revenue cannot be obtained in comparison with the baseline scenario, taxes must be raised (or scheduled reductions must be postponed), to avoid a change in the budget balance. Contrary to this, financing by means of debts or from surpluses, which are then not used for amortisation, would result in a more severe outcome.

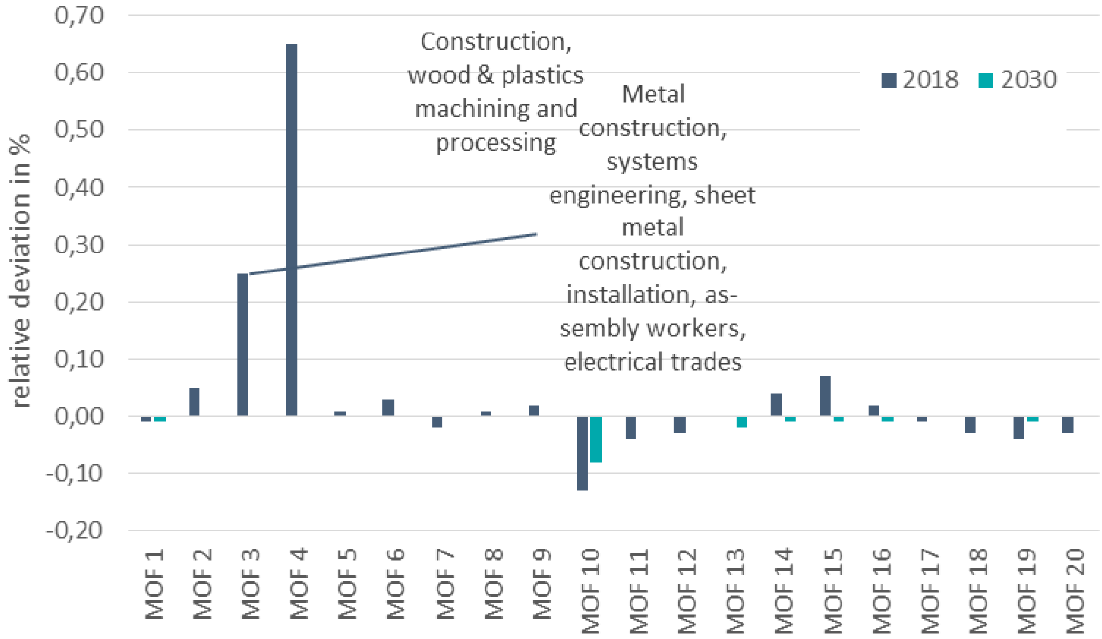
Figure 11
Partial scenario 2 – Change in gross domestic product and its components in comparison with partial scenario 1



Source: diagram by author.

Figure 11 shows the effects on the components for 2018 and 2030. Here we selected the year 2018 apart from the other illustrations because it illustrates the last year of additional building investments. There are no additional investments in 2020. Compared to the preceding partial scenario 1, 2018 shows a considerable increase of the price adjusted building investments. However, the impacts on the gross domestic product are less severe. At the same time, imports of intermediate goods are also associated with building investments, resulting in a decline of the trade balance. There are no remaining impacts in 2030 since partial scenario 2 also only assumes an upgrade will take place but not that the new options will also be used.

Figure 12
Partial scenario 2 – Number of employees by primary occupational fields in comparison with partial scenario 1



Source: diagram by author.

Likewise, the changes in primary occupational fields also only provides a picture of the exclusive impacts of building investments (Figure 12). However, it becomes apparent that the specific intervention in building investments (civil engineering and electronic equipment) primarily addresses professions in the building sector but also those in metal construction and systems engineering.

4.3 Material and personnel costs (partial scenario 3)

Material and personnel expenses for the investing branches of production are introduced in the following partial scenario 3. Until now, the companies have invested (partial scenario 1&2). Earnings from the investments were not yet taken into account. Nevertheless, a cumulative additional € 33 billion adjusted for price are assumed to be spent by 2025. However, additional costs for continuing education, consulting services and IT services are required for the best possible utilisation of potential gains in efficiency. Ultimately, the return on investment is reflected in the changed expense situation. Five interventions are taken for this purpose. Three refer to the additional costs (cost increases) and two are potential savings (cost reductions). The result shows a change in material and personnel costs for the company:

Cost increases:

(1) Increase of the companies' (branches of production) proportional costs for continuing education,

(2) Increase of the companies' cost fractions for consulting services and

(3) Massive use of additional IT services.

Cost reductions:

(4) Reduction in the material cost ratio (material costs relative to sales volume) by reducing wear and waste,

(5) Reduction in the personnel cost ratio by improving labour productivity.

While the assumptions for continuing education (see above), consulting services and the use of additional IT services can still be estimated relatively well, the savings for materials and work input depends on numerous factors, which are not taken into account here. For instance, it must be assumed the branches of production have different percentages of waste (e. g. surface finishing, production of forgings, pressed parts, drawn parts and stamped parts as well as metal tanks) between 2 to 6 per cent (Emec et al. 2013). Moreover, some trades produce more waste than others. Manufacturing wooden window frames can generate up to 50 per cent waste (Mantau et al. 2013).

At the same time, the great uncertainty regarding the assumptions (4 & 5) is associated with significant impacts on added value and distribution. For instance, the sectors of the manufacturing industry supplied each other with intermediate inputs amounting to € 720 billion in 2010 according to the input-output chart. Provides that nothing else changes (ceteris paribus assumption), savings of merely one per cent would imply a growth in value amounting to € 7.2 billion in one year. Applied to the gross domestic product, that is a growth of approximately 0.3 per cent. The advantage of reduced material costs due to a new production process then applies to all subsequent years. Over ten years this would generate a growth in added value of € 72 billion, which would then already exceed the investments totalling € 33 billion (adjusted for price). In order to make an appropriate assumption which is not overly optimistic, it seems reasonable to first take a look at the three assumptions regarding the cost increases.

(Assumption ❼) Agricultural companies and those in the manufacturing sector must invest additional money in continuing education in years to come in order to be able to utilise the advantages of Industry 4.0. Additional costs amounting to € 1,000 per employee are estimated.

Approximately 7 million people work in the manufacturing sector. Training each one means an additional € 7 billion over the next ten years, or € 0.7 billion annually. According to the input-output chart 2010, approximately € 1.2 billion per year are already being spent now on training from outside providers. Furthermore, we also assume that companies spend the same amount for in-house training. Thus, all companies spend approximately € 2.4 billion. Therefore, the increase of € 0.7 billion represents a growth of nearly 30 per cent. It is furthermore assumed that the cost per training unit will increase over the next ten years. This cost increase complies with the price development in the teaching and education sector. It will amount to approximately 20 per cent for 2010 to 2016.

(Assumption ❽) 1.5 per cent in additional consulting services are required to implement the new production methods in a company.

According to the input-output chart, the manufacturing sector acquires approximately € 26 billion in outside services. 1.5 per cent higher costs for consulting services corresponds to approximately € 0.4 billion more for a production value of € 1,600 billion for the concerned sectors (agriculture and manufacturing sector). The costs will continue to rise until 2025 due to price trends and will further increase the amount.

(Assumption ❾) The digitisation rate within the manufacturing sector will increase from 20 per cent today to 40 per cent.

According to PricewaterhouseCoopers Aktiengesellschaft (PWC 2014), a digitisation rate of 80 per cent is necessary for the implementation of Industry 4.0; therefore, based on today's costs of IT services, an increase of costs by four-fold would have to be assumed for linear relationships. However, this appears to be an extreme assumption, which is why we will only "only" assume it doubling. In 2010, the branches of production in the manufacturing sector spent approximately € 7.6 billion according to the input-output chart. Doubling this implies an increase to € 15 billion under otherwise identical conditions. The transition begins in 2016 and ends in 2025. There are also price trends, so that the nominal additional costs in 2025 exceed € 7.6 billion.

To obtain an overview of the costs and investments of companies in the manufacturing sector, the implicit cash flows are examined coherently. In order for the costs (assumptions ❼❽❾) and investments in equipment (assumptions ❶❷❸) to be profitable, the cost savings associated with material and personnel costs must at least cover the additional costs over the next ten years.

(Assumptions ❿ & ⓫) The costs paid generate a return of 9.3 per cent (discounted: 4.7 per cent) and savings required for this purpose of 1.2 per cent in 2025 accrue for intermediate inputs in the area of raw, semi-finished and finished products for power and water as well as work input on a pro rata basis.

Therefore, 1.2 percent less is used for raw, auxiliary and operating materials as well as for procured goods in each production process in agriculture and the manufacturing sector, to ensure production is unchanged (Table 2). Based on labour costs, this means that the workforce can be used more efficiently and therefore, that labour productivity increases by 1.2 per cent. The number of hours used for production in a branch of the manufacturing sector or in agriculture decreases by 1.2 per cent.

In 2024, the accumulated savings will exceed the accumulated costs (payments) for the first time. The depicted payments include price changes and indirect impacts.

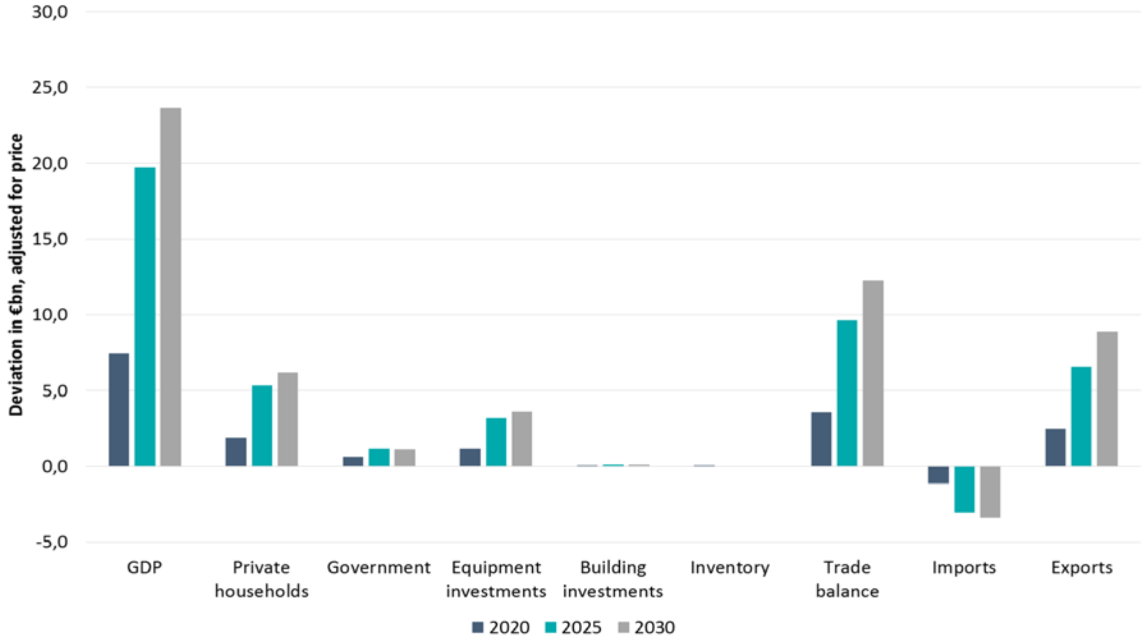
Unlike the microeconomic perspective, the result of the assumptions is not a zero sum game in macroeconomic terms, given that Germany is not a closed economy: Although the investing companies can record an additional profit according to the trend shown in Chart 2, additional demand is also generated in other sectors (e. g. ICT). Furthermore, there will not only be cost savings for German suppliers but also for foreign suppliers. Imports drop. Moreover, costs per unit are reduced for companies in agriculture and the manufacturing sector, so that competitiveness is improved and e. g. more exports can be achieved. Figure 13 shows the effects of partial scenario 3 on the components of the gross domestic product in comparison with partial scenario 2.

Table 2
Comparison of costs (payments) and savings, nominal

In €bn Rounded to 100m	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Cumulative	Discounted to 2015
Continuing education	900	900	900	1,000	1,000	1,000	1,100	1,100	1,100	1,200	10,200	7,800
Consulting	500	500	600	600	600	600	700	700	700	700	6,200	4,700
IT service	500	1,000	1,600	2,300	3,100	4,000	4,900	6,000	7,200	8,600	39,200	27,500
Investments	3,800	4,100	4,100	3,900	3,800	3,900	4,000	4,200	4,400	2,400	38,600	30,000
Costs (payments)	5,700	6,500	7,200	7,800	8,500	9,500	10,700	12,000	13,400	12,900	94,200	70,000
Cumulative	5,700	12,200	19,400	27,200	35,700	45,200	55,900	**67,900**	**81,300**	94,200		
… intermediate inputs	1,200	2,500	3,900	5,300	6,900	8,400	10,100	11,800	13,600	15,100	78,800	56,000
… wage payments	400	900	1,300	1,700	2,200	2,600	3,100	3,500	4,000	4,500	24,200	17,300
Savings	1,600	3,400	5,200	7,000	9,100	11,000	13,200	15,300	17,600	19,600	103,000	73,300
Cumulative	1,600	5,000	10,200	17,200	26,300	37,300	50,500	**65,800**	**83,400**	103,000		
Profit or loss	-4,100	-3,100	-2,000	-800	600	1,500	2,500	3,300	4,200	6,700	8,800	3,300
Cumulative	-4,100	-7,200	-9,200	-10,000	-9,400	-7,900	-5,400	**-2,100**	**2,100**	8,800		
Return (result in relation to costs)											9.3	4.7

Source: diagram by author.

