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Results from the project work of IAB

Economy 4.0 and its labour market and economic impacts

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

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Zusammenfassung

Mit diesem Forschungsbericht liegt die erste modellbasierte Wirkungsabschätzung einer Wirtschaft 4.0 auf Arbeitsmarkt und Wirtschaft in Deutschland vor. D.h. es werden nicht nur Auswirkungen der Digitalisierung in der Industrie sondern in der Gesamtwirtschaft betrachtet. 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 die daraus folgenden Kosten- und Gewinnstrukturen der Unternehmen (3) und eine veränderte Nachfragestruktur nach Berufen und Qualifikationen (4). Darüber hinaus werden in einem weiteren Teil-Szenario Arbeitsmarkteffekte einer möglicherweise steigenden Nachfrage nach Gütern (5) in den Blick genommen. Die kumulativen Effekte der fünf Teil-Szenarien werden mit einem Referenz-Szenario, das keinen fortgeschrittenen Entwicklungspfad zu Wirtschaft 4.0 enthält, verglichen.

Im Ergebnis zeigt sich, dass eine Wirtschaft 4.0 den Strukturwandel hin zu mehr Dienstleistungen beschleunigen wird. Dabei sind Veränderungen im Charakter der Arbeitswelt zwischen Branchen, Berufen und Anforderungsniveaus 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 sich bei einer verzögerten oder gar verschleppten Umsetzung die Annahmen gegen den Wirtschaftsstandort Deutschlands wenden: Wir werden weniger exportieren und mehr „neue“ Güter im Ausland nachfragen.

Um die Wirkungen der Digitalisierung auf die künftige Berufsstruktur näher zu beleuchten, aber auch um die Erkenntnisse über die ökonomische Zusammenhänge weiter zu verbessern, ist eine Fortentwicklung des QuBe-W4.0-Projekts geplant.

Abstract

This study focuses on the economic effects of the phenomenon of "Economy 4.0", the digitalisation of the economy as a whole and not only in industrial production processes. These developments involve considerable challenges at enterprise and political level. The five-step scenario analysis begins with the impacts of increased investments of enterprises in equipment (1) and of the state in the network infrastructure (2) on the overall economy and the labour market. On this basis we further model the consequent personnel and material costs of the enterprises (3) and a changed pattern of demand for occupations and skills (4). In a further scenario the effects on the labour market of a potentially increasing demand for goods (5) are taken into consideration. The cumulative effects of these five partial scenarios are compared with a baseline scenario which contains no advanced development path to Economy 4.0.

The results show that Economy 4.0 will accelerate the structural change towards more services. In this process labour force movements between branches, occupations and job requirements are much larger than the change of the number of gainfully employed persons in total. The turnover on the labour market are accompanied by an increasing value added which is leading not only to more economic assets but also – due to higher requirements for the labour force – to higher aggregate wages.

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

In order to analyse the effects of digitization on the future occupational structure, but also to improve the knowledge about the economic interdependencies, further advances of the QuBe-E4.0 project are planned.

Acknowledgement: We would like to thank Britta Matthes along with numerous audiences at presentations of the previous study, Wolter et al. (2015) for their comments.

1 Economy 4.0 will bring a variety of changes

Progressive digitisation of the production and working environment is under heavy, contentious discussion. The use of new technologies which allow an interactive network of product, machine and manpower, but also for horizontal (between the company, supplier and the customer) and vertical integration (between the units within the company) (cf. PWC 2014; Wolter et al. 2015), is seen as an opportunity for Germany's industrial sector to exploit and expand competitive advantages (e.g. BITKOM 2014; PWC 2014; DBR 2014). The service industry also continues to develop new concepts for using new digital technologies. To distinguish it from the frequently used term "Industry 4.0", "Economy 4.0" therefore describes the fact that digitisation will not only result in a change in industrial production, but also in all service industries and therefore affect all areas of life[1].

In addition to the opportunities which arise, however, it also addresses the risks and social challenges of such Economy 4.0 (cf. e.g. BMAS 2015). Technical advances bring new opportunities to automate operations with machine programs, which is often associated with a general loss of employment. However, not much research has been done on just how significant this could be in the future. A lot of studies were done based on Frey and Osborne (2013) to examine the potential of replacing people with machine processes (e.g. Brzeski and Burk 2015, Bonin et al. 2015, Dengler and Matthes 2015, Tiemann 2016a, Pfeiffer and Suphan 2015). However, all authors point out the calculated risk cannot provide any information about the extent to which companies will actually exploit these potentials. Estimating the effects on the labour market most notably not only require taking into account the actual replicability, but also a number of complex and ambivalent effects (Weber 2016): Jobs will be lost, new ones will be created, requirements change, production becomes more efficient, new products will be developed, income is generated and enters the national economic cycle, labour supply and demand, as well as wages and prices will adapt.

Wolter et al. (2015) were the first to use a 5-step scenario analysis to examine the effects a transformation to Industry 4.0 will have on the manufacturing industry and agriculture. Their results indicate that with respect to the labour market structure, the changes in the working environment could be much more significant than the net effects on employment. It shows that Industry 4.0 will potentially accelerate the structural change toward a service society. This structural change can already be seen in past developments. The proportion of the labour force in agriculture and manufacturing industry is declining steadily, and growing in the service industry.

Based on the concept of Wolter et al. (2015), this article examines which changes can be expected when examining more than the industry and instead examining the national economy. Thus the question is, whether the innovations expected in line with

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[1] The publicly discussed consequences of "digitising work" as well as the green paper "Work 4.0" (BMAS 2015) refer to Economy 4.0 to that effect.

Economy 4.0 will accelerate the structural change the same way as digitising the manufacturing industry and whether it will have a significant impact on the working landscape with respect to the occupational and qualification structure. It further addresses the question of which impacts transitioning to Economy 4.0 will have on the economic development and the size of labour force as a whole. Based on new knowledge from company surveys, assumptions made in Wolter et al. (2015) are further corrected in this scenario where an empirical approach has provided more insightful findings.

We identify influential variables (parameters) which will change in line with transitioning to Economy 4.0. A scenario analysis based on the methods and results of the fourth wave of the QuBe project (Maier et al. 2016; www.qube-projekt.de) investigates how a change in influential variables will affect educational standards, professions, industries and the macroeconomic development. Wolter et al. 2015 still compared the results of the Industry 4.0 scenario with the baseline projections from the third projection wave (Maier et al. 2014a). We arrive at the overall scenario step by step, using the following five partial scenarios:

(1) Increase in equipment investments
(2) Increase in building investments
(3) Change in cost and profit structures
(4) Change in the occupational field structure
(5) Increased demand for new goods and services

The progressive structure of the scenarios gives the paper a chronologic sequence of investments and the results. The results of the individual scenarios are therefore always compared to the results from the previous partial scenario. The impacts of the cumulative effects from the partial scenarios 1 to 4 or 1 to 5 are further reflected in the reference scenario from the 4th wave of the QuBe project (Maier et al. 2016). This has the advantage that instead of considering the labour force demand by levels of qualification, we can now examine which changes in requirements in the workplace Economy 4.0 will be aimed at the labour force.

When including all assumptions in the examination, the digitised working environment in 2025 (partial scenario 5) will be compared with a world where technical advances by 2025 will be based on the previous trajectory of development (QuBe baseline projection). This comparison shows the impacts digitisation will have on the overall level in labour demand of 30k jobs is rather low. However, these two working environments will clearly differ in the structure of the industry, occupation and requirements. In the digitised world, on one hand 1.5 million jobs, which according to the baseline projection will still exist, will be eliminated in 2025. On the other hand, in the Economy 4.0 scenario there will also be 1.5 million new jobs which will not exist in the baseline projection. In summary, the character of the working landscape in the digitised scenario differs from the QuBe baseline projection by about 7 percent (= 3 million of 43.4 million jobs).

Results from the scenario analyses will essentially depend on the assumptions made. These should therefore preferably be supported by an empirically founded data situation. We were able to confirm or adjust part of the assumptions already made in the Industry 4.0 scenario based on company surveys. However, additional information or a more detailed model will also be required in the future. The project partners will therefore also continue to adapt the study presented here. Another scientific analysis examining the impacts of the chosen level of replicability will be released in the near future. In addition to the concept of Dengler and Matthes (2015) used here, it will also compute scenarios using the routine index of Tiemann (2016a), the labour capacity index of Pfeiffer and Suphan (2015), as well as a replicability index based on the BIBB qualification panel (QPE) (Helmrich et al. 2016).

2 Methods, influencing factors and assumptions

2.1 Methods: Scenario technique and the use of models

The scenario technique is used to show the consequences of transitioning to Economy 4.0. This computes at least two scenarios which are compared absolute or relative e.g. for a selected point in the future. This requires a reference scenario which describes a currently plausible and consistent future development, and an alternate scenario which documents a different development. Whilst both scenarios describe potential future working environments, they do differ with respect to their assumptions for exogenous factors (e.g. demographic development) and/or endogenic patterns (e.g. production methods). This requires a model which can compute both the reference and the alternate scenario.

The baseline projection from the BIBB-IAB Qualification and Occupational Field Projections (QuBe Baseline Projection) published in line with the 4th wave of the QuBe projections (Maier et al. 2016, method box 1) is used as the reference scenario. The development described in it of course already includes technological progress, but this rate of progress is based on the typical development shown in the empirics. Germany taking on a worldwide leading role in the transition to Economy 4.0, as this paper assumes, further requires additional efforts or investments, which are represented in a comprehensive scenario specification.

The Q-INFORGE model used to create the QuBe baseline projection is also used to compute the Economy 4.0 scenario. The Q-INFORGE model is based on the IAB/INFORGE model (Schnur and Zika 2009; Distelkamp et al. 2003; method box 3), where the labour market was clearly expanded in line with the QuBe project (method box 1). The goal of the QuBe project is to regularly make projections for qualifications and professions whilst advancing methods and analyses (Helmrich and Zika (ed.) 2010; Zika and Maier (ed.) 2015). The 4th projection wave (Maier et al. 2016) was the first to allow refer to the 2010 classifications professions. This on one hand resulted in reducing the previous 54 BIBB occupational fields to 50 (Tiemann 2016b; method box 2). On the other hand this now presents the opportunity to differentiate by four different requirement levels (support jobs, technical jobs, complex specialists and highly complex jobs) on the demand end. This allows for a more precise representation of the level of complexity required of the labour force than by updating demand by formal qualifications.[2]

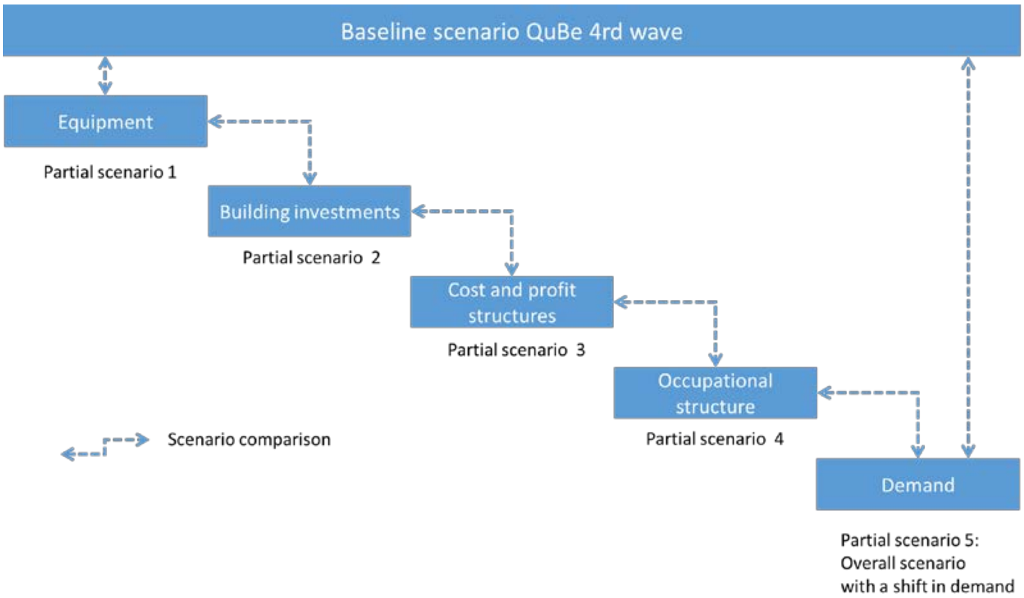
Detailed modelling of the industries with cost structures based on the input-output calculation of the Federal Statistical Office and the detailed description of the 50 occupational fields by 63 economic sectors and 4 requirement levels based on microcensus data is particularly valuable for the following scenario analysis, as it allows for illustrating the changes in the production method within the industries as well as the occupational and demand structure by industry.

Operationalisation of the Economy 4.0 scenario is based on assumptions and quantitative recruitment with respect to the required investments in both final demand components, as well as the cost structure of individual industries and the type and scope of the labour market. The complexity of this scenario therefore requires a number of actions, the overall macroeconomic effects are difficult to quantify through "contemplation" without any background in the model theory. Once the "parameters" has been set, the complex modelling approach of the QuBe project simultaneously allows a dynamic assessment of the affects on the national economy and the labour market.

Based on the high complexity of an Economy 4.0 scenario we compute five partial scenarios which build on one another. Each is compared with the previous partial scenario (Figure 1). The partial scenarios describe the changes in equipment investments and building investments, the resulting material, storage and personnel costs, adjustments in the structure of the occupational field, and lastly the effects on the remaining demand components. In addition to material and storage costs, adjustments to the cost and occupational field structure also include labour costs as well as changes in the structures of the occupational field within the investing industries. The overall scenario including changes in demand is only compared with the QuBe baseline projection.

[2] Professional qualifications are personal. Whether a person has vocational or academic training does not indicate the type of work they actually perform.

Figure 1
Sequence of partial scenarios



Source: own diagram

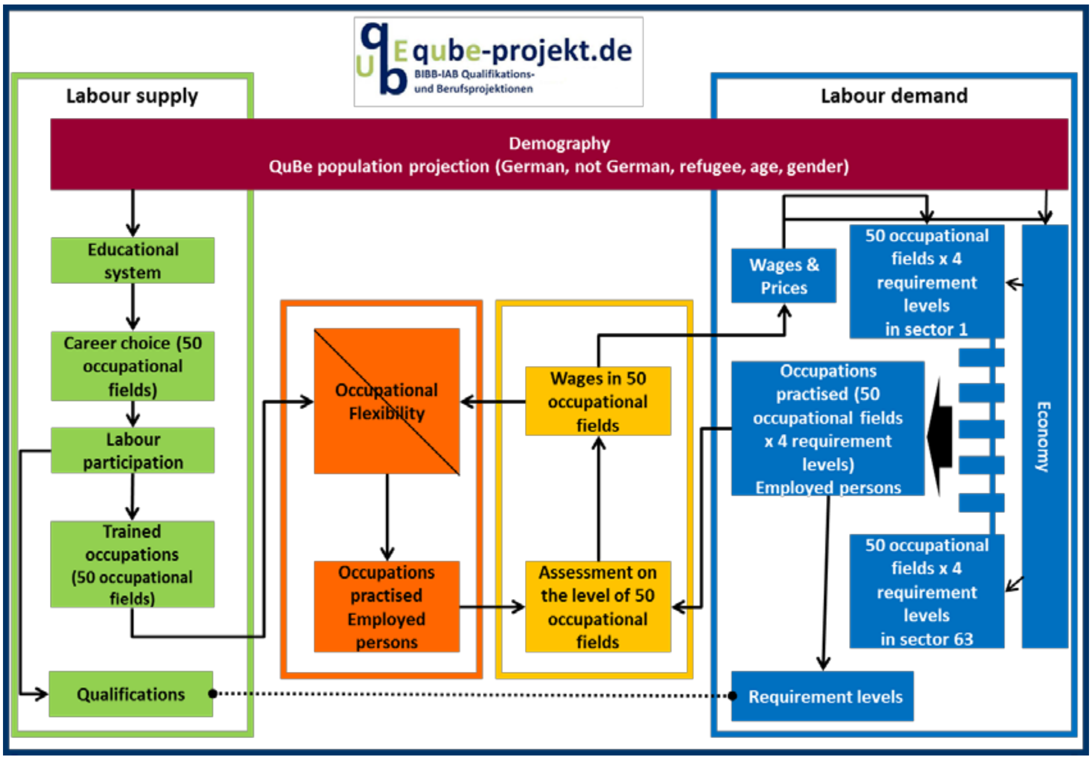
Method box 1: The QuBe project

Using model calculations, the BIBB-IAB Qualification and Occupational Field Projections (QuBe Project) resulting from cooperation with The Institute of Economic Structures Research (GWS) and the Fraunhofer Institute for Applied Information Technology (FIT) show how supply and demand for qualifications and professions may develop in the long term. Here the data basis is the microcensus (in this projection to 2013): an official sample statistic of the Federal Statistical Office on population and the labour market, covering one percent of all households in Germany each year, aligned with benchmark figures from the national accounts (in this projection to 2014). Wage information originates from the employment history of workers subject to social insurance contribution (in this projection to 2013). BIBB created a uniform classification of occupational fields for differentiating between occupations which groups professions at the three-digit level of the classification of professions by activities (Tiemann et al. 2016b and method box 2). To simplify the account, these 50 occupational fields are aggregated into 20 primary occupational fields.

The results here are based on the baseline projection from the fourth projection wave. This builds on the methods from the first (Helmrich and Zika 2010b, Maier et al. 2014b), second (Helmrich et al. 2012, Zika et al. 2012) and third wave (Maier et al. 2014b) and further includes other updates. On the demand end the job-specific labour supply in heads and hours is also included in the wage determination for the occupational fields. This estimates the development in each economic sector by 50 occupational fields using 4 requirement levels each. The supply end models wage dependencies of the occupational flexibilities which allow the labour supply to respond to the changed wages in the occupational fields. The labour market can therefore be accounted both from a technical point of view by comparing employed persons and labour force by occupational fields as well as from a qualifications perspective by comparing the formal level of qualifications of the employed person with the labour force's level of educational requirement.

The QuBe project follows an empiricism based concept in the baseline projection: It only projects patterns verifiable thus far for the future. Any changes in patterns which have not been detected in the past are therefore not part of the baseline projection. This also applies to the modelled market adjustment mechanisms. Figure 2 provides a rough outline how the model works.

Figure 2
Model structure of BIBB/IAB Qualification and Occupational Field Projections



Source: own diagram
For more information visit www.QuBe project.de.

Method box 2: The updated BIBB occupational fields

The classification criteria of the focus of activity and the focus of the industry, along with their significance, remained intact in the updated BIBB occupational fields (first the activity, then the industry) (for the first edition cf. Tiemann et al. 2008). The focuses of activity and industry for the professions in the classification of professions (KldB) 2010 were determined using the microcensus (special analysis of sub-samples from 2011 and 2012) and the BIBB/BAuA Labour Force Survey 2012 (Hall/Siefer/Tiemann 2014).

Table 1
Definition of occupational fields and primary occupational fields

MOF	Main occupational field (MOF)	OF	Occupational field (OF)
1	Raw material processing occupation	1	Agriculture, husbandry, forestry, horticulture
		2	Miners and mineral extraction workers
2	Non-skilled workers, janitors	16	Auxiliary workers without further specified task
		38	Janitors
3	Metal production and processing, installation,	7	Metal, plant and sheet metal construction, installation, fitters
		11	Electrical occupations
4	Construction, woodworking, plastic manufacture and processing occupation	15	Construction, woodworking, plastics manufacture and processing occupations
5	Other processing, producing and maintaining occupation	3	Stoneworking, construction materials production, ceramics and glass
		9	Vehicle and aircraft construction, maintenance occupations
		10	Precision engineering and related occupations
6	Machinery and equipment steering and maintainance occupation	4	Chemical and plastics occupations
		5	Paper manufacture, paper processing, printing
		6	Metal production and processing
		8	Industrial mechanics, tool mechanics
		12	Textile occupations
7	Commodity trade in retail	23	Commodity trade in retail
8	Commodity trade merchandise	24	Wholesale/retail service occupations
		26	Other commercial occupations (not including wholesale, retail,
9	Transport, warehouse operatives, packers	28	Transport and logistics occupations
		29	Aviation, shipping occupations
		30	Packers, warehouse and transport occupations
10	Personal protection, guards and secutrity occupation	37	Personal protection, guards
		39	Security occupations
11	Hotel, restaurant occupation, housekeeping	13	Cooks
		14	Production of beverages, food and tobacco, other nutrition occupations
		49	Hotel and restaurant occupations, housekeeping
12	Cleaning, disposal occupation	50	Cleaning and disposal occupations
13	Office and commercial services occupation	25	Banking and insurance professionals
		32	Public administration occupations
		33	Finance, accounting, bookkeeping
		35	Commercial office occupations
		36	Auxiliary office occupations, telephone operators
14	IT and natural science	17	Engineers
		18	Chemists, physicists, scientists
		34	Core IT occupations
15	Technical occupation	19	Technicians
		20	Technical draughtsmen/ draughtswomen, related occupations
		21	Surveying and mapping
		22	Specialist skilled technicians
16	Legal, management and business science	31	Managing directors, auditors, management consultants
		40	Legal occupations
17	Media, arts and social science	27	Advertising specialists
		41	Artists, musicians
		42	Designers, photographers, advertising creators
		47	Journalists, librarians, translators, related academic research occupations
18	Health occupation	43	Healthcare occupations requiring a medical practice licence
		44	Healthcare occupations not requiring a medical practice licence
		48	Body care occupations
19	Social occupation	45	Social occupations
20	Teaching occupation	46	Teaching occupations