Figure 13
Partial scenario 3 – Change in gross domestic product and its components in comparison with partial scenario 2

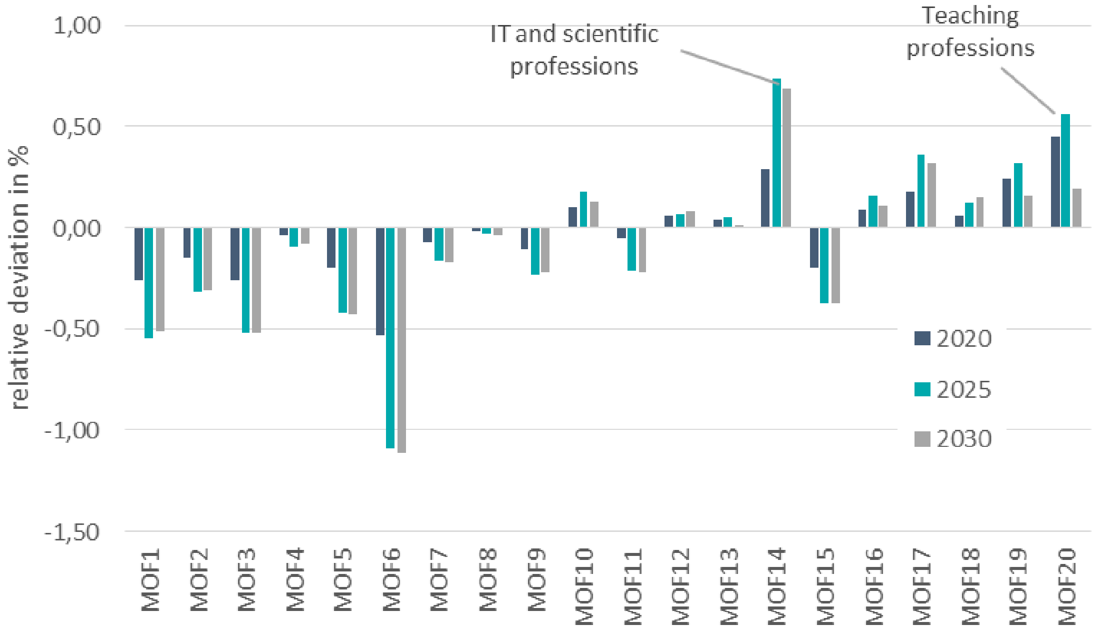


Source: diagram by author.

The trade balance improves; the positive impulses increase via income cycles of the private households' consumer demand. Furthermore, the tax revenue (direct and indirect) and consequently, the government's financial power can increase. Overall, the gross domestic product is significantly higher. The effect increases over time, all cost savings have not been completely implemented until 2025.

The structure of the primary occupational fields has also changed. Overall, demand for service professions increases at the expense of professions in the manufacturing sector. In particular, IT and scientific professions (MOF 14) can benefit. Teaching professions (MOF 20) take second place, which not only include teachers at general-education and vocational schools but also persons working in adult education (Figure 14).

Figure 14
Partial scenario 3 – Number of employees by primary occupational fields in comparison with partial scenario 2

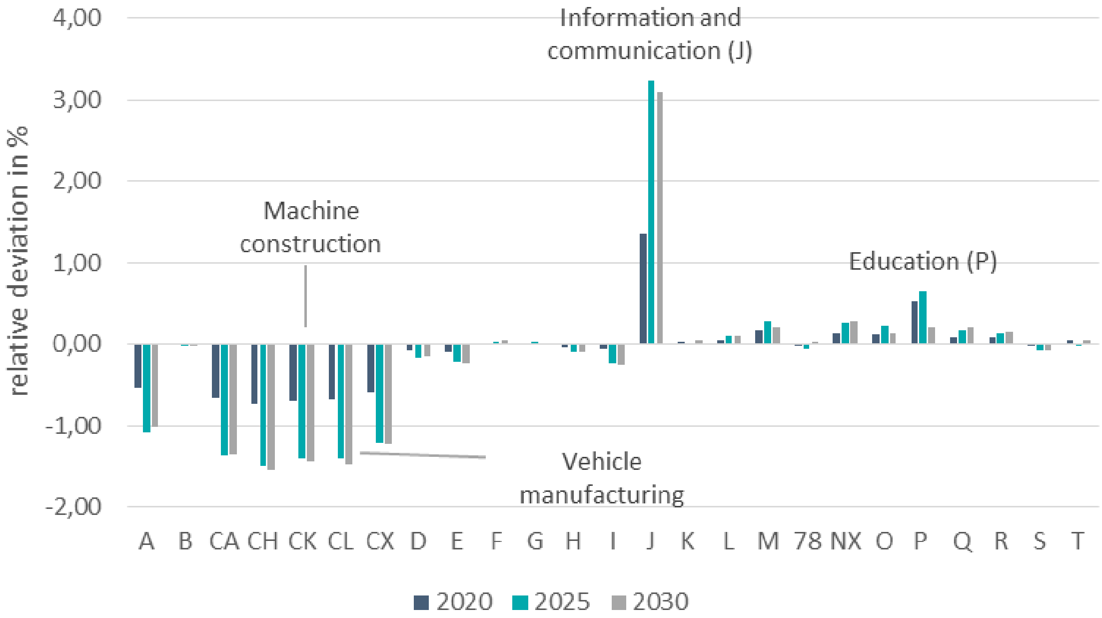


Source: diagram by author.

In particular, the primary occupational fields “resource extraction professions (MOF 1)”, “auxiliary workers/caretakers (MOF 2)”, “metal construction, systems engineering, sheet metal construction, installation, assembly workers, electrical trades (MOF 3)”, “other processing, manufacturing and repair professions (MOF 5)” as well as “system and machinery control and maintenance professions (MOF 6)” and “technical professions (MOF 15)” are affected by declines. This results directly from the change in cost structure: The sectors supplying intermediate inputs have to supply less for the same output of the subordinate sector. They themselves require less raw materials. At the same time, labour productivity in agriculture and the manufacturing sector increases, which leads to further drops in demand. Imports decrease and the orders from subordinate sectors do as well. Consequently, there is less work to be done. The “traffic-related, warehousing and transport professions (MOF 9)” are also affected negatively. The use of smaller quantities of material also leads to a reduction of quantities to be transported. On the other hand, the decline in catering professions (MOF 8) is indirectly associated: Less people need to be catered to in canteens, cafeterias, etc. Furthermore, cooks are part of the catering professions; however, cooks are also employed in the food industry. An increase in labour productivity is also assumed there.

The assumptions ❼-⓫ trigger the change even more distinctly: The manufacturing sector (CA to CX) and agriculture (A) lose jobs (Figure 15). The information and communication (J) sectors have a considerable increase in employees. Other positive, although minor, effects can be identified in the remaining service sectors (M to P). The other services (NX) not including the supply of temporary workers 78 may also increase. Special mention must be made to the education sector (P), which can record significant increases, above all in the first years.

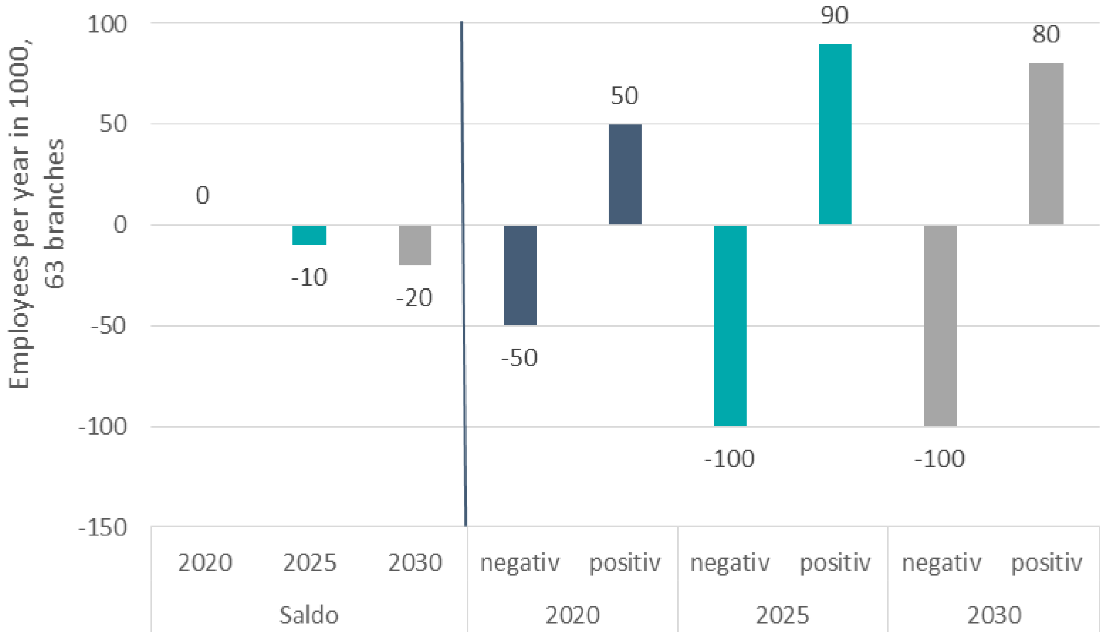
Figure 15
Partial scenario 3 – Number of employees by branches in comparison with partial scenario 2



Source: diagram by author.

What are the consequences for the employees? Do they have to change sectors? Or their occupation, or both? For this purpose, the changes in industrial sectors and occupational fields are examined. The net changes (sum of all) are compared to the respective positive and negative gross changes (sum of all negative and all positive changes).

Figure 16
Partial scenario 3 – Number of jobs lost and created by branches in comparison with partial scenario 2

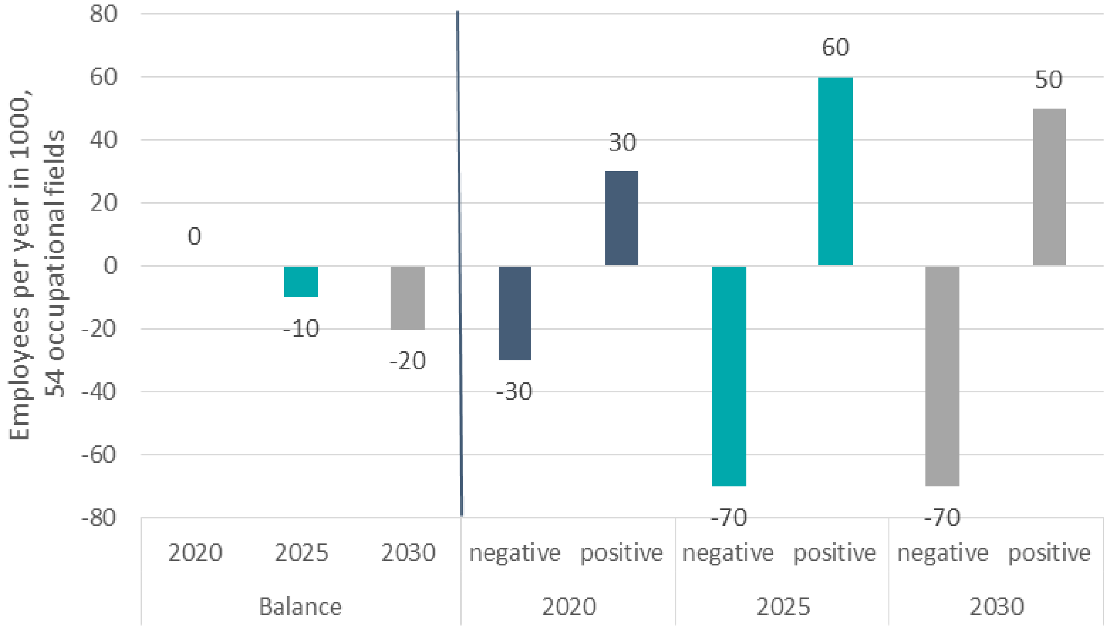


Source: diagram by author.

Figure 16 shows that compared to partial scenario 2, no jobs are lost in 2020 in terms of the overall economy. The number of employees remains the same. Nonetheless, there are consequences for the work environment: Approximately 50,000 jobs are lost in the sectors with a decline in employment figures. Other sectors can hire a total of 50,000 additional employees. Therefore, 100,000 jobs are affected. In 2030, all structural changes are in effect; there are then approximately 20,000 fewer jobs than in partial scenario 2. However, the change in the work environment is far greater: The negatively affected sectors cut 100,000 "old" jobs, the benefiting sectors can provide 80,000 "new" jobs at the most.