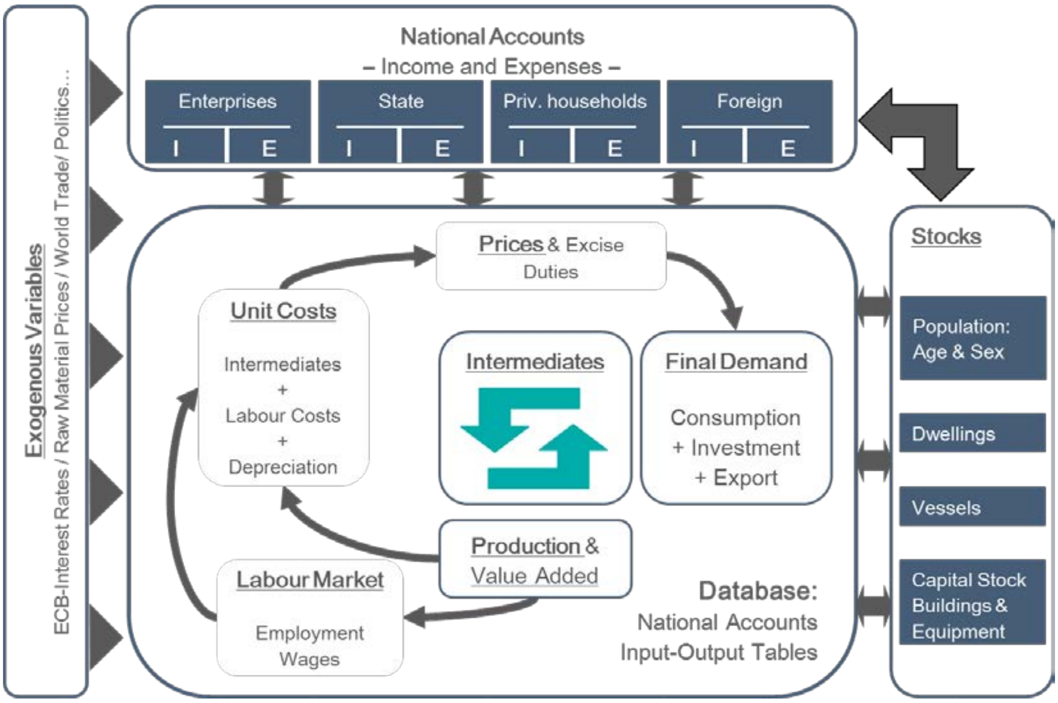
Source: own diagram.

In this case, "professions" refers to the three-digit level of the KldB 2010 ("Occupational Groups") along with information on the level of educational requirement, which is defined by the fifth digit of the KldB 2010 classification positions. This combination must be used, as the level of qualification in previous classifications on which the occupational fields are based was an implicit structuring characteristic. "Cutting out" the fourth digit yields 432 positions (or "professions") which are classified by occupational field. Information from persons switching from KldB 92 to KldB 2010 per statistics of the Federal Employment Office, a matrix of gainful occupations according to KldB 92 and the KldB 2010 from the Labour Force Survey (where both classifications were coded separately and did not have persons switching) was added to the analysis of the emphases of activity when assigning occupational fields. The structure of the occupational fields was also adjusted slightly: former occupational field 19 "Goods inspectors, Shipping Clerks" was replaced with occupational field 34 "Packer, Warehouse-, Transport Clerks"; occupational field 12 "Textile Occupations" were merged with occupational field 13 "Textile Processing, Leather Production". Likewise, the former occupational fields 14 "Bakery, pastry, confectionery production", 15 "Butchers" and 17 "Beverage-, semi-luxury food, other food occupations" are now one occupational field. This leaves 50 occupational fields. These can be condensed into primary occupational fields as before. Table 1 shows the definition of the updated (primary) occupational fields. The occupational fields were renumbered from 1 to 50 for use in the QuBe projections.

Method box 3: The IAB/INFORGE model

The IAB/INFORGE model is an econometric forecasting and simulation model for Germany which is deeply disaggregated by production areas and categories of goods, developed by The Institute of Economic Structures Research (GWS) and continuously used and updated since 1996 (Schnur and Zika 2009). The model is based on the design principles "bottom-up" and "complete integration". "Bottom-up" means the individual sectors within the national economy are modelled in great detail and the macroeconomic variables are generated through aggregation in a model context. This not only yields complete representation of the individual sectors in a macroeconomic context and in intersectoral relation, but also explains macroeconomic relationships which the national economy considers to be the total for the industries. "Complete integration" refers to a model structure which includes a representation of interindustrial relation and an explanation on the use of income of private households from income generated within the individual sectors (Figure 3). Export demand is determined by Germany's export relation with the rest of the world. The forecast import demand for 60 countries and regions determine Germany's goods-specific exports through bilateral trade matrixes.

Figure 3
IAB/INFORGE at a glance



Source: own diagram

Although the IAB/INFORGE model does show a very high level of endogenisation, it cannot forego exogenous default: In addition to instrument variables in fiscal policy such as tax rates, this includes the central bank interest rates of the European Central Bank, the exchange rate, and price trends for raw materials. The development in other countries is an exogeneous factor in determining German exports, just as the demographic development and its age structure are for the labour supply.

2.2 Possible parameters and assumptions

Among the influencing factors and correlations discussed above, the following also describes the parameters in the Q-INFORGE model of the QuBe project for implementing Economy 4.0 in Germany. The parameters discussed below refer to the national accounts (VGR) of Federal Statistical Office behind the model.

Actions are discussed along the input-output table in Figure 4. The respective actions on the input-output table are explained below and can be located using the respective numbering in the input-output table. The input-output table serves as a guide grid, as it is the only thing which provides an industry-specific picture of demand, input relations and production and the structural consequences of Economy 4.0 can only be explicitly addressed and classified in a macroeconomic context here.

Introducing Economy 4.0 into the national economy affects the areas which are marked. On the one hand this affects building investments ❶. Among other things, this includes civil engineering, which involves expanding the wiring system ("high-speed internet"). Equipment investments ❷ not only provide information about machinery purchased in industrial machine construction, but also the IT and information services required. Both factors will change in the context of introducing Economy 4.0. Stock changes ❸ represent another part of gross fixed capital formations: They provide information on the change in the stock: negative values represent a stock reduction. A change in stock in the course of using new technologies is conceivable.

Whilst items ❶ to ❸ primarily describe the required investments, the following items address a change in the demand for goods. This can be triggered by a change in pricing: Products may become less expensive. Furthermore, new products or a change in qualities may generate additional demand. After all there is "related" demand, which for example shows in increased demand for continuing education.

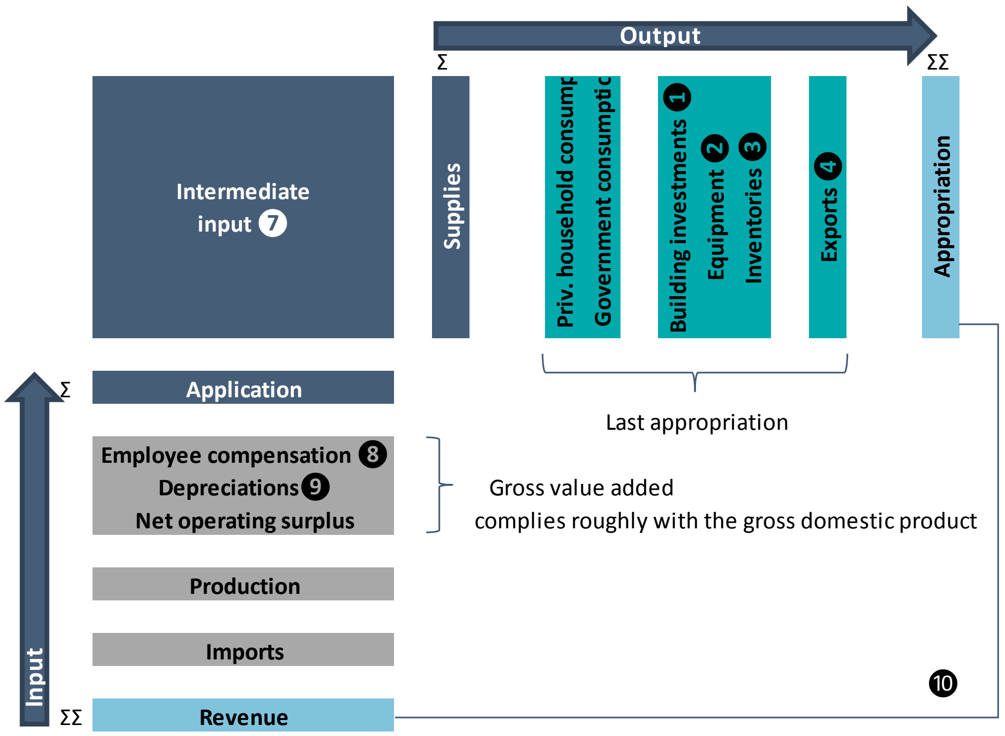
Germany's exports ❹ are, simply put, affected by developments in the import demand of other countries and by how competitive prices of German products are. Add to this long-term relationships between supplier and recipient along with German products being of different quality. The latter also becomes evident in the goods structure of German exports, which concentrate on chemistry, machine construction and automotive manufacturing. This type of concentration can not only be attributed to a competitive edge in pricing.

Exports may see direct and indirect effects in line with switching to Economy 4.0. On one hand, demand may change due to new product qualities, on the other hand the production process will change so that export prices will also be subject to change.

Similar considerations apply to the demand of private households ❺: New demand may arise and consequences may arise based on new price developments. Add to this that the higher quality of products or customising goods and services may also result in the consumers' willingness to pay more, i.e. private households would be willing to pay a higher price for the same service. Private households may pay for continuing education they seek in order to keep up with technology. Government spending ❻ includes the cost of education, among other things. This also includes activities of the Federal Employment Agency booked to the government as part of national insurance in line with national accounts. Again, an increase in training programmes is conceivable.