The change in the sectors, which is caused by the integration of changed material and personnel costs, not only leads to effects on the work environment based on sectors but also with respect to occupational fields: Sectors are distinguished by the occupations required in order to produce. A change in the structure of the sectors also entails a new structure of the employees by occupational fields.

Figure 17
Partial scenario 3 – Number of jobs lost and created by occupations in comparison with partial scenario 2



Source: diagram by author.

Figure 17 shows the same changes for employees in total (net total) as shown in Figure 16, however, profit and loss are significantly lower: Based on occupational fields, 70,000 jobs are lost in 2025 and 2030 – based on sectors, it was 100,000 (see Figure 16). As a result, the jobs change more excessively between sectors than between occupations. This is also due to the fact that no change in occupational structure within a sector has been modelled based on the introduction of Industry 4.0. This is taken into account in the fourth partial scenario.

4.4 Occupational field structure (partial scenario 4)

In addition to the effect of the economic structure, which results from the integration of material and personnel costs, there is also the effect of the occupational field structure. Therefore, the fourth partial scenario deals with the changes in the occupational field structure within the sectors. Vital for the following is the assumption, that not only the sector but also the structure of the occupations to be employed change in the course of the implementation of Industry 4.0. In order to be able to assess the resulting dynamics, the past change in occupational fields from 1996 to 2011 is depicted (Figure 18).

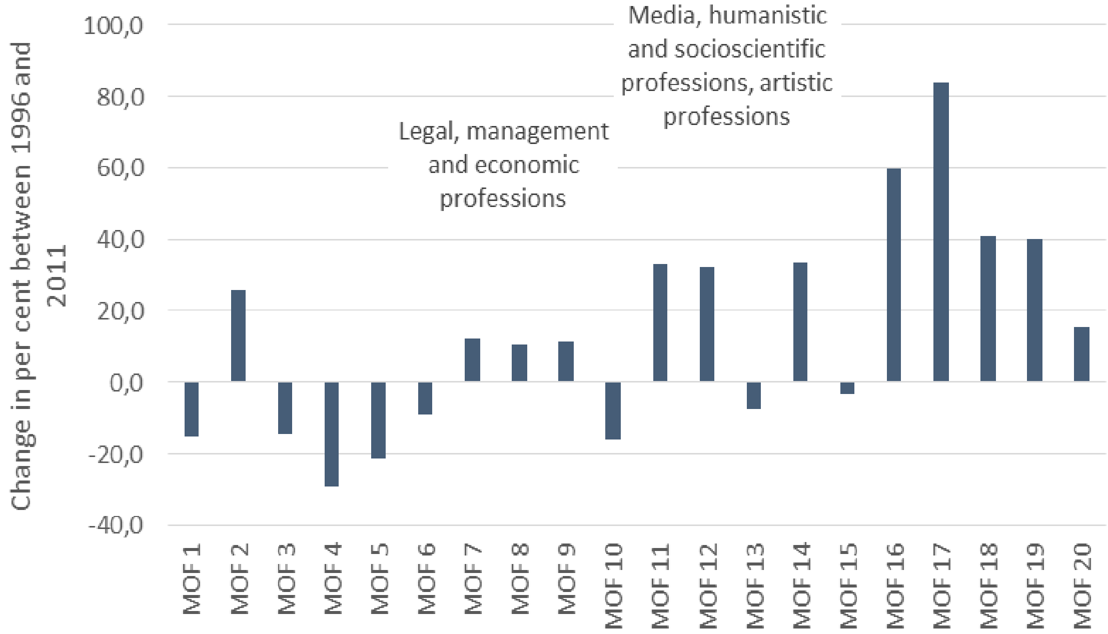
In the past, significant changes have taken place over 15 years. The number of employees increased by +10 % from 1996 to 2011. At the same time, a substantial structural change took place. Occupations which are often found in the manufacturing sector sustained losses.

(1) MOF 3 metal construction, system engineering, sheet metal construction, installation, assembly workers, electrical trades
(2) MOF 4 construction trades, wood, plastics processing and treatment
(3) MOF 5 other processing, manufacturing and repair professions
(4) MOF 6 machine and systems control and service professions

Contrary to this trend, MOF 14 “IT and scientific professions” was able to record growth. Many occupations which can be classified as services (including health services) could grow:

(1) MOF 11 catering professions
(2) MOF 12 cleaning and disposal professions
(3) MOF 16 legal, management and economic professions
(4) MOF 17 media science professions, professions in humanities and social sciences, artistic professions
(5) MOF 18 healthcare professions
(6) MOF 19 social professions
(7) MOF 20 teaching professions

Figure 18
Change in employees by primary occupational fields between 1996 and 2011



Source: diagram by author.

Which effects the transition to Industry 4.0 will have on the structure of the occupational fields in a sector is unknown. Assuming that as a result of the transition to Industry 4.0 primarily occupations with a high percentage of routine jobs will be cut back and occupations with a low percentage of routine jobs will increase (Author et al. 2013; Bonin et al. 2015; Bowles 2014; Brzeski/Burk 2015; Frey/Osborne 2013), the possible effects of Industry 4.0 for employment in the sectors can be assessed. For this purpose, the percentages of routine jobs identified by Dengler and Matthes (2015) are used in the BIBB occupational fields based on the occupational data from the expert databank BERUFENET of the Federal Employment Agency.[8] In this connection, job tasks which “can be conducted according to programmable standards” are described as routine jobs; “while non-routine [jobs] can merely be supported by computers” (ibid.).[9]

(Assumption ⓬) The higher the percentage of non-routine jobs in an occupational field relative to the sector average, the more an occupational field benefits from transitioning to Industry 4.0.

For instance, if the sector average of non-routine jobs in an occupational field is 40 per cent and 80 per cent for an occupational field within the same sector, the number of employees in the occupational field with a higher percentage of routine should

8 Cf. Tiemann 2008 for the BIBB occupational fields. Similar routine percentages can be determined for the 54 occupational fields based on the collective employee survey conducted by the Federal Institute for Vocational Education and Training and the Federal Institute for Occupational Safety and Health.

9 We would like to take this opportunity to thank Dengler and Matthes for calculating the routine percentages by occupational fields.

show a greater decline in line with the transition to Industry 4.0. However, because there are also numerous reasons, which argue against a complete adaptation according to routine percentages, it is furthermore assumed that merely half the routine jobs can be saved by technological progress, at the most. Nevertheless, which routine percentages can actually be saved cannot be determined in advance because in addition to the assumptions made, further changes in the occupational field structure result from the model – for instance due to varying wage growth. (Maier et al 2014b).

The changes in the occupational field structure resulting which result in the course of the transition to Industry 4.0 have consequences: Along with assigning more complex work, the percentage of occupations with higher wages increases. Therefore, the average wage costs of the sector increase.

(Assumption ⓭) Labour productivity increases by 0.9 per cent based on the restructuring of the occupational fields, so that wage costs and profit remain the same.

As in the assessment of the material and personnel costs it is again assumed that the companies will not make any changes which reduce their profit. Therefore, in line with assumption ⓭, the assumption is made that labour productivity will increase by another 0.9 per cent by 2025. The 0.9 per cent correspond to the increase in wage costs in the selected sectors for an exclusive restructuring of the occupational fields.

In other words: The occupational fields, which are considerably above the average routine percentage in their sector, lose; occupational fields with a relatively low routine percentage compared to the sector average will win. Overall however, employment in the sectors in which investments were made will decrease in equal measure due to the assumed increase in labour productivity.

Table 3 shows a fictitious example of a sector with four occupational fields, which is used to explain the approach.

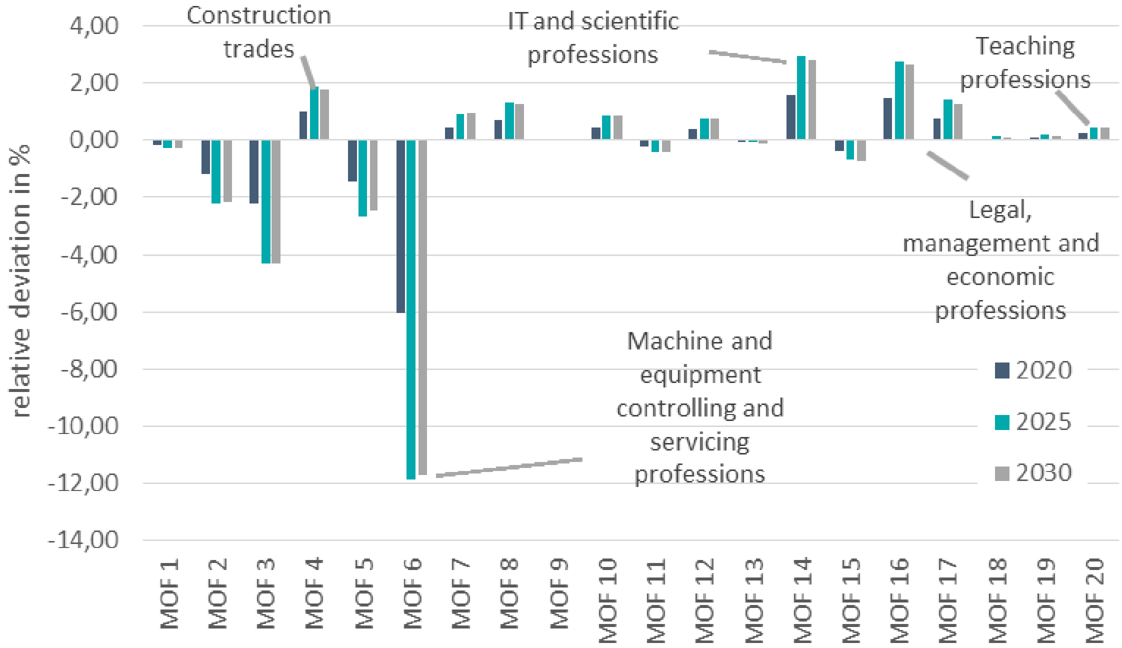
Table 3
Integration of the routine percentage, model calculation

		Occupational fields					
		1	2	3	4	Total	Average
Employees in 2015	in persons	1,000	1,000	3,000	5,000	10,000	
.. in %	in % of total	10	10	30	50	100	
Routine percentage of the job	in %	10	70	80	90		77
Halving of the routine percentage	in %	5	35	40	45		
Percentage of the complex jobs at halved routine percentage	in %	95	65	60	55		61.5
Bonus/malus: In relation to the industry sector average, scaling factor	Factor	1.54	1.06	0.98	0.89		
Employees considering the bonus/malus factor in 2025	in persons	1,545	1,057	2,927	4,472	10,000	
Considering the increase of labour productivity by 1.2 %	in persons	1,526	1,044	2,892	4,418	9,880	

Source: diagram by author.

To uncover the consequences for the occupational fields, these are compared to the preceding scenario. Figure 19 shows the changes in primary occupational fields, which solely trace back to the assumptions ⓬ and ⓭.

Figure 19
Partial scenario 4 – Number of employees by primary occupational fields in comparison with partial scenario 3

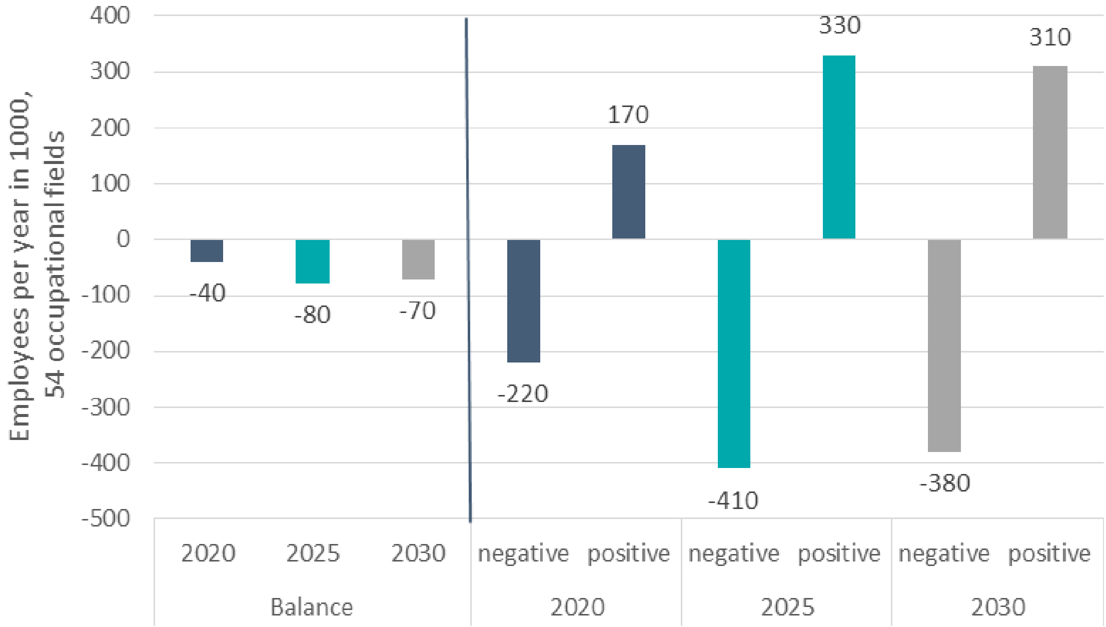


Source: diagram by author.

It is quite apparent that the system and machinery control and maintenance professions (MOF 6) decrease; they lose up to 12 per cent in the course of transition. However, compared to the previous shifts in the occupational fields over time (Figure 18), this is still a comparatively minor change, but it must be taken into account that Figure 19 only depicts scenario effects beyond the basic development of the baseline scenario. The IT and scientific professions (MOF 14) benefit most. However, so do the construction trades (MOF 4), for which only small routine percentages are indicated according to Dengler and Matthes (2015).

In conclusion, the gross flows within the occupational fields are looked at. The fluctuations for the primary occupational fields in partial scenario 3 were less than those for the sectors, but partial scenario 4 shows significantly greater fluctuations (Figure 20).

Figure 20
Partial scenario 4 – Number of jobs lost and created by occupations in comparison with partial scenario 3



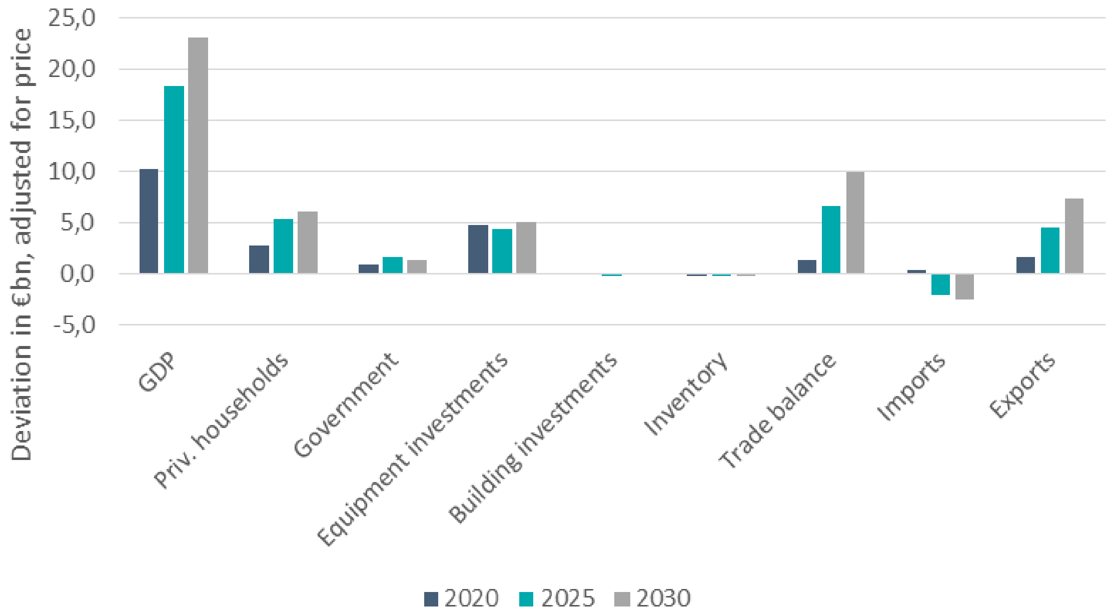
Source: diagram by author.

In 2025 and 2030 a total of 700,000 employment relationships will be impacted by the assumption made. The balance for these years shows a numerical loss of 70,000 to 80,000 employees. This decline is attributed to the macroeconomic consequences of the occupations being reallocated and the again increasing labour productivity.

4.5 Overall effect without additional demand (partial scenarios 1-4)

Until now, the scenarios were compared step by step to be able to identify the isolated effects. In the following, the interferences in the first four partial scenarios will be compared to the baseline scenario (Figure 4). The difference between the QuBe baseline scenario and the overall scenario without shifts in demand is therefore attributed to all previous interferences (assumption ❶-⓭). The consequences for the gross domestic product and its components are illustrated in Figure 21. The gross domestic product will increase less in the beginning but more during the last five years. Even without any other interferences in the area of consumption and export, there will be an increase in export and consumption due to cyclical flow effects (cyclical flow of income) and due to improved competitiveness (lower manufacturing costs). The decreasing import demand is also important for the result, which is caused by less demand for imported intermediate inputs for raw, semi-finished and finished products in agriculture and the manufacturing sector. The gross domestic product will exceed the gross domestic product in the baseline scenario from 2025 to 2030 by approximately € 20 billion each year. Therefore, an additional price adjusted added value of more than € 120 billion will be created in those six years. The average growth rate over the entire period (growth path) increases by 0.05 %. Overall, the effect on the gross domestic product is slightly smaller than when only examining the material and personnel costs (partial scenario 3). The reason lies in the financing of investments (partial scenarios 1&2), which provides for negative growth impulses after 2025. Furthermore, the reallocation of the occupational fields in sectors with a higher demand for highly qualified manpower provides for a slight increase in average hourly wages.

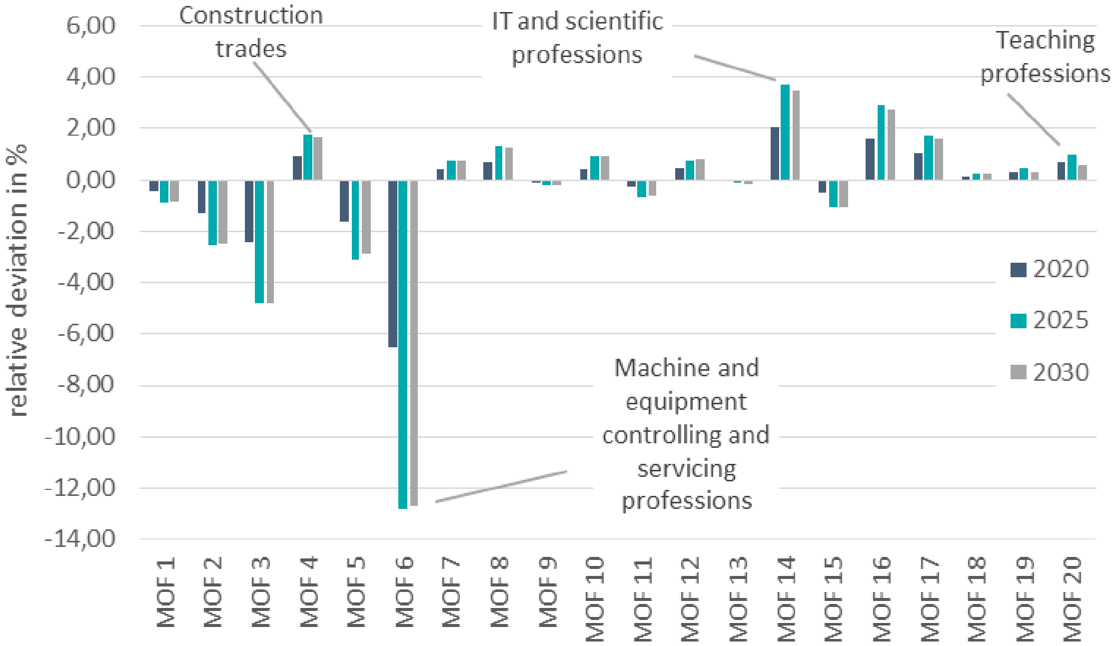
Figure 21
Overall scenario 1-4 – Change in gross domestic product and its components in comparison with the baseline scenario



Source: diagram by author.

Based on the structure of the occupations, there are conflicting influences in the manufacturing sector (Figure 22): The increase in equipment investments has positive effects on employment, at least until 2024. The consequences of the changes in cost structure and increasing labour productivity counteract this.

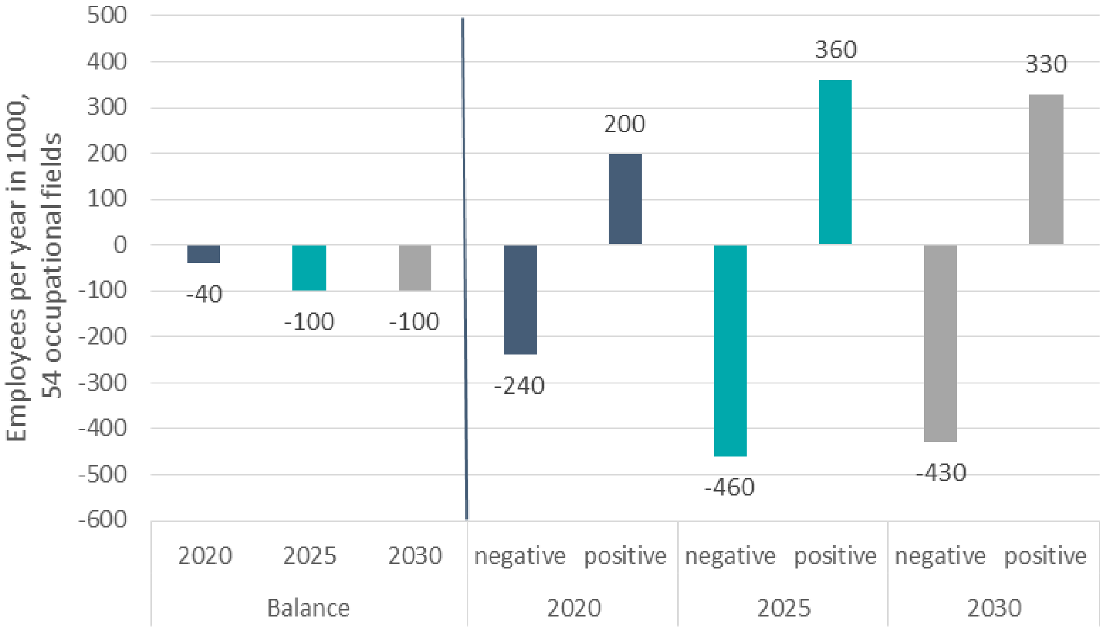
Figure 22
Overall scenario 1-4 – Number of employees by primary occupational fields in comparison with the baseline scenario



Source: diagram by author.

A look at the structure of the primary occupational fields shows that above all, manufacturing professions decrease and service-oriented professions increase. Special attention must be given to construction trades, which are affected positively. The high initial investments yield the positive result. Given that there are no private investments in the construction sector and therefore no productivity gains, there is no long-term decline in employment figures shown in comparison with the baseline scenario. Moreover, in the sectors directly addressed by the Industry 4.0 modelling, the low routine percentages in the construction trades lead to slight increases compared to other occupational fields. The "machine and systems control and service professions" (MOF 6) show the relatively highest increase. "IT and scientific professions" (MOF 14) can relatively increase the most due to the higher equipment investments and due to the degree of digitisation in agriculture and the manufacturing sector. The "teaching professions" (MOF 20) benefit from the increased rise of the companies' costs for continuing education.

Figure 23
Overall scenario 1-4 – Number of jobs lost and created by occupational fields in comparison with the baseline scenario



Source: diagram by author.

There will be 40,000 fewer jobs in 2020 (Figure 23). Furthermore, the negatively affected occupational fields lose approximately 240,000 jobs; on the other hand, 200,000 jobs are created in other occupational fields: Therefore, 440,000 jobs will see a change. Some will be lost, others created. In 2025 and 2030 there will be 820,000 resp. 760,000 jobs affected by the changes. A total of 100,000 jobs will be lost.

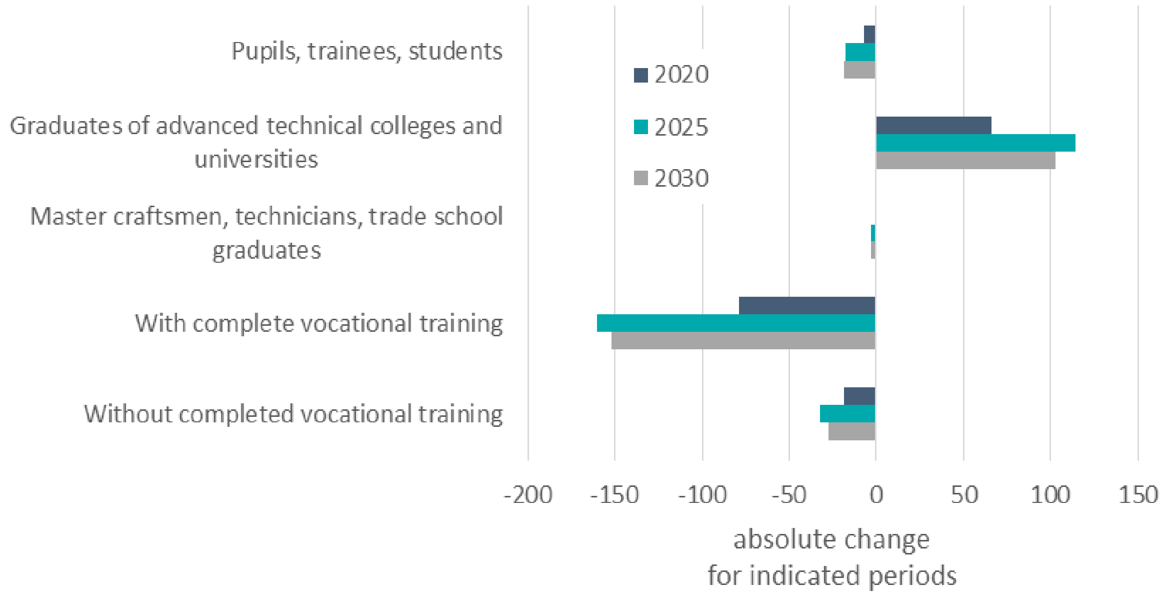
An examination by sectors now shows a smaller transition between jobs (Figure 24). In 2025 and 2030, there will be 100,000 fewer people employed again. However, 200,000 or 190,000 jobs will be eliminated and 100,000 or 90,000 will be created elsewhere. That means that approximately 300,000 jobs from the previous scenario settings will be shifted between the sectors.