The input relations ❼ between the branches of production provides information on deliveries ("Which goods are delivered to which branch of production?") (row) and the cost structure (column). The latter shows how much of which goods and services is required for production. Economy 4.0 will permanently change these supply structures. So it can be assumed that to some extent, less (raw materials, semi-finished goods) and/or different (electronic products) goods will be required. AT the same time, a higher demand for services may arise (ICT). Since by definition, production minus input equals added value, changes in the cost structure will directly affect these. From a company's microeconomic perspective, less material expenses, which includes purchased services, at unchanged sales yields higher gross profit.

Figure 4
Diagram of the input-output table



Source: own diagram.

To simplify matters, added value itself is split into employee wages ❽ (personnel costs), depreciation ❾ and net operating surplus (similar to profit). Employee wages are affected by several influencing factors. If production decreases, less workers will be required for unchanged production methods. This type of situation may arise if there is less demand for a company's goods based on the changed cost structures in other branches of production. However, labour productivity may also change; unchanged production may require less workers than before in connection with Economy 4.0.

Depreciation ❾ is directly affected by investments ❶&❷: E.g. expenses for new machinery is spread across the usual life and recorded on the cost side in form of depreciation. At the same time, technological advances may result in machinery no longer being used because using them for production is no longer profitable or there is no demand for the goods produced with that machine. Both cases may result in extraordinary depreciation resulting from a shorter life.

The other factors not addressed are typically indirectly affected at any rate. This applies to e.g. imports. Production is the result of supply (pricing) and demand (❶ to

❻). Pricing may be the result of calculating the cost per unit, derived from the ratio of input plus wages and depreciation relative to production adjusted for cost.

Based on the abundance of influencing factors that Economy 4.0 has on the economic process, the prior does not allow information on the overall result, so the change in the gross domestic product and the size and structure of the labour force. All consequences Economy 4.0 addressed ultimately affect the entire use or the total volume. After all, due to the double-entry accounting behind the input-output table, the volume and use must be equal for each commodity produced ❿. As a result, both changes in demand as well as supply will yield a new result.

The presentation selected is a simplification. The actions discussed will change the earned income and profit income. This will have consequences on the budget of the government (direct and indirect taxes) and of private households (disposable income). At the same time the labour market will change. The number and wages of workers are subject to change which will have consequences on unemployment and the financial strengths of national insurances. Even if these and other context are not represented, they are in fact shown in the Q-INFORGE model used (Maier et al. 2014b).

2.3 Assumptions – general estimates

As in all prior publications on Industry or Economy 4.0, the scenario presented here also assumes that Economy 4.0 will not be implemented ad-hoc but that the transition will instead be a long process which will take 2025[3]. Economy 4.0 is considered fully implemented from that point on and will continue until the end of the projection horizon, 2035.

Literature frequently mentions creating new business models, products and services for consumer demand under opportunities and potentials of Economy 4.0. The opportunities arising from digitisation are undisputed. However, whether demand will also be created for the new business models and, if so, to which extent, is uncertain. In this scenario, the effect on the demand end based on new offerings (so not based a change in demand based on pricing), which is frequently described rather ambiguously in the above studies, is realised through assumed developments in the last partial scenario.

One consequence of cost reduction resulting from digitisation is a relative price advantage for products made in Germany. This can infer a repatriation of production processes being moved abroad, which would convey a reduction in input imports. In this scenario, however, we assume production facilities will be brought back to Germany, as the previously mentioned background discussions showed no evidence of this type of development.

[3] Later implementation times are also specified.

Furthermore, the scenario assumes that Germany will start introducing and implementing digitisation quite early compared to all other countries. This is the only option for generating "temporary monopoly profits" over foreign competitors. We can generally assume, as documented in international studies (Berger 2014), that Germany is not the only country pursuing a fourth industrial revolution. Efforts for realising the productivity potentials of digitisation can also be seen in the USA or China. One possible result of quicker implementation of Economy 4.0 abroad could be that Germany's import structure would need to change. So this assumption could result in overestimating the actual consequences.

3 Scenario calculations and results

Based on the contexts illustrated, the following uses a series of assumptions in the QuBe model (Q-INFORGE; Maier et al. 2016). To maintain clarity, Table 2 lists the assumptions and assigned the individual partial scenarios (TSZ) and overall scenarios described and the results of which are addressed below. The assumptions are detailed under the respective partial scenarios. Here the respective assumptions refer to the respective number in Table 2.

Table 2
List of assumptions

Assumptions		Partial scenarios
Equipment investments		PSC 1
1	Additional investments	
2	Conversion of capital stock sensor technology	
3	Conversion of capital stock IT services	
Building investments		PSC2
4	Capital expenditure “high-speed Internet”	
5	Distribution on industries	
6	Balanced Government budget	
Cost and profit structures		PSC3
7	Continuing education	
8	Consulting services	
9	Digitisation	
10	Decrease in raw materials, consumables and supplies as well as purchased services	
11	Decrease in the cost of logistics	
12	Increasing labour productivity	
Change in the structures of occupational fields and requirements		PSC4
13	Adjustment in occupational structure with industrial sectors considering routine	
14	Adjustment in labour productivity	
Increases in demand		PSC5
15	Higher government spending on security	
16	Additional demand from private households	
17	Higher willingness to pay	
18	Increases in export	
Comparison with the baseline scenario (baseline projection) QuBe project		

Source: own diagram.

3.1 Equipment investments (partial scenario 1)

The additional investments in equipment required for transitioning to Economy 4.0 and over how long is crucial with respect to economic development. There is no conclusive answer to this, as newly purchased equipment goods may already have the features but were eventually replaced with new equipment during general replacement processes. We can therefore only attempt to make assumptions about additional investments through plausibility considerations.

(Assumptions ❶ and ❷) The manufacturing industry will convert or upgrade part of the current equipment goods by replacing control units and procuring the IT services this requires.

As measured by the capital stock for equipment, the share of equipment investments is about 10 percent. Meaning, capital stock is normally replaced every ten years. We are assuming that of the last ten investment years, only the later five will be equipped with Economy 4.0-compatible control instruments. For older systems this would not pay off, as these would be scheduled to be replaced within the next five years. We furthermore assume that not only will control instruments be required, but also IT services to integrate the respective machinery in the new production process.

According to the 2012 input-output table[4], of the 276 billion Euro of equipment investments, a total of 21 billion Euro bill be spent on DP equipment, electronic and optical equipment; about a third of this (7 billion Euro) will be "measuring, control, etc. instruments and equipment, electromedical equipment, and data storage devices". Another 21.7 billion Euro will be used for "IT and information services". The two combined make up a share of about 10 percent of the total equipment investments.

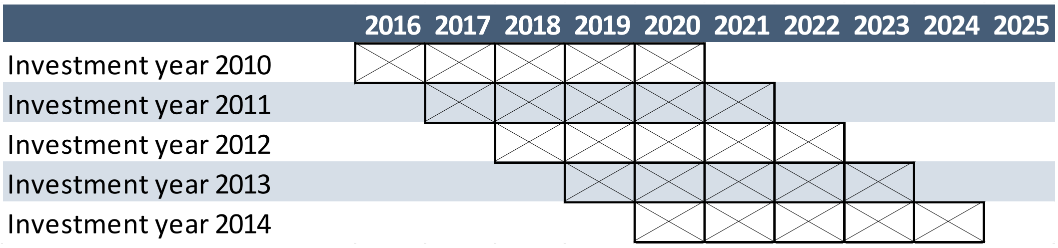
The production statistics provide no data on how much of the 7 billion Euro mentioned is for measuring and control instruments. We assume this share to be 25 percent. The same number is assumed for IT services (21.7 billion Euro total). So for a "normal" investment year of 276 billion, about 72 billion Euro or 2.6 percent will be spent on the required sensor technology and IT services.

It is further implied only 50 percent of eligible machinery will actually be converted. Therefore an additional approx. 3.6 billion Euro would need to be invested annually. It is further assumed that machinery which is now five years old will be converted within the next five years. This also applies to the next four years, but each moved back by one year. This stretches the approx. 18 billion Euro investments adjusted for price required for conversion, which will start in 2016, over nine years. The conversion

4 Input-output table for 2010 prior to audit of the national accounts. The model has since been updated to include input-output tables after the audit. Since the new tables no longer list the economic sector "measuring, control, etc. instruments and equipment, electromedical equipment, and data storage devices" separately, the table from before the audit is still used for the assumption.-

costs apply to 2017 to 2024 (Figure 5). So there are only eight years left. So by 2024 an additional 16 billion Euro will be invested.

Figure 5
Vintages of conversion investments



Source: own diagram.

(Assumption 3) In addition to the investments required to upgrade existing equipment goods, current investments in new equipment and other new systems of approx. 300 billion Euro adjusted for price total per year are increased by an additional 0.5 percent for the conversion to Economy 4.0. The investments are added to agriculture and manufacturing industries (cf. Wolter et al. 2015). In the reference test investments increase from 2017 to 2025, adding 13.5 billion Euro adjusted for price over the subsequent 9 years, an average of 1.5 billion Euro per year.