Figure 24
Overall scenario 1-4 – Number of jobs lost and created by branches in comparison with the baseline scenario

Source: diagram by author.

In conclusion, a look at the formal qualifications (Figure 25). Each occupational field has a different qualification structure, which is also projected for the future (Maier et al. 2014b). Due to the new resulting occupational field structure, the qualification structure of the national economy changes as well. The demand for persons with a university or advanced technical college degree increases, given that cognitive occupations with small routine percentages are in higher demand. Persons who have completed vocational training are in less demand due to the relatively higher routine in their jobs. In 2025 as well as 2030 approximately 150,000 fewer persons with these qualification are required.

Figure 25
Overall scenario 1-4 – Number of employees by qualification level in comparison with the baseline scenario



Source: diagram by author.

Results part 1:

(1) Industry 4.0 accelerates structural change in services. At least 11 per cent of jobs in the selected sectors will also change.

(2) Although the added value will increase due to increasing competitiveness and a reduction in imports, there will still be approximately 100,000 less persons employed than in the baseline scenario in the overall course of time.

(3) IT professions and teaching professions benefit from the investment on a long term basis.

(4) The demand for highly qualified manpower increases at the expense of persons with training qualification and routine jobs.

(5) The effects on the number of jobs overall are moderate compared to "common" changes in employment figures in business cycles.

(6) Nonetheless, 760,000 jobs will shift between occupational fields by 2030.

4.6 Demand (partial scenario 5)

Consumer demand from private households and the export demand are incorporated in the following scenario. Additional demand can arise from private households due to the new options of Industry 4.0.

(Assumption ⓮) Germany has a worldwide pioneering role in the transition to Industry 4.0 and foreign countries react with a five-year delay. Therefore, international demand for machinery and measurement technology takes place five years later (i. e. 2020) than in Germany and then also continues for ten years. For a plausible increase in export demand it is assumed the investment increase for this scenario (approx. € 3.2 billion) is correlated with the domestic production: In 2012, the production value in machine building and electronic products amounted to a total of approximately € 340 billion. Given that the additional demand for investments particularly focuses on both of these branches, this increases the production by approximately 1 per cent. It is assumed that the demand will increase similarly worldwide and German exports will increase accordingly.

(Assumption ⓯) Private households are interested in the new consumption opportunities which result after the transition to Industry 4.0. Products can be customised to individual needs, the interest in new things and a push in networking of previous end devices with home or a car, for example, may be potential causes. The dynamics and the extent of this additional demand is difficult to assess. It is therefore assumed that demand will only increase by 2 per cent by 2025 for selected consumer purposes. The selection of the respective purposes follows the products produced by the industrial sectors in the manufacturing sector, that is, which have changed their production method in line with the scenario analysis and therefore can also produce customised products. Food and beverages represent an exception because we do not assume additional food consumption. Furthermore, in addition to the export assumption (pioneering role), it is consequently assumed that the new goods can only be acquired domestically, i. e. import is not possible. Therefore, for goods with a high import percentage it is assumed the demand for imported finished products will not increase until 2020. This applies to clothing, furniture and automobiles. The imported intermediate inputs (raw materials and semi-finished products) were left unchanged, given that it is assumed that these will not be enhanced and are processed inside the country.

The selected purposes (Table 4) always deal with goods which characterise the domestic consumption of private households. Goods and services cannot always be clearly distinguished. Therefore, the purpose “goods and services for the operation of private vehicles” is not selected because in this case, fuels are usually recorded.

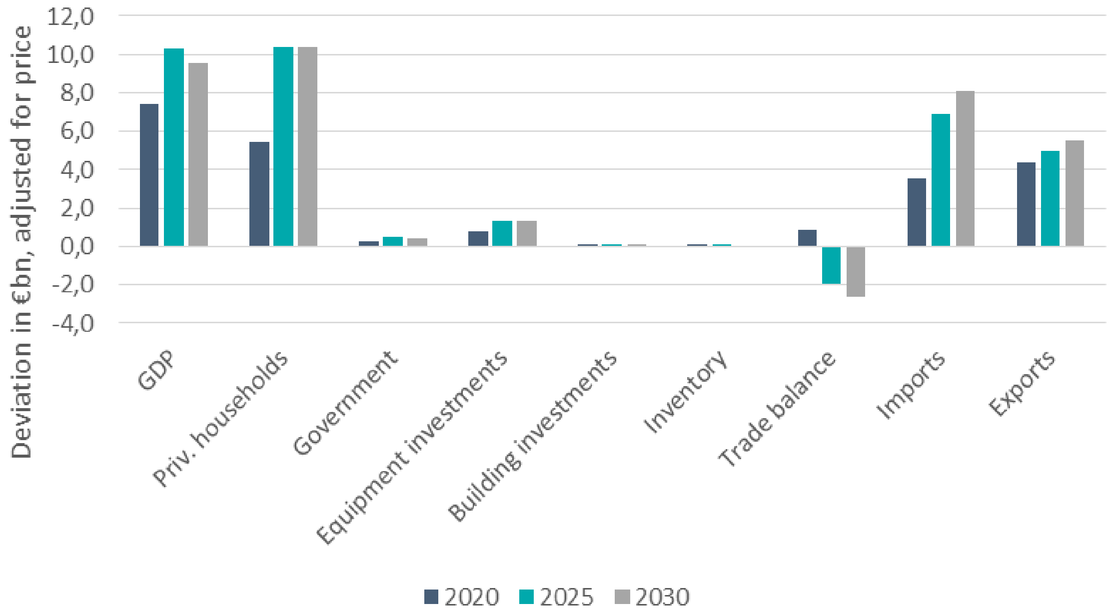
Table 4
Selection of purposes (highlighted in blue)

	Purpose
1	Food products
2	Non-alcoholic beverages
3	Alcoholic beverages
4	Tobacco products
5	Clothing
6	Shoes
7	Actual rent payments
8	Alleged rent payments
9	Routine maintenance and repair of residences
10	Water supply and other services associated with the residence
11	Electricity, gas and other fuels
12	Furniture, interior design, carpeting and similar
13	Home textiles
14	Household appliances
15	Glassware, dishware and other domestic consumer goods
16	Tools and equipment for home and garden
17	Domestic goods and services
18	Medical products, devices and equipment
19	Outpatient medical services
20	Inpatient medical services
21	Vehicle purchases
22	Goods and services for the operation of private vehicles
23	Transportation services
24	Postal and courier services
25	Telephone and fax devices, incl. repairs
26	Telephone and fax services, Internet
27	Audiovisual, photographic and information processing equipment and accessories, including repairs
28	Other durable consumer goods for recreation and culture (incl. repairs)
29	Other devices and products for recreational purposes (including repairs), garden products and consumer goods for garden maintenance, pets
30	Leisure time and cultural service
31	Newspapers, books and stationery supplies
32	Package holidays
33	Education
34	Food services
35	Lodging services
36	Personal care
37	Personal commodities
38	Services from social institutions
39	Insurance services
40	Financial services
41	Other services, not otherwise specified

Source: Federal Statistical Office, diagram by author.

Illustrating the sole effects of the changes in demand on the components of the gross domestic product yields Figure 26.

Figure 26
Partial scenario 5 – Change in gross domestic product and its components in comparison with partial scenario 4



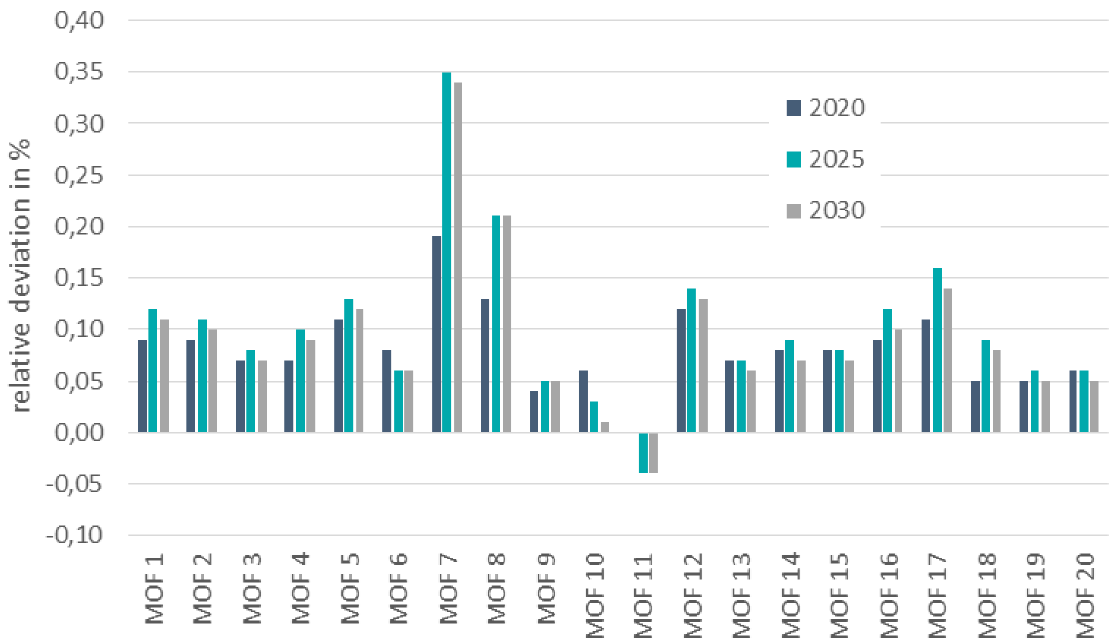
Source: diagram by author.

Exports and consumption of the private households are higher after 2020 than before because exports do not pick up until later (2020) and consumer demand is continuously increased. Imports increase significantly, given that many audiovisual end devices are not produced in Germany and must be imported accordingly. Furthermore, demand for services by private households, which has a serious domestic impact (e. g. rent payments or personal hygiene), is not directly affected by the scenario assumptions. Ultimately, additional exports are also associated with additional imports. Therefore, despite increasing exports, the overall foreign trade balance is negative compared to partial scenario 3.

The consequences of partial scenario 5 for the primary occupational fields are far less specific than the preceding ones (Figure 27). Due to the consumption of private households, the demand for “professions in merchandising – service and sales (retail trade) (MOF 7)” increases the most. Overall, service professions are somewhat more in demand than professions in the manufacturing sector. The hotel and restaurant industry records a slight loss. It is not part of the selected purposes.

It is apparent that in Economy 4.0 the retail trade (“Trade 4.0”) can also be organised differently. However the preceding scenario only examines industrial digitisation.

Figure 27
Partial scenario 5 – Number of employees by primary occupational fields in comparison with partial scenario 4



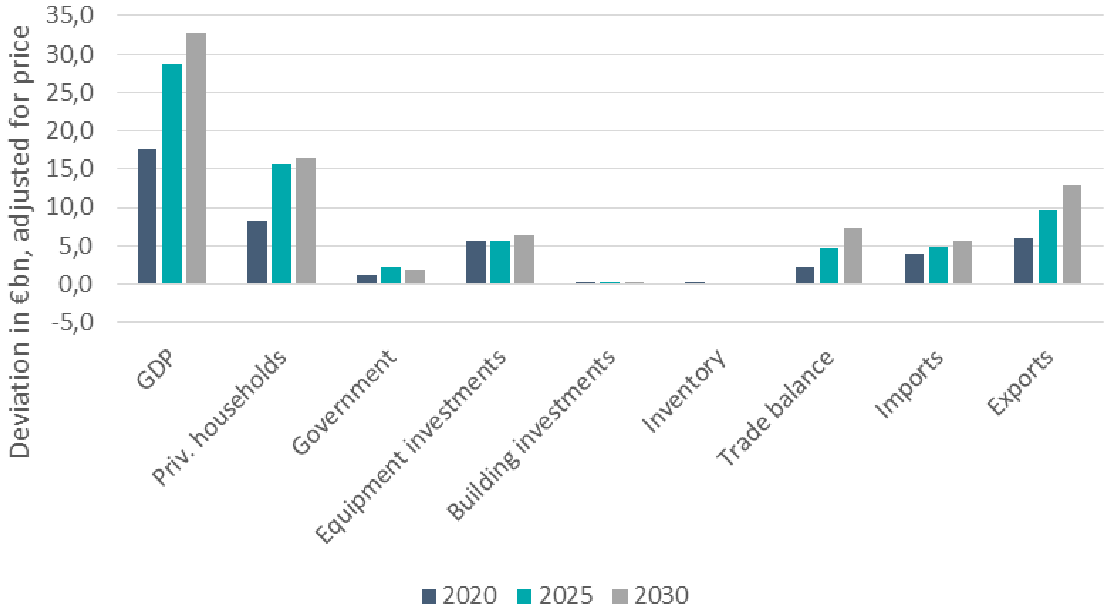
Source: diagram by author.

4.7 Industry 4.0 scenario (overall scenario 1-5)

The result of the Industry 4.0 scenarios consists of the five partial scenarios discussed previously. The effects of all assumptions on the economic development and the labour market are depicted in Chart 1 (❶-⓯).

The result shows positive changes: Consumption, investments (primarily equipment) and trade balance are positive in both periods examined (Figure 28). However, the advantage of declining imports is lost due to the additional demand (partial scenario 5).

Figure 28
Overall scenario 1-5 – Components of the gross domestic product in comparison with the baseline scenario



Source: diagram by author.

The result cannot be determined until the partial scenarios are examined together (Table 5). The overall scenario has a positive effect on the consumption of private households; this is caused by increasing demand (partial scenario 5) and effects resulting from the cyclical flow of income (partial scenario 1 & partial scenario 3). Government consumption can achieve an overall positive result in the second period. The effects are only minor in the partial scenarios; a positive effect only results in the synopsis.

The equipment investments are either directly initiated (partial scenario 1) or are increased based on cyclical flow relationships (partial scenario 5). Overall, the result is positive. In contrast, building investments only achieve noteworthy positive values (by 2018) in partial scenario 2. The changes in inventory are not part of a scenario and they are also not able to achieve a positive change through indirect effects.

There is a noteworthy increase of imports overall. However, partial scenario 4 shows obvious declines due to the low demand of raw and semi-finished products. This can lead to an overall positive change in the trade balance, given that exports indicate consistent positive results with the exception of the first partial scenario.

Table 5

Overall scenario 1-5 Effects on the components of the gross domestic product in the partial scenarios and overall

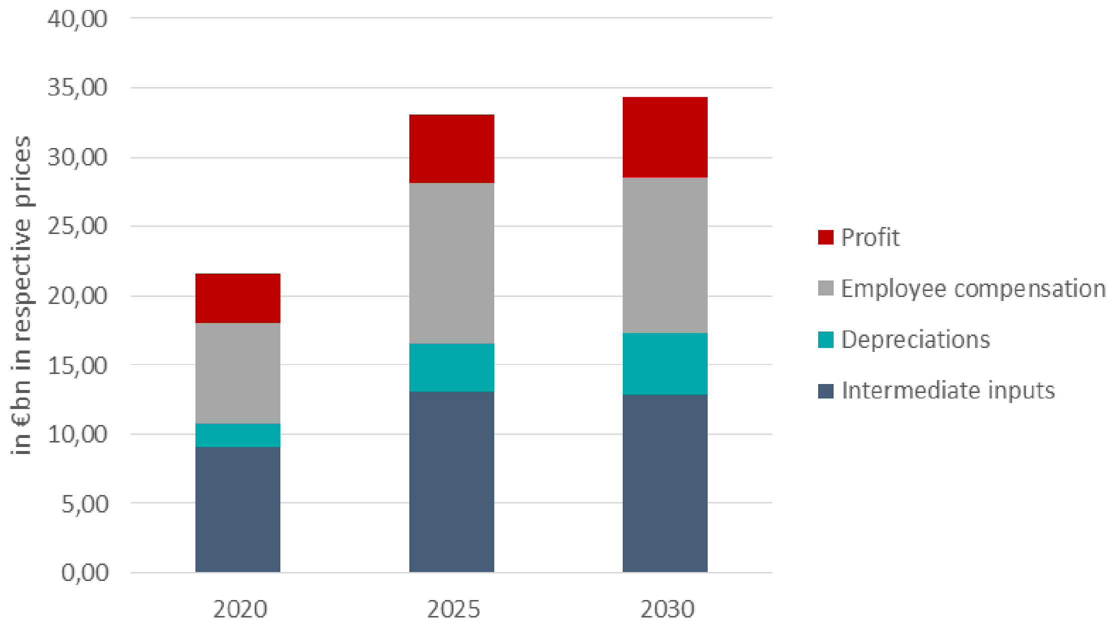
	Equipment investments Partial scenario 1		Building investments Partial scenario 2		Material and personnel costs Partial scenario 3		Occupational fields Partial scenario 4		Demand Partial scenario 5		Industry 4.0 1 to 5	
	2016-25	2026-30	2016-25	2026-30	2016-25	2026-30	2016-25	2026-30	2016-25	2026-30	2016-25	2026-30
Gross domestic product	+	-	+	O	+	+	O	+	+	+	+	+
Consumption of private households	O	-	O	O	+	+	O	+	+	+	+	+
Government consumption	O	O	O	O	O	+	O	O	O	O	+	+
Equipment investments	+	+	O	O	+	+	O	O	O	+	+	+
Building investments	O	O	+	O	O	O	O	O	O	O	+	O
Inventories	O	O	O	O	O	O	O	O	O	O	O	O
Trade balance	-	-	-	O	+	+	O	O	O	-	+	+
Imports	+	O	+	O	-	-	O	O	+	+	+	+
Exports	O	-	O	O	+	+	O	O	+	+	+	+

“O” +/- one bn.; “+” > 1bn.; “-” < 1bn

Source: diagram by author.

Figure 29 shows the effect on production. As per definition, production consists of the produced intermediate inputs and the generated added value. These in turn can be broken down into employee compensation, depreciations and net operating surpluses (profit). Overall, production increases over the years. In 2020, it can increase by approx. € 22 billion – in 2025 and 2030 even by more than € 30 billion. While the demand increases in the beginning and the cost structures change, all effects are simultaneously and consistently active as of 2025.

Figure 29
Overall scenario 1-5 – Primary inputs and intermediate inputs in comparison with the baseline scenario



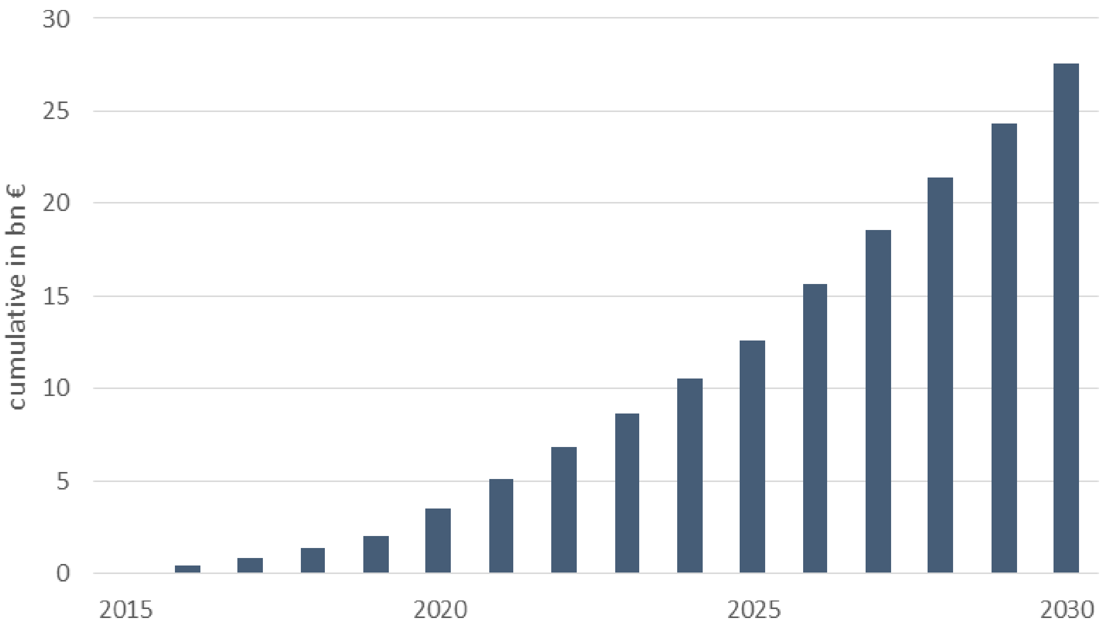
Source: diagram by author.

Essentially, the added value of the national economy consists of profit, employee compensation and depreciations. Added value also predominantly defines the gross domestic product. In terms of the composition of the additional production, it must be pointed out that the intermediate inputs are in fact higher but do not continue to increase after 2025. This is due to the gains in efficiency which, among other things, lead to a more efficient use of raw, semi-finished and finished products.

Furthermore, significant increases in employee compensation can be identified. The reduction of routine jobs and increasing labour productivity in the manufacturing sector favours occupational fields with a higher level of qualification and higher wages. The assumed increase in labour productivity results in wage increases for employees under productivity-oriented wage policy.

Ultimately, depreciations will increase over time: Even after the last investments have been made, depreciations will continue. Given that depreciations for the investment years (vintage years) accumulate, the highest depreciations will accrue after the peak investments, i. e. after 2025, during the second period. At first glance, additional profits appear minor. However, the profit in the past is also less than half of employee wages with regard to the economy as a whole.

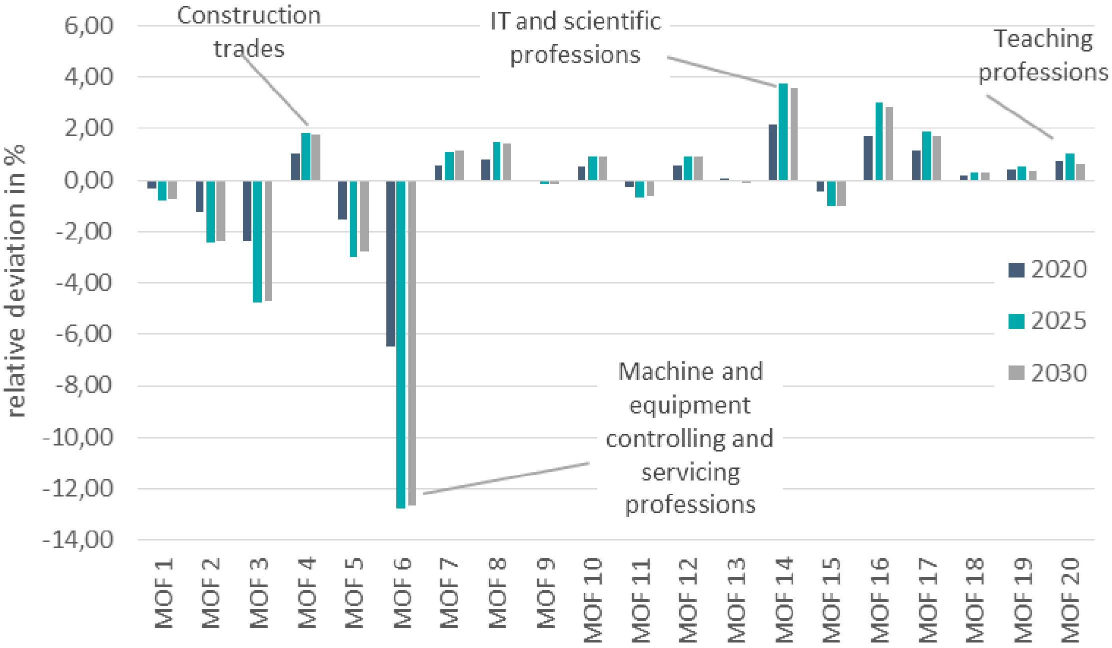
Figure 30
Development of the accumulated profit in agriculture and the manufacturing sector in comparison with the baseline scenario



Source: diagram by author.

Profit development in agriculture and the manufacturing sector is examined separately (Figure 30). When taking the variations from the baseline scenario into account, positive profits are consistently identified from 2016 to 2025; if these are accumulated, an accumulated difference in profit amounting to € 12.5 billion is achieved by 2025. That is more than was previously determined in the calculation for partial scenario 3 (€ 8.3 billion, Chart 2). The losses there do not occur in the overall scenario because consumption growth and later on, increases in export demand are added. In the years following 2025, the profits can then be further increased: The transition has taken place and the market pull persists.