Over the entire projection period (2017–2035) this corresponds to 30 billion Euro in additional investments. The investing economic sectors (simplified: industries) are found in the manufacturing industry and agriculture. In allocating investments in the industries to investment goods it is assumed this will only apply to the categories of goods (GG) which actually guarantee compatibility with Economy 4.0. In detail the categories of goods are:

(1) GG 27 - Electrical equipment
(2) GG 28 - Machinery
(3) GG 33 - Repairs, maintenance and installation of machinery and equipment
(4) GG 62-63 - IT and information services

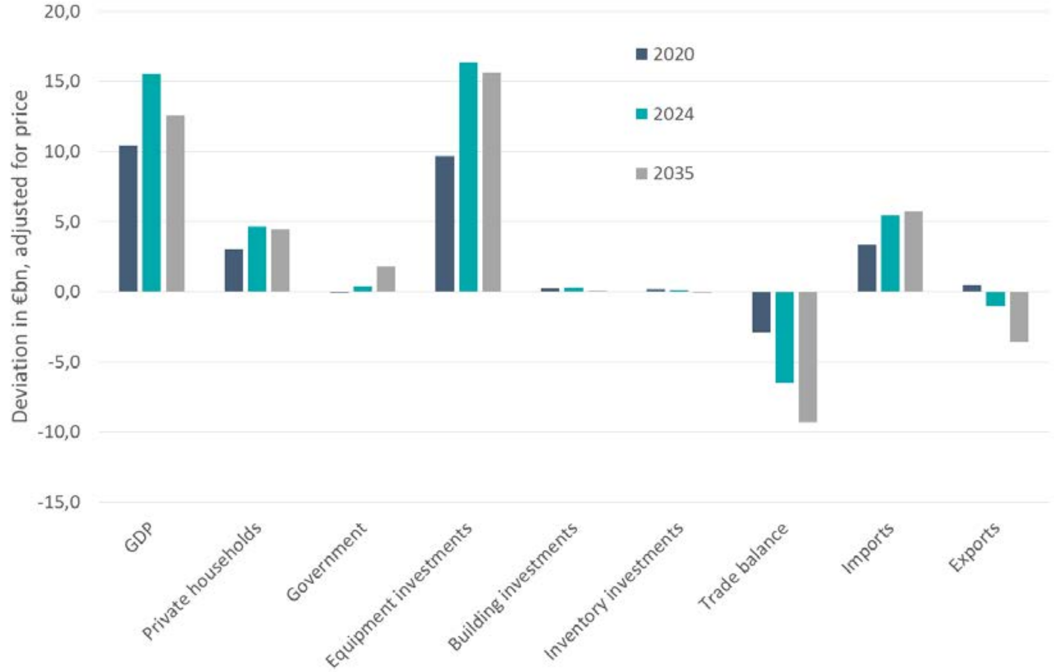
The above mentioned only included investments in the manufacturing industry. A broader approach – Economy 4.0 – should also include investments in the service industries. The national accounts now also list investments in new equipment and other new systems separately, allowing a more detailed consideration by economic sectors. According to methodical explanations on the national accounts, other new systems particularly includes so-called intellectual property of a national economy. This records investments in research and development, software and databases and copyrights.

It should further be noted that in 2014 a total of 103.2 billion Euro was spent on intellectual property (research and development: 74.5 billion Euro, software and databases: 23.4 billion Euro, other: 5.3 billion Euro). It is assumed about two thirds of the investments in software and databases (approx. 15 billion Euro) will come from the service industry. This corresponds to about one third of all service industry investments in other new systems. Along the lines of the assumption that input expenses for ICT services will need to increase by 60 percent by 2025 to achieve 80 percent digitisation (Assumption 9), the service industry's investments in software and databases must also increase by 60 percent compared to the QuBe baseline projection. For 2017 to 2025 this means a growth of approx. 40 billion Euro. Provided the distributions among other new systems will not change, investments will therefore be one third larger in 2025 than in the reference.

In total (Assumption 1 - 3) about 70 billion Euro more, adjusted for price, will be invested from 2017 to 2025 than in the QuBe baseline projection (manufacturing industry: 16 billion Euro in sensor technology and IT services and 13.5 billion Euro additional investments; service industry: approx. 40 billion Euro). The general additional annual investments will continue from 2026 to 2030. The manufacturing industry and agriculture will invest another approx. 15 billion Euro, and the service industry about 100 billion, meaning with the assumptions made, an additional approx. 185 billion Euro will be invested from 2017 to 2035. Of this, approx. 45 billion will be in agriculture and the manufacturing industry, and 140 billion Euro in the service industry. The IAB-ZEW company survey on Working Environments 4.0 also estimates the use of 4.0 technologies will involve large investments (Arntz et al. 2016). Investments will be financed through depreciations, which will either reduce the companies' profits or be shifted to ex works prices.

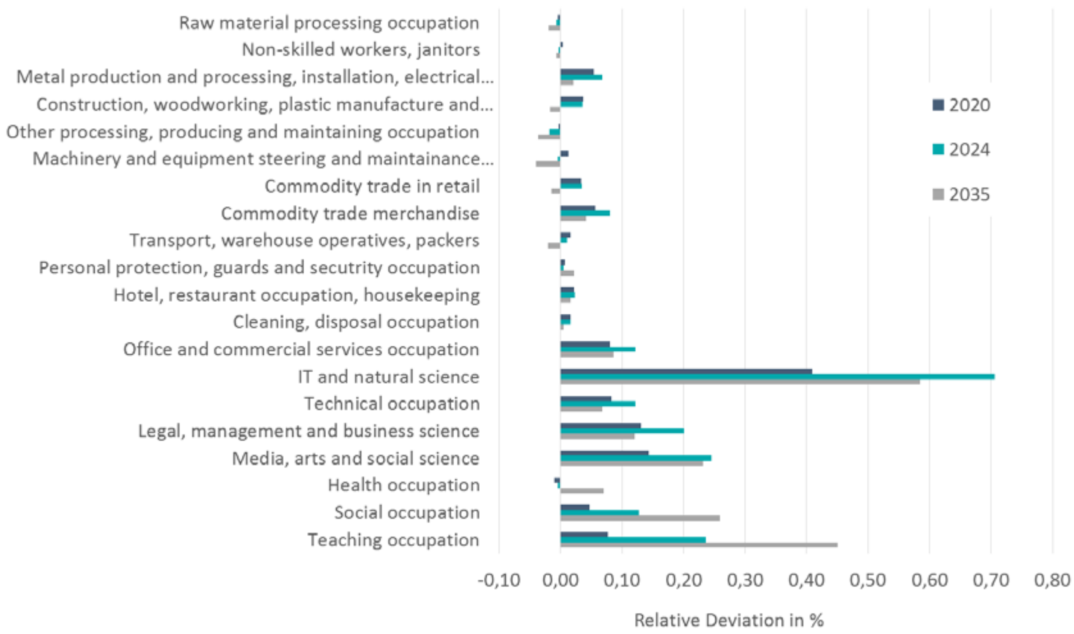
A look at the components of the gross domestic product (Figure 6) shows that although once the conversion phase is completed in 2024, equipment investments will still be larger than in the QuBe baseline projection, the gap will shrink.

Figure 6
Partial scenario 1 – Changes in the gross domestic product and its components compared to the QuBe baseline projection



Source: own diagram.

Figure 7
Partial scenario 1 – Number of gainfully employed persons by primary occupational fields compared to the QuBe baseline projection



Source: own diagram.

The result comes as no surprise, as the partial scenario 1 by itself is incomplete: So far only expenses have been added to the model, no earnings. And yet the first changes in the occupational field structure can be noticed (Figure 7). The increase in investments and the associated higher overall growth will initially particularly result in higher demand for IT and scientific professions (BHF 14), media/arts professions (BHF 17) (including design) as well as teaching professions (BHF 16).

IT makes up for 7.5 percent of all education provisions (if unable to provide themselves) (IOT 2012) and many of the social professions (BHF 19) are also used in the education industry. Furthermore, investments in intellectual property in the economic sector education will increase significantly. The increasing number of teachers can be considered a complementary development of larger investments.

3.2 Building investments (partial scenario 2)

Upgrading to "high-speed internet" is a fundamental requirement for implementing digital business. According to the TÜVRheinland study on behalf of BMWi (TÜVRheinland 2013), the upgrade will cost approx. 20 billion Euro in order for 100 percent of households to have a 50 Mbit/s connection. When aiming for 95 percent, this cost is 12 billion Euro.

(Assumption 4) Over the next three years 4 billion Euro per year will be invested in the upgrade to ensure about 95 percent of all households will have a 50 Mbit/s connection by 2018.

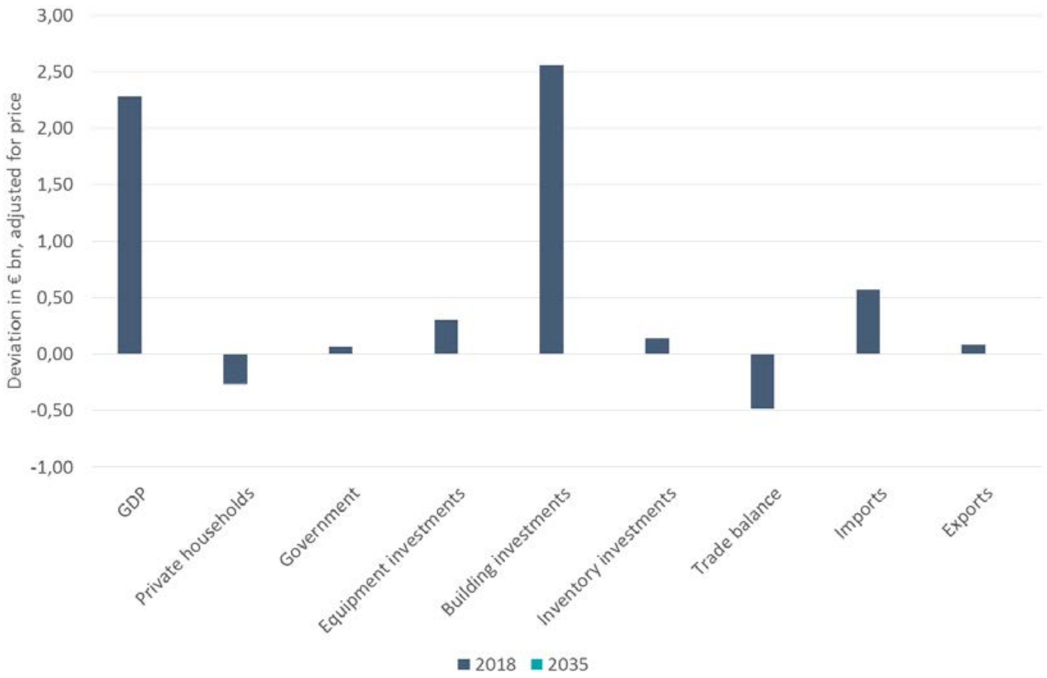
According to the study the goal to provide this nationwide (so 100 percent) will be achieved by 2018. Based on the assumption that hardly any additional investments were made in 2014 and 2015, this only leaves 2016, 2017 and 2018. Due to the short timeframe and the large investment required, probably only about 95 percent will be upgraded by 2018 so that an additional 4 billion Euro per year will need to be invested from 2016 to 2018, assuming the investments for 2016 were already made.

(Assumption 5) Wired technologies (TÜVRheinland 2013) are generally used. Therefore, in the Q-INFORGE model this will affect civil engineering and the use of electronic equipment (e.g. cables). The electronic equipment only make up a small portion of building investments: According to input-output calculation of the Federal Statistical Office, approx. 1 percent. It is therefore assumed that this part of the investments has largely already been used for upgrading lines and will now by 100 percent (so approx. 1 billion Euro per year). The remaining 3 billion Euro will be spent on civil engineering services. The entire counter-entry applies to government investments.

(Assumption 6) The government does not finance the investments by increasing debt. It is rather assumed the government's net lending will remain unchanged.

So this could be financed through e.g. additional tax revenues generated over time. However, if insufficient additional tax revenue is generated compared to the QuBe baseline projection, taxes will need to be raised (or planned cuts delayed) for net lending to remain unchanged. Financing through lending or surplus, which then will not be used for debt repayment, on the other hand would have stronger impact.

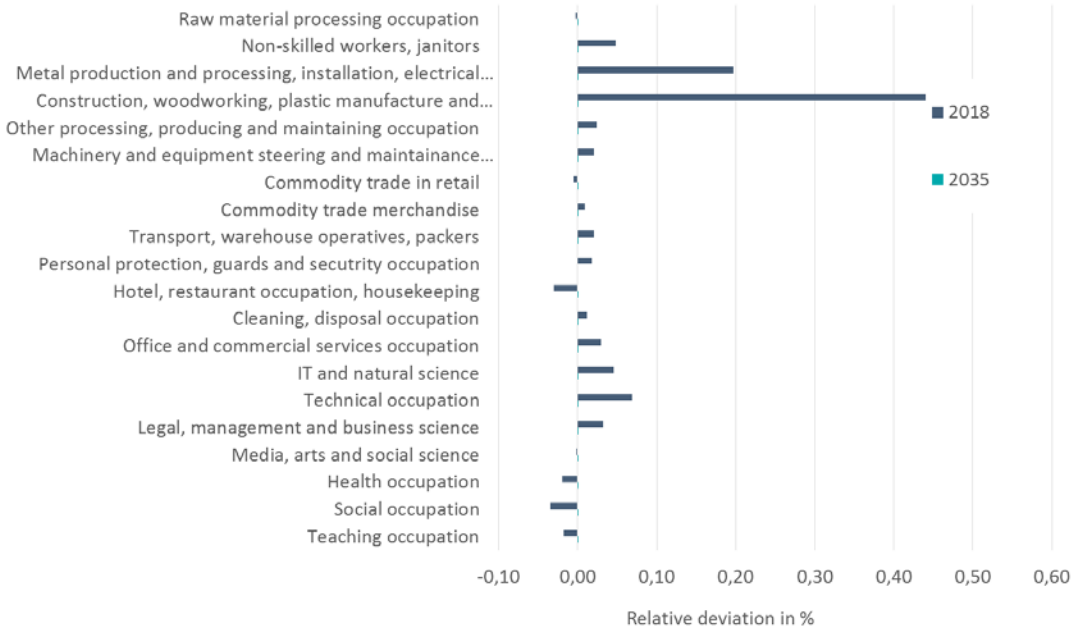
Figure 8
Partial scenario 2 – Changes in the gross domestic product and its components compared to partial scenario 1



Source: own diagram.

Figure 8 shows the effects on the components for 2018 and 2035. Unlike other diagrams, the year 2018 is used here, as it is the last year with additional building investments. There are no additional investments in 2020. Compared to the previous partial scenario 1, 2018 shows the substantial increase in building investments adjusted for price. However, there is less impact on the gross domestic product. Building investments also entail importing intermediate goods, resulting in a decrease of net export. In 2035 no effects remain, as even partial scenario 2 only assumes an upgrade, not the utilisation of the new opportunities.

Figure 9
Partial scenario 2 – Number of gainfully employed persons by primary occupational fields compared to partial scenario 1



Source: own diagram.

So even the changes in the primary occupational fields only provide a feel for the exclusive effects building investments will have (Figure 9). Yet it shows the specific actions taken for building investments (civil engineering and electronic equipment) is particularly aimed at professions in the building industry as well as metal and plant construction.

3.3 Cost and profit structures (partial scenario 3)

In the following partial scenario 3 material and personnel expenses are introduced for the investing branches of production. So far the companies have invested (partial scenarios 1&2). Earnings from the investments have not be included thus far. After all, by 2025 a cumulative additional 70 billion Euro is spent as expected. However, optimal exploitation of the potential gains in efficiency requires additional expenses in continuing education, consulting services and IT services. Ultimately the earnings from investments shows in the change in the expense situation. Six actions are taken for this purpose. Three pertain to additional expenses (cost increases) and three to potential savings (cost reductions). As a result, a company's material and personnel expenses change:

Cost increases:

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

(2) Increasing the companies' portion of expenses for consulting services and

(3) Massive commitment of additional IT services.

Cost reductions:

(4) Lowering the cost-of-materials ratios (costs of materials in relation to turnover) by reducing wear and scrap,

(5) Reducing logistics expenses

(6) Lowering the personnel expenses ratio by improving labour productivity.

Although the assumptions regarding continuing education (see above), Consulting services and the use of additional IT services are still relatively easy to estimate, material and the employment of labour depends on many influencing factors which have not yet been defined here. So it should be assumed the amount of scrap (e.g. surface finishing, producing forged, moulded, drawn and die-cut parts as well as metal tanks) will vary between 2 to 6 percent among the branches of production (Emec et al. 2013). Likewise, some trade will have more scrap than others. Scrap in the production of wooden windows can be up to 50 percent (Mantau et zikal. 2013).

At the same time the great uncertainty with respect to the assumptions (4 & 5) also involves significant impacts on added value and distribution. For example, according to the input-output table in 2012 the sectors of the manufacturing industry provided each other with input in the amount of 817 billion Euro. A mere one percent of savings, assuming nothing else changes (ceteris paribus assumption) would mean a growth in added value of 8.2 billion Euro over one year. In terms of the gross domestic product this means a growth of about 0.3 percent. The benefit of lower material costs due to a new production process would then persist in all subsequent years. After ten years this would yield a growth in added value of 82 billion Euro, which would then already exceed the investments listed in the amount of 33 billion Euro (adjusted for price). In order to make a suitable yet not overly optimistic assumption, it makes sense to first look at the three assumptions on cost increases.

(Assumption 7) The IAB-ZEW company survey on Working Environments 4.0 shows that continuing education is very important in preparing employees in order to be able to successfully use new digitised technologies within the company. It is therefore assumed the companies will spend additional funds for continuing education over the next few years.

Our calculation of costs of continuing education uses the results from Continuing Vocational Training Survey 4 (CVTS4) on the costs of courses per employee and the participation rates for employees in company training in 2010 for Germany by economic sectors (Federal Statistical Office 2013). According to this, the participation rate for company training both in the manufacturing industry and in the service industry was approx. 39.5 percent. Assuming the transformation toward a digitised working environment affects a high portion of employees, for the Economy 4.0 scenario we assume the participation rate for additional training required is twice as high, and therefore 79 percent of employees will be participating in additional continuing education in the context of digitisation by 2025. According to the results of the CVTS4

(Federal Statistical Office 2013), the cost of one training session per employee is approx. 561 Euro in the manufacturing industry and 784 Euro in the service industry. Considering the rates of price increase in the economic sector teaching, by 2025 the cost of company training will total approx. 6.6 billion Euro in the manufacturing industry and approx. 18.8 billion Euro in the service industry.

(Assumption ❽) Additional consulting services in the amount of 1.5 percent will be required to implement the new production method within the company.

According to the input-output table, companies procure about 135 billion Euro in outside services. At a production value of 5312 billion Euro, a 1.5 percent increase in expenses for consulting service amounts to about 0.4 billion Euro more. By 2025 expenses will increase due to price developments, further increasing this amount.

(Assumption ❾) The level of digitisation will increase to 80 percent in both the manufacturing industry and the service industry.

According to the IAB-ZEW company survey on Working Environments 4.0, the level of digitisation is about 37 percent in the manufacturing industry and about 44 percent in the service industry. In order to achieve 80 percent digitisation with unchanged costs, the expenses for IT services would therefore need to increase 116 percent in the manufacturing industry and 81 percent in the service industry compared to today. However, the companies' level of digitisation also increases in the QuBe baseline. Taking these increases into account, the expenses for IT services would need to double in the manufacturing industry and increase by 66 percent in the service industry compared to the QuBe baseline. Since the ICT sector itself procures a lot of outside ICT services (32 billion Euro), it is assumed the level of digitisation is already adequate (80%) in this industry.

To get an overview of expenses and investments for companies in the manufacturing industry the implied cash flow is considered in a coherent manner. For the expenses (assumptions ❼❽❾) and investments in equipment (assumptions ❶❷❸) to be profitable the cost savings associated with material and personnel expenses must at a minimum cover the additional expenses over the next ten years.

(Assumptions ❿ & ⓫ & ⓬): In agriculture and in the manufacturing industry the input drops by 0.72 percent by 2025 compared to the QuBe baseline projection (service industry: 0.8 percent) and expenses for logistics by um 0.8 percent (service industry: 0.65 percent). Labour productivity will be 1 percent higher until 2025 than in the QuBe baseline projection.

The gradations taken for cost savings are based on two online company surveys, the IAB/ZEW survey on Working Environments 4.0 and the QuEst survey (Quality in Establishment Surveys) by IAB. A total of about 2000 companies were polled on digitisation and its desired effects in line with these surveys. The results showed that an increase in labour productivity is most likely expected. With respect to material and transport costs, however, expectations varied, which was taken into account in the assumptions.

When including increases in turnover (cf. assumptions ⑮, ⑯ and ⑰) in the costs and savings, after 9 years the returns for agriculture and the manufacturing industry (Table 3) and the service industry (Table 4) are (almost) 8 percent each. This is the design principle for the Economy 4.0 scenario: Based on the expenses required for implementation the individual cost savings, gains in efficiency and increases in turnover were calibrated so as microeconomically to yield a good return. Of course this does not have to capitulate in each individual case, but on average is plausible for all companies. The relation between individual parameters was primarily established by the results from the two representative company surveys.