Figure 31
Overall scenario 1-5 – Number of employees by primary occupational fields in comparison with the baseline scenario

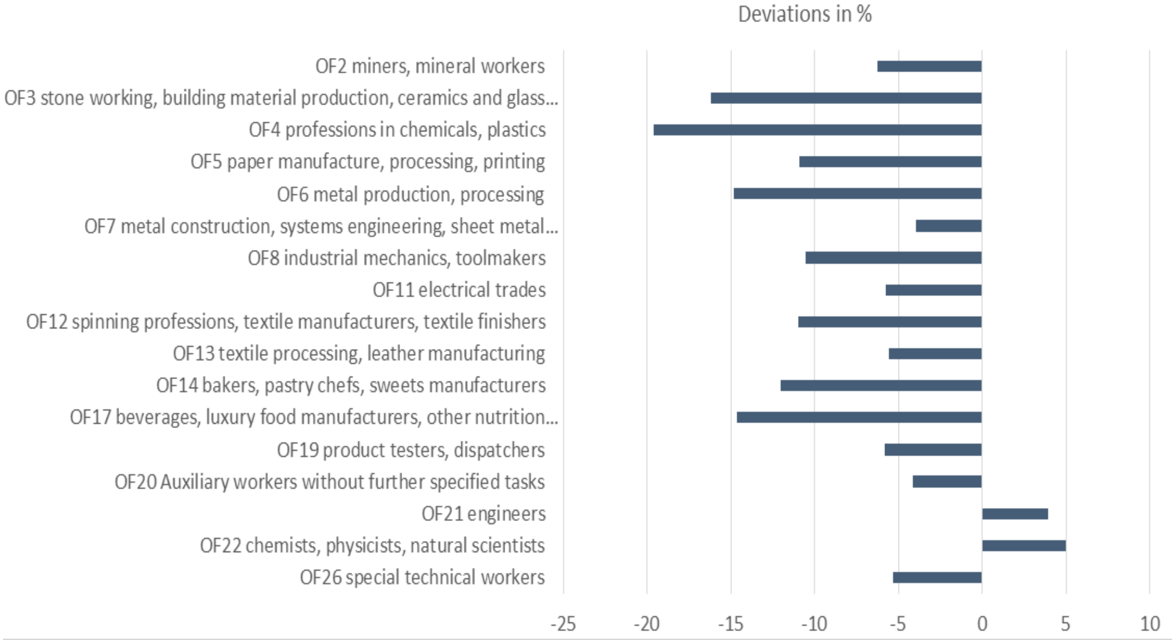


Source: diagram by author.

A look at the primary occupational fields shows that occupations found in the manufacturing sector in particular (especially "system and machinery control and maintenance professions"), are affected negatively despite the implementation of additional demand (Figure 31). The increase in demand cannot even compensate for the consequences of the changed intermediate inputs and the change in the occupational field structure in partial scenario 5. Occupations which benefit most from the scenario are in the area of technology and sciences (MOF 14), in the area of business consultancy (MOF 16), teaching professions (MOF 20) and construction trades (MOF 4). The positive effects on the professions in media and the arts (MOF 17) depend on the demand for design and are characterised by the general macroeconomic developments.

The level of the 54 occupational fields is examined in the following (Figure 32). For clarity purposes, only the occupational fields with a positive or negative deviation from the baseline scenario of more than 3.5 per cent are selected. The most severe deviations are negative. These occupational fields can normally be attributed to the manufacturing sector. In particular, the professions in chemicals and plastics (MOF 4) are seriously impacted. This is not surprising given that they are greatly affected by the restructuring of the production processes as well as by the rearrangement of the occupational situation because the routine percentage is very high according to Dengler and Matthes (2015).

Figure 32
Overall scenario 1-5 – Number of employees by select*) occupational fields in comparison with the baseline scenario in 2030



*) selection criterion: Deviation according to amount > 3.5 per cent.
Source: diagram by author.

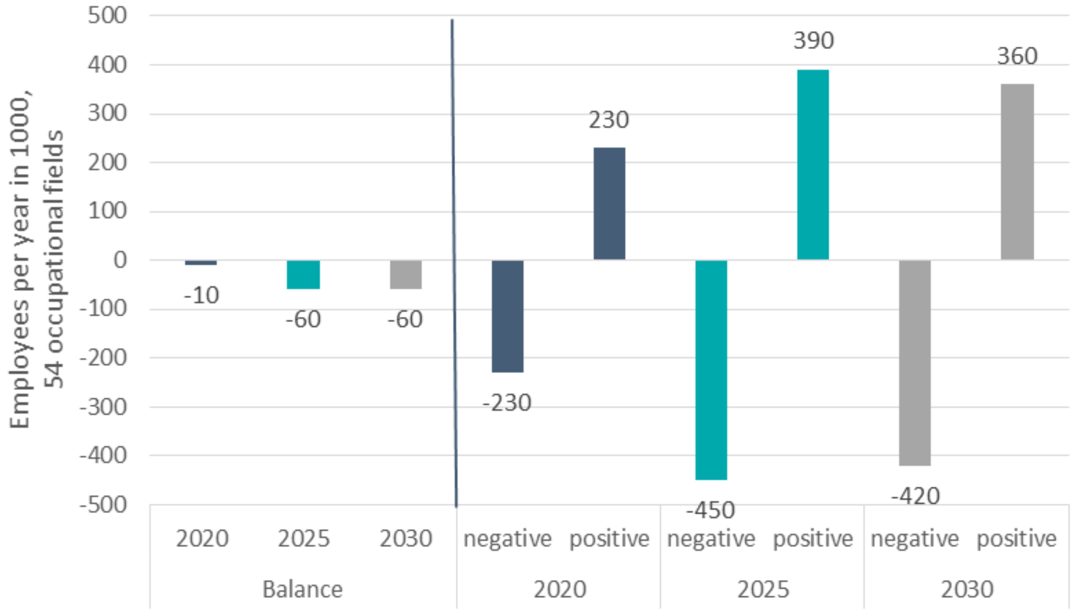
The change amongst jobs by sectors has continued to increase in the overall scenario with the changes in demand (Figure 33). The sectors with declining employment figures will have cut back 200,000 jobs in 2025. The other sectors can create approximately 140,000 new jobs by 2025. A total of nearly 60,000 jobs are lost. The sectors with job losses are in agriculture and the manufacturing sector. An overall additional demand for employees results due to higher consumption by private households, but mainly in service sectors (retail, among others).

Figure 33
Overall scenario 1-5 – Number of jobs lost and created by branches in comparison with the baseline scenario

Source: diagram by author.

The reallocation amongst the 54 occupational fields is also greater than before (Figure 34). It is also still greater than amongst the branches. A total of approximately 450,000 jobs will be lost by 2025 based on the occupational fields, with 390,000 jobs created elsewhere. In the case of an increasing demand for products, the loss of jobs would be reduced from previously 100,000 (compare section 4.5) to approximately 60,000.

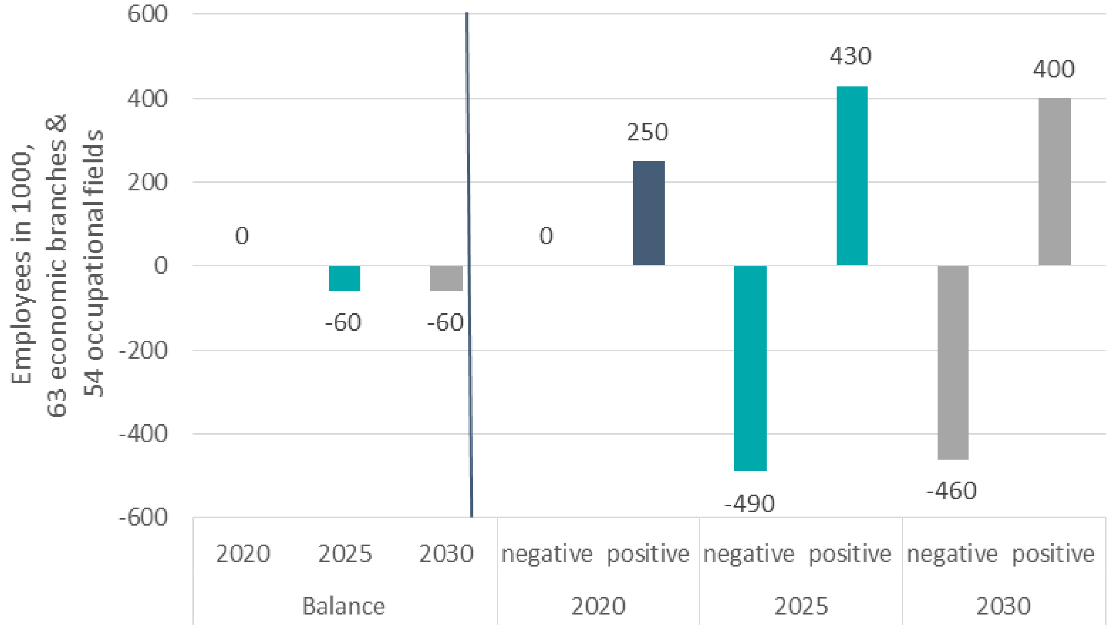
Figure 34
Overall scenario 1-5 – Number of jobs lost and created by occupational fields in comparison with the baseline scenario



Source: diagram by author.

However, not all reallocations are included in the analysis of jobs lost or created at industrial sector level or in the analysis on the level of occupational fields. The expected upheaval on the labour market based on the implementation of Industry 4.0 becomes most obvious when comparing the employment figures for each of the 54 occupational fields within the 63 industrial sectors and including all 54 x 63 potential cell allocations in the analysis (Figure 35). Finally, a flow calculation is approximated for this examination by means of a small-scale calculation of inventory change. According to this, approximately 490,000 jobs will be cut back by 2025, while 430,000 new jobs will be created elsewhere.

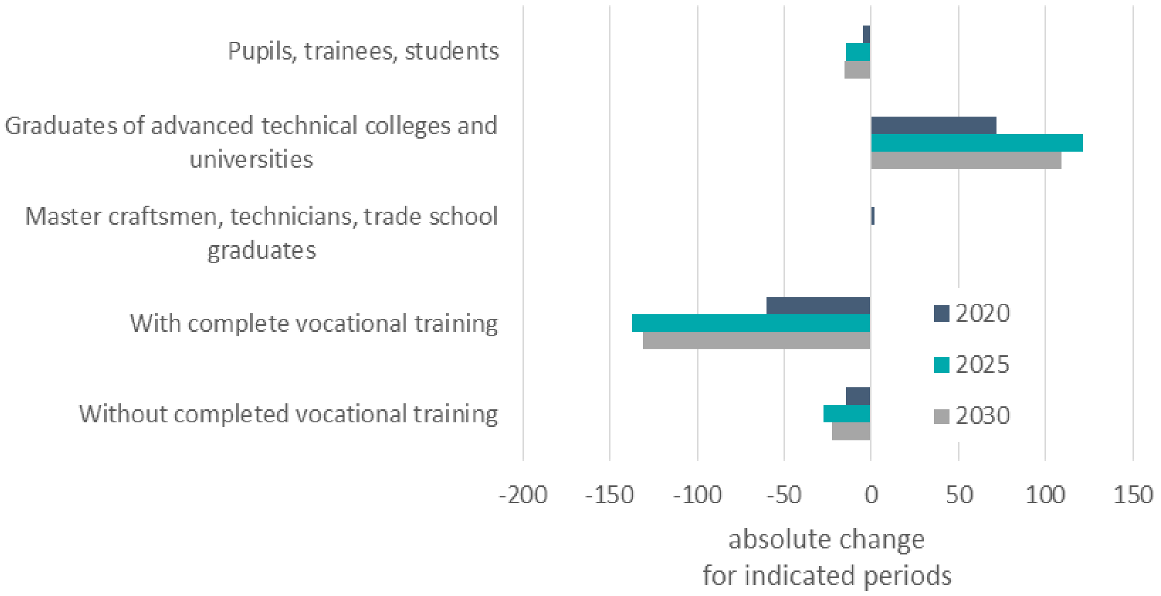
Figure 35
Overall scenario 1-5 – The jobs lost and created by branches and occupational fields in comparison with the baseline scenario



Source: diagram by author.

In terms of qualification levels (Figure 36), the negative consequences for the level of intermediate skills have now also declined with a loss of approximately 130,000 employees. This is due to the additional demand, amongst others in retail trade, which is attributed to a growth in consumption and which leads to additional demand for persons with vocational training.

Figure 36
Overall scenario 1-5 – Number of employees by qualification levels in comparison with the baseline scenario



Source: diagram by author.

Results part II

(1) Additional demand can in fact improve the labour market figures overall, however, this will lead to even greater changes in the labour market. Structural change to more services accelerates.

(2) The occupations in the manufacturing sector continue to be those most affected by job cuts.

(3) The additional added value in the manufacturing sector as part of production, however, increases the economic profits as well as wages. The increases in productivity in the manufacturing sector and in agriculture provide for increased wages. The wage gaps between the manufacturing sector and the service sector increase.