Table 3
Comparison of costs (payments) and savings in agriculture and the manufacturing industry, nominal

Agriculture and production industry in €bn rounded to 100m	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Discounted to 2016
Continuing education	0	700	700	700	700	700	700	800	800	800	0	0	0	5.200
Consulting	0	500	500	500	500	500	500	500	500	500	500	500	500	3.600
IT service	0	1.000	2.000	3.000	4.100	5.200	6.400	7.700	9.000	10.300	10.200	10.000	9.900	35.800
Investments	0	3.500	3.600	3.600	3.600	3.700	3.700	3.800	3.800	1.600	1.700	1.700	1.700	24.600
Costs (payments)	0	5.700	6.800	7.800	8.900	10.100	11.300	12.800	14.100	13.200	12.400	12.200	12.100	69.200
Cumulative	0	5.700	12.500	20.300	29.200	39.300	50.600	63.400	77.500	90.700	103.100	115.300	127.400	
… intermediate inputs	0	900	1.800	2.700	3.700	4.800	5.800	6.900	8.100	9.300	9.500	9.600	9.800	32.300
… logistics	0	100	100	200	300	300	400	500	600	700	700	700	700	2.400
… wage payments	0	600	1.200	1.800	2.400	3.000	3.600	4.300	5.000	5.700	5.800	5.900	6.000	20.300
Savings	0	1.600	3.100	4.700	6.400	8.100	9.800	11.700	13.700	15.700	16.000	16.200	16.500	55.000
Cumulative	0	1.600	4.700	9.400	15.800	23.900	33.700	45.400	59.100	74.800	90.800	107.000	123.500	
Revenue growth (domestic+international), after tax	0	2.800	5.700	8.800	12.100	15.700	19.400	23.500	27.700	32.200	33.400	34.500	35.700	108.400
From which wage and intermediate inputs	0	2.300	4.900	7.500	10.300	13.200	16.400	19.800	23.300	27.100	28.100	29.100	30.000	91.500
Surplus	0	500	800	1.300	1.800	2.500	3.000	3.700	4.400	5.100	5.300	5.400	5.700	16.900
Cumulative	0	500	1.300	2.600	4.400	6.900	9.900	13.600	18.000	23.100	28.400	33.800	39.500	
Profit or loss	0	-3.600	-2.900	-1.800	-700	500	1.500	2.600	4.000	7.600	8.900	9.400	10.100	2.700
Cumulative	0	-3.600	-6.500	-8.300	-9.000	-8.500	-7.000	-4.400	-400	7.200	16.100	25.500	35.600	
Return (result in relation to costs)										**7,9**				3,9

Source: own diagram.

Table 4
Comparison of costs (payments) and savings in the service industry, nominal

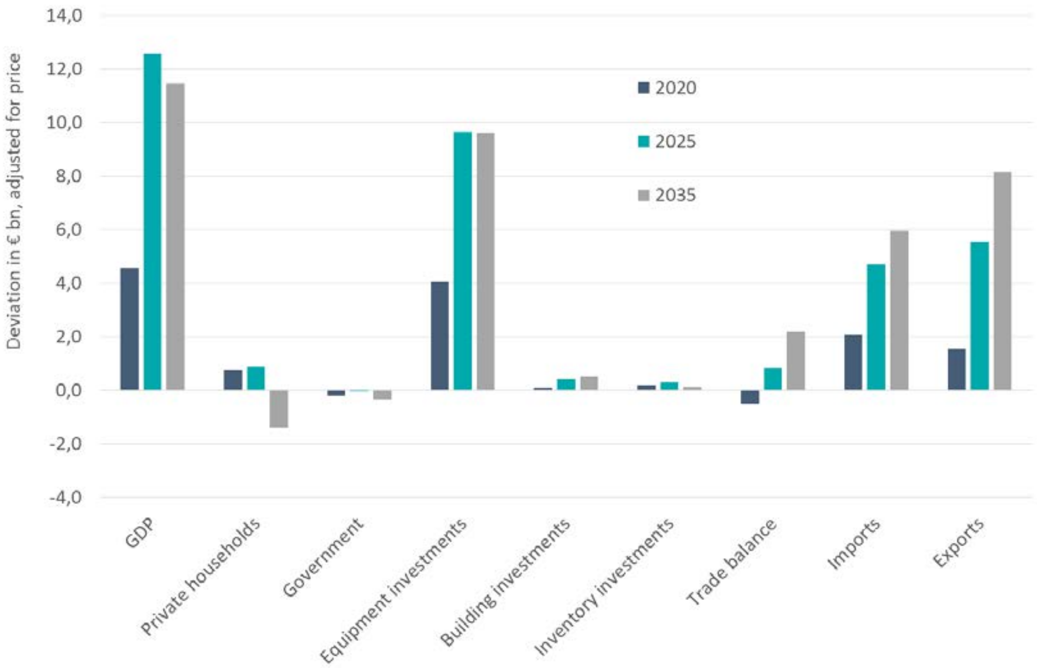
Service sector in €bn rounded to 100m	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	Discounted to 2016
Continuing education	0	1.900	2.000	2.000	2.000	2.100	2.100	2.200	2.200	2.300	0	0	0	14.700
Consulting	0	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	1.700	12.100
IT service	0	1.800	3.600	5.400	7.200	9.100	11.000	13.000	15.000	17.000	16.800	16.500	16.300	61.300
Investments	0	1.100	2.200	3.300	4.300	5.400	6.500	7.600	8.700	9.800	9.800	9.800	9.800	36.100
Costs (payments)	0	6.500	9.500	12.400	15.200	18.300	21.300	24.500	27.600	30.800	28.300	28.000	27.800	124.200
Cumulative	0	6.500	16.000	28.400	43.600	61.900	83.200	107.700	135.300	166.100	194.400	222.400	250.200	
… intermediate inputs	0	200	300	500	700	800	1.000	1.200	1.400	1.600	1.700	1.700	1.700	5.700
… logistics	0	100	300	500	600	800	1000	1200	1400	1600	1700	1700	1700	5.500
… wage payments	0	1.200	2.500	3.800	5.100	6.500	7.900	9.400	11.000	12.600	12.900	13.200	13.500	44.100
Savings	0	1.500	3.100	4.800	6.400	8.100	9.900	11.800	13.800	15.800	16.300	16.600	16.900	55.300
Cumulative	0	1.500	4.600	9.400	15.800	23.900	33.800	45.600	59.400	75.200	91.500	108.100	125.000	
Revenue growth (domestic+international), after tax	0	4.600	9.500	14.500	19.600	25.000	30.600	36.400	42.500	48.900	50.100	51.200	52.400	170.200
From which wage and intermediate inputs	0	2.600	5.200	8.000	10.900	13.800	16.900	20.100	23.500	26.900	27.600	28.200	28.900	94.000
Surplus	0	2.000	4.300	6.500	8.700	11.200	13.700	16.300	19.000	22.000	22.500	23.000	23.500	76.200
Cumulative	0	2.000	6.300	12.800	21.500	32.700	46.400	62.700	81.700	103.700	126.200	149.200	172.700	
Profit or loss	0	-3.000	-2.100	-1.100	-100	1.000	2.300	3.600	5.200	7.000	10.500	11.600	12.600	7.300
Cumulative	0	-3.000	-5.100	-6.200	-6.300	-5.300	-3.000	600	5.800	12.800	23.300	34.900	47.500	
Return (result in relation to costs)										7,7				5,9

Source: own diagram.

Contrary to a microeconomic perspective, the result of the assumptions is not a macroeconomic zero-sum situation, as Germany is not a closed economy: Although the investing companies do show additional profit in the comparisons shown in Table 3 and Table 4, there will also be additional demand in other industries (e.g. ICT). In addition, German suppliers will not be the only ones to see cost savings, so will foreign suppliers. Imports decrease. Furthermore, the cost per unit will decrease for companies in agriculture and the manufacturing industry so that competitiveness will improve and e.g. more export can be generated. Figure 10 shows the effects partial scenario 3 will have on the components of the gross domestic product compared to partial scenario 2.

Net export will not improve from the high import share of investments; positive stimuli will increase consumer demand of private households through the income cycle. Furthermore, tax revenues (direct and indirect) and with it the government's financial power will increase. Overall, the gross domestic product is significantly higher. The effect will increase over time, all cost savings are not fully implemented until 2025.

Figure 10
Partial scenario 3 – Changes in the gross domestic product and its components compared to partial scenario 2

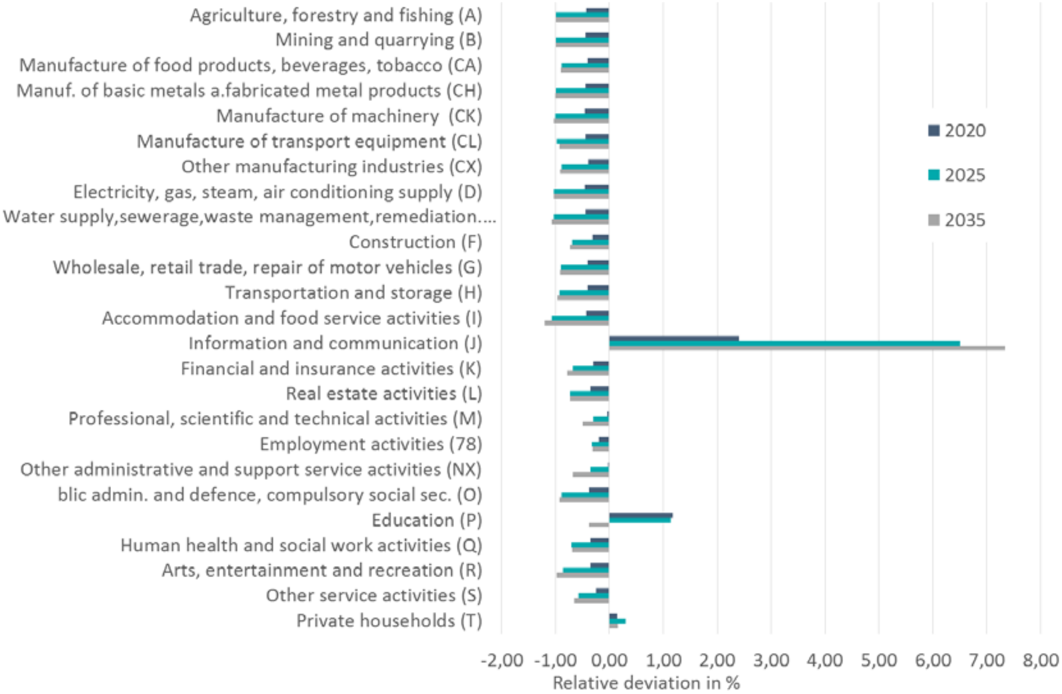


Source: own diagram.

Investments increase significantly. This can also be attributed to the considerable production expansion for ICT services, which also invested about the amount of production trend in the past; about half the investments trace back to this economic sector.

The manufacturing industry (CA to CX) and agriculture (A) will lose jobs (Figure 11). The information and communication industries (J) may see a significant increase in the labour force. Other positive, even if relatively minor effects, can be seen in the remaining service industries (M to P). We should point out the teaching industry (P), which may particularly see considerable growth during the first few years.