5 Conclusions

The overall effects of the Industry 4.0 scenario on the demand for labour are relatively moderate: From 2000 to 2010, hourly productivity of labour increased by approximately 15 per cent, i. e. by approximately 1.5 per cent annually. The derived assumptions pertaining to the increases in productivity (1.2 per cent in partial scenario 3) are based on these assumptions. Furthermore, partial scenario 4 implies that labour productivity increases by an additional 0.9 per cent. Both labour productivity increases enhance the productivity path already included in the baseline scenario. Jobs with routine tasks in the manufacturing sector, which are lost due to the increases in productivity, are accompanied by a growth in occupations with non-routine tasks, which on average require a higher level of qualification. When assuming that a new demand for products is generated through the implementation of Industry 4.0 (partial scenarios 1 to 4), more than 490,000 jobs which previously existed will be lost by 2025, however, 430,000 new jobs will also be created. A shift towards a service-based economy is improved by the transition to Industry 4.0. Furthermore, there are also consequences for other existing jobs: Extensive initiatives for continuing education have already been taken into account in the scenario. Therefore, the transition to Industry 4.0 is associated with adjustments for persons remaining in their jobs. There will be new work flows and tasks and others will be eliminated.

Due to the demographic change shown in the model processes, a tendency towards shortages in the segment of intermediate level skills result in the QuBe baseline scenario. The considerably increasing supply in the area of academic skills is not entirely included according to the anticipated trends formalised in the model. The Industry 4.0 scenario counteracts this change in labour supply because the demand for personnel in the upper segment – in particular for MINT professions (German acronym for jobs in mathematics, informatics, sciences and engineering) – increases and declines in the intermediate segment. However, underemployment for persons without vocational training will increase even more.

An implementation of Industry 4.0 is also profitable without the modelled “additional” demand for new products. Stronger economic growth is achieved; at the same time however, imports decline. Given that Germany is a country lacking natural resources, a large part of the imports can be directly or indirectly (semi-finished products) attributed to the supply of raw materials. An increase in average wages can be noted; this is caused by increasing labour productivity and including the routine percentages of the occupational fields.

The results of the previous studies indicate that digitisation requires complete implementation. Although digitisation yields positive results in agriculture and the manufacturing sector in the opinion of the companies involved, the whole economy falls short of its full potential. The demographic trend depicted in the model still assumes a net annual migration gain of approximately 200,000 persons. Therefore, in view of the current net migration, the indicated development trajectory remains below the overall economic growth, which is stunted in the model by the comparatively small labour force. The growth path can in fact be increased by the assumed changes in labour productivity with virtually unchanged employment figures however, it could be even higher under the assumptions made if the productivity advances in the service sector are also increased.

However, the scenario calculations and the assumptions clearly show: Ultimately, there is no other way – if Germany is not capable of implementing Industry 4.0, other countries will still do so. And, the assumptions, which have a positive effect on Germany in the aforementioned scenario (pioneer, additional demand from abroad, competitive advantages) are then directed against a business location here. Declines in production and additional unemployment will result. This is caused by losing the competitive position and domestic demand shifting to imported products. Therefore, the task can only be to organise the transition in the most effective way possible.

In principle, higher increases in productivity than those modelled are also conceivable. Likewise, the costs considered for digitisation can also be higher. Here, twice the amount was assumed, however, studies (as already defined) even assume four times the costs. The assumed changes in occupational structures in the sectors lead to significant shifts between occupational fields. All three factors can at least significantly increase the effect of the transition between new and old jobs. To date, the positive employment trend in Germany is taking place at a slow rate in economy and the labour market (Klinger/Weber 2015). Therefore, a more intense growth in investments and productivity could invigorate the basis of this trend.

In light of this, the assumptions and modelling made must be critically reviewed. Should new findings regarding the transition to Industry 4.0 arise, the scenarios would need to be adapted or even upgraded accordingly. Therefore, the scenario presented can only represent a first step in illustrating the impacts Industry 4.0 has on the labour market and the economy. At the moment, there is no answer to much the implementation of Industry 4.0 in other regions (USA, EU, BRICS[10]) will impact Germany as an industrial location. Furthermore, information must be obtained on to which extent trade-specific structural changes regarding occupations or even company organisations actually take place and whether or not potential demand for new occupations arises.

In order to comply with these and other requirements, additional data sets will have to be evaluated and for instance, in the future results from additional company surveys will have to be included in creating the scenario. Ultimately, it makes sense to analyse a digitisation of the overall economy. Precise links or recommendations for government or corporate actions could be derived from this.

References

Author, David H.; Levy, Frank; Murnane, Richard J. (2013): The Skill Content of Recent Technological Change: An Empirical Exploration. In: The Quarterly Journal of Economics, page 118(4).

Berger, Roland (2014): INDUSTRY 4.0 The new industrial revolution. How Europe will succeed.

BITKOM (2014): Industrie 4.0 – Volkswirtschaftliches Potenzial für Deutschland. Study.

[10] BRICS is the acronym for the five countries: Brazil, Russia, India, China and South Africa.

BMAS (2015): Arbeiten weiter denken. Green Paper. Arbeiten 4.0. Federal Ministry of Labour and Social Affairs.

BMBF (2014): Zukunftsbild Industrie 4.0. Hightech-Strategie. Federal Ministry of Education and Research.

Bonin, Holger; Gregory, Terry; Zieran, Ulrich (2015): Transfer of the study from Frey/Osborne (2013) to Germany. Expert synopsis on behalf of the Federal Ministry of Labour and Social Affairs.

Bowles, Jeremy (2014): The computerisation of European jobs-who will win and who will lose from the impact of new technology onto old areas of employment?, Brussels: Bruegel.

Brzeski, Carsten; Burk, Inga (2015): Die Roboter kommen. Folgen der Automatisierung für den deutschen Arbeitsmarkt. INGDiBa Economic Research.

DBR (2014): Industrie 4.0 – Upgrade des Industriestandorts Deutschland steht bevor. Current topics. Deutsche Bank Research. February 2014.

Dengler, Katharina; Matthes, Britta (2015, forthcoming): Substituierbarkeit von Berufen durch Computerisierung in Deutschland (IAB research report), mimeo.

DIE WELT (2014): Deutschland droht die Zukunft zu verschlafen. 12/9/2014. URL: www.welt.de/135151615.

Die ZEIT (2014): In der Zukunftsfabrik. 01/23/2014.

Distelkamp, Martin; Hohmann, Frank; Lutz, Christian; Meyer, Bernd ; Wolter, Marc I. (2003): The IAB/INFORGE model: Ein neuer ökonometrischer Ansatz gesamtwirtschaftlicher und länderspezifischer Szenarien. In: Beiträge zur Arbeitsmarkt- und Berufsforschung (BeitrAB), volume 275, Nuremberg.

Drosdowski, Thomas; Wolter, Marc Ingo together with Helmrich, Robert; Maier, Tobias (2010): Entwicklung der Erwerbspersonen nach Berufen und Qualifikationen bis 2025: Modellrechnung mit dem BIBB-DEMOS-Modell. In: Helmrich, R.; Zika, G. (2010): Beruf und Qualifikation in der Zukunft, Bonn.

Emec, Soner; Stock, Tim; Bilge, Pinar; Tufinkgi, Philippe; Kaden, Cornelia; Seliger, Günther (2013): Analyse von Potenzialen der Material- und Energieeffizienz in ausgewählten Branchen der Metall verarbeitenden Industrie. Berlin.

Forschungsunion & acatech (2013): Deutschlands Zukunft als Produktionsstandort sichern: Umsetzungsempfehlungen für das Zukunftsprojekt Industrie 4.0. Final report of the Industry 4.0 study group Sponsored by the Federal Ministry of Education and Research.

Frey, Carl Benedikt; Osborne, Michael A. (2013): The Future of Employment: How Susceptible are Jobs to Computerization?, University of Oxford.

Heng, Stefan (2014): Industrie 4.0 - Upgrade des Industriestandortes Deutschland steht bevor. Deutsche Bank Research.

Helmrich, Robert; Zika, Gerd [ed.] (2010): Beruf und Qualifikation in der Zukunft, BIBB-IAB-Modellrechnungen zu den Entwicklungen in den Berufsfeldern und Qualifikationen bis 2025, publication series from the Federal Institute for Vocational Education and Training, Bonn.

Helmrich, Robert; Zika, Gerd; Wolter, Marc Ingo; Schandock, Manuel; Maier, Tobias; Kalinowski, Michael; Hummel, Markus; Hänisch, Carsten; Drosdowski, Thomas; Bremser, Felix; Bott, Peter (2012): Shortages on the labour market: Changes in education and employment behaviour will mitigate shortages of skilled workers. BIBB-Report 18/12, Bonn.

Hummel, Markus; Thein, Angela; Zika, Gerd (2010): Der Arbeitskräftebedarf nach Wirtschaftszweigen, Berufen und Qualifikationen bis 2025, IAB model calculations. In: R. Helmrich & G. Zika (ed.), Beruf und Qualifikation in der Zukunft. BIBB-IAB-Modellrechnungen zu den Entwicklungen in den Berufsfeldern und Qualifikationen bis 2025, (reports on vocational training), Bielefeld. Bertelsmann, pages 81–102.

Kalinowski, Michael; Quinke, Hermann (2010): Projektion des Arbeitskräfteangebots bis 2025 nach Qualifikationsstufen und Berufsfeldern. In: Helmrich, R.; Zika, G. (2010): Beruf und Qualifikation in der Zukunft, Bonn.

Klinger, Sabine; Weber, Enzo (2015): GDP-Employment decoupling and the productivity puzzle in Germany. University of Regensburg working papers in business, economics and management information systems, 485.

Maier, Tobias; Zika, Gerd; Wolter, Marc Ingo; Kalinowski, Michael; Helmrich, Robert (2014a): Shortages in the medium qualifications area despite increased immigration. Latest results from BIBB and Institute for Employment Research (IAB) qualifications and occupational field projections up until the year 2030 taking wage developments and occupational flexibility into account. In: BIBB-Report 23/14, Bonn.

Maier, Tobias; Zika, Gerd; Mönnig, Anke; Wolter, Marc Ingo; Kalinowski, Michael; Hänisch, Carsten, Helmrich, Robert; Schandock, Manuel; Neuber-Pohl, Caroline; Bott, Peter; Hummel, Markus (2014b): Wages and occupational flexibilities as determinants of the interactive QuBe labour market model. A methodological report on the basic projection of the 3 wave of the BIBB-IAB qualifications and occupational field projections. Wissenschaftliche Diskussionspapiere BIBB issue 149.

Mantau, Udo; Döring, Przemko; Hiller, Dirk (2013): Holzeinsatz im Bauwesen – Verwendungsstrukturen nach Gebäuden und Gewerken. In: Weimar, H. & Jochem, D. (ed.): Holzverwendung im Bauwesen – Eine Marktstudie im Rahmen der „Charta für Holz". Thünen Report 9.

PWC (2014): Industrie 4.0 – Chancen und Herausforderungen der vierten industriellen Revolution. Study. October 2014.

Reflex Verlag (2015): Industrie 4.0 Die vierte industrielle Revolution. Insert in the Handelsblatt March 2015.

Schnur, Peter ; Zika, Gerd (ed.) (2009): The IAB/INFORGE model. Ein sektorales makroökonometrisches Projektions- und Simulationsmodell zur Vorausschätzung des längerfristigen Arbeitskräftebedarfs. IAB library 318, Nuremberg.

Spath, Dieter (ed.); Ganschar, Oliver; Gerlach, Stefan; Hämmerle, Moritz; Krause, Tobias; Schlund, Sebastian (2013): Produktionsarbeit der Zukunft – Industrie 4.0. Fraunhofer Institute for Industrial Engineering (IAO).

Tiemann, Michael; Schade, Hans-Joachim; Helmrich, Robert; Hall, Anja; Braun, Uta; Bott, Peter (2008): Berufsfeld-Definitionen des BIBB auf Basis der KldB1992. Federal Institute for Vocational Education and Training.

TÜVRheinland (2013): Szenarien und Kosten für eine kosteneffiziente flächendeckende Versorgung der bislang noch nicht mit mindestens 50 Mbit/s versorgten Regionen. Study on behalf of the Federal Ministry of Economics and Technology. Abstract.

VDE (2013) VDE study: Industrie 4.0 lässt vorerst auf sich warten. Asscociation for Electrical, Electronic and Information Technologies. Press release 32/2013 dated April 8, 2013.

www.plattform-i40.de.

Zika, Gerd; Helmrich, Robert; Kalinowski, Michael; Wolter, Marc Ingo; Hummel, Markus; Maier, Tobias; Hänisch, Carsten; Drosdowski, Thomas (2012): In der Arbeitszeit steckt noch eine Menge Potenzial. Qualifikations- und Berufsfeldprojektionen bis 2030. In: IAB Kurzbericht 18/2012, pages 1–12.

Zika, Gerd; Maier, Tobias (ed.) (2015): Qualifikation und Beruf in Deutschlands Regionen bis 2030. Konzepte, Methoden und Ergebnisse der BIBB-IAB-Projektionen. IAB library 353, Institute for Employment Research (IAB), Nuremberg.

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