Figure 11
Partial scenario 3 – Number of gainfully employed persons by industries compared to partial scenario 2

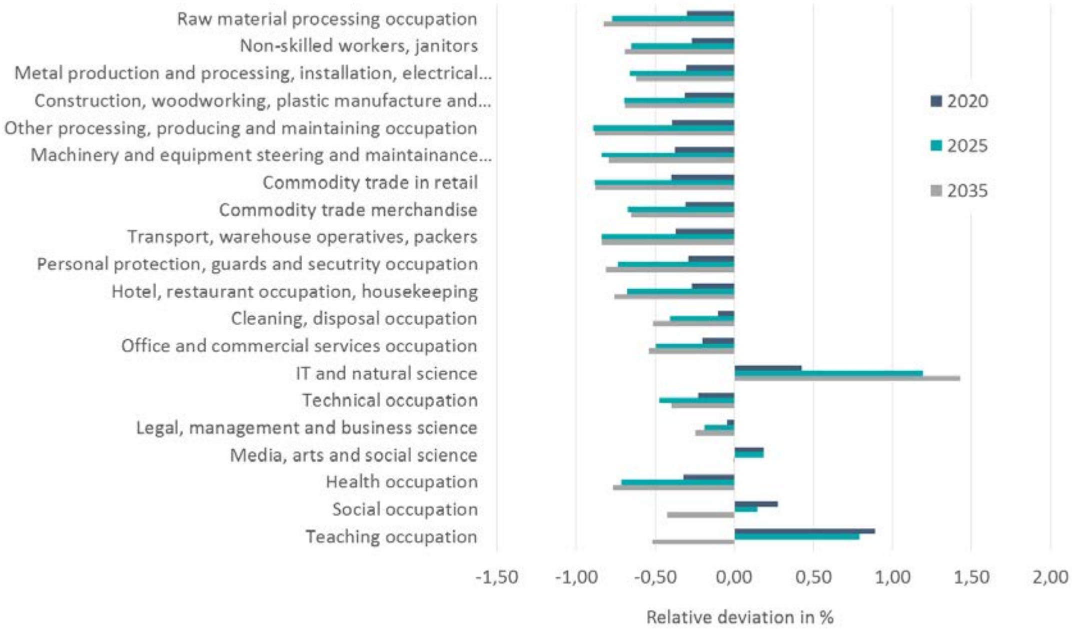


Source: own diagram.

The structure of the primary occupational fields has also changed. Overall the demand for service occupations will increase, at the expense of professions in the manufacturing industry. Particularly IT and scientific professions (BHF 14) may benefit. In second place are teaching professions (BHF 20), which not only includes teachers in general education and at vocational schools, but also those in continuing education (Figure 12).

The increases in labour productivity apply to the entire economy, so that no industry is excluded from the potentially negative effects on employment. Positive changes can only be seen if and so long as positive impacts (e.g. investments or demand for continuing education) are added. Even teaching professions will lose once increased continuing education efforts stop. On the occupational field with ICT professions can grow permanently. Overall, the negative effects will be less severe on occupations in the service industry.

Figure 12
Partial scenario 3 – Number of gainfully employed persons by primary occupational fields compared to partial scenario 2

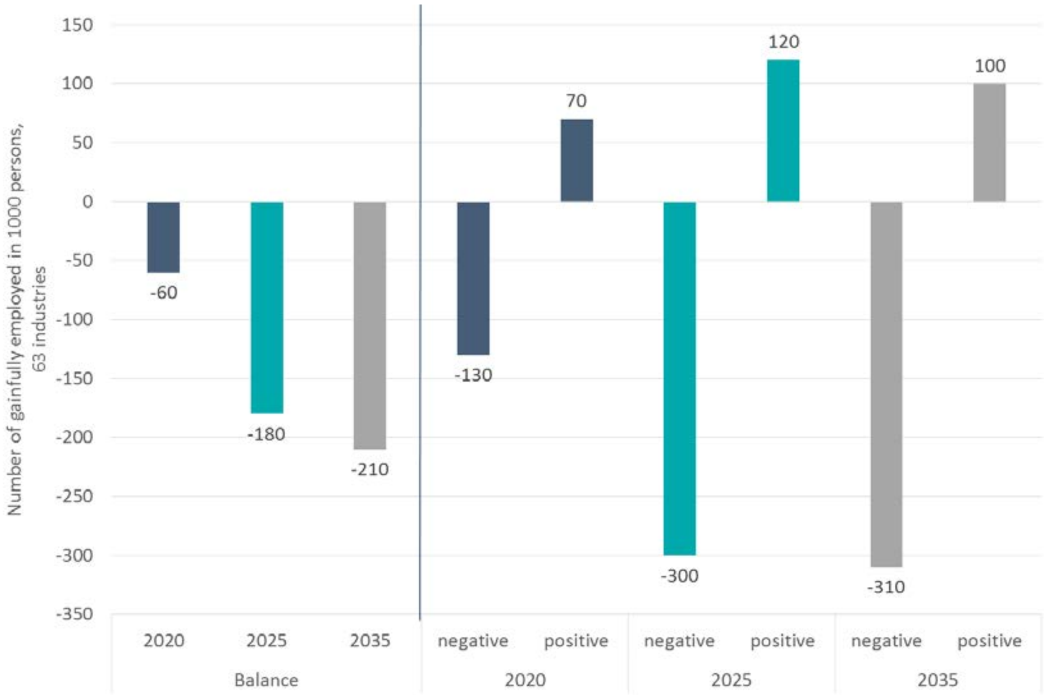


Source: own diagram.

What are the consequences for the labour force? Where will jobs be added and reduced? For this we will be looking at the changes by economic sector and occupational field. The net differences (total across all) of the respective positive and negative gross differences (total of all negative and positive differences) are compared.

Figure 13 shows that macroeconomically 60,000 jobs will already be lost in 2020 compared with partial scenario 2. There are also are consequences for the working environment: About 130,000 jobs will be lost in industries with a decline in the labour force. Other industries can hire an additional 70,000 gainfully employed persons total. This means 200,000 jobs are affected. In 2035 all structure changes are effective; there will then be approx. 200.000 jobs less than in partial scenario 2. The changes in the working environment, however, are far greater: Industries seeing negative effects will cut 310,000 "old" jobs, the benefiting industries can at most offer 100,000 "new" jobs.

Figure 13
Partial scenario 3 – Number of jobs eliminated and newly created jobs by industry compared to partial scenario 2

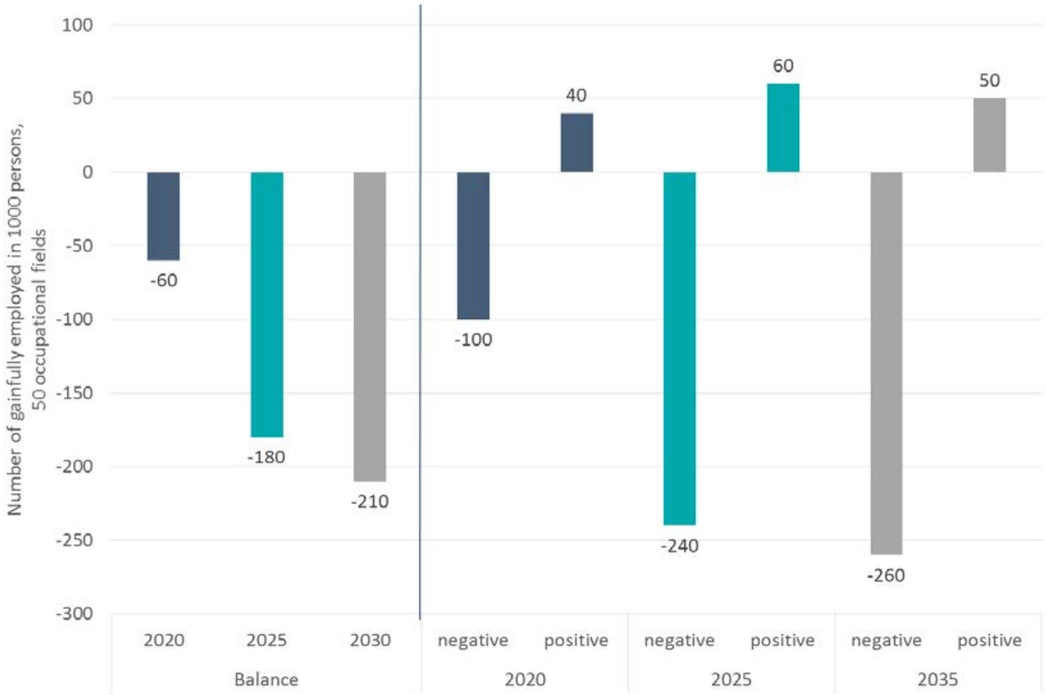


Source: own diagram.

The change in the industries resulting from including changed material, logistics and personnel expenses will not only affect the working environment relevant to industries, but also with respect to occupational fields: The industries differ in the professions needed for production. A change in the composition of the industry also entails a new composition of gainfully employed persons by occupational fields.

Figure 14 again shows the same changes for the labour force as a whole (net total) as Figure 13, but profits and losses are considerably lower: With respect to occupational fields, about 250,000 jobs will be lost in 2025 and 2035 – in terms of industries this was 300,000 (see Figure 13). Ultimately the character of the jobs will change more between industries than between professions. This is also because so far a changed occupational structure within an industry due to the introduction of Economy 4.0 has not yet been modelled. This is taken into account in the fourth partial scenario.

Figure 14
Partial scenario 3 – Number of jobs eliminated and newly created jobs by occupational fields compared to partial scenario 2



Source: own diagram.

3.4 Occupational field and requirement structure (partial scenario 4)

In addition to the economic structural effect, resulting from including material and personnel expenses, there is the occupational field structural effect. The fourth partial scenario therefore addresses changes in the occupational field and requirement structure within the industries. The following is based on the assumption that not only the industry but also the composition of the professions used and their requirement levels will change in the course of implementing Economy 4.0. Past change in the occupational fields from 1996 to 2013 is shown to be able to assess the resulting dynamic (Figure 15).

In the past there have been considerable changes over 17 years. The Number of gainfully employed persons grew by +10 % from 1996 to 2013. At the same time there was a substantial structural change. Professions often found in the manufacturing industry have seen losses:

(1) BHF 3 metal-, plant-, sheet metal construction, installation, assembly, electrical trades
(2) BHF 4 Building trades, wood and polymer processing
(3) BHF 5 Other processing and repair professions
(4) BHF 6 Machinery and plant control and maintenance professions

In contrast to this trend, BHF14 "IT and scientific professions" saw growth. Even many professions which can be categorised as services (including health care services), were able to grow:

(1) BHF 11 Food service professions

(2) BHF 12 Cleaning and waste management professions

(3) BHF 16 Legal, management and economic professions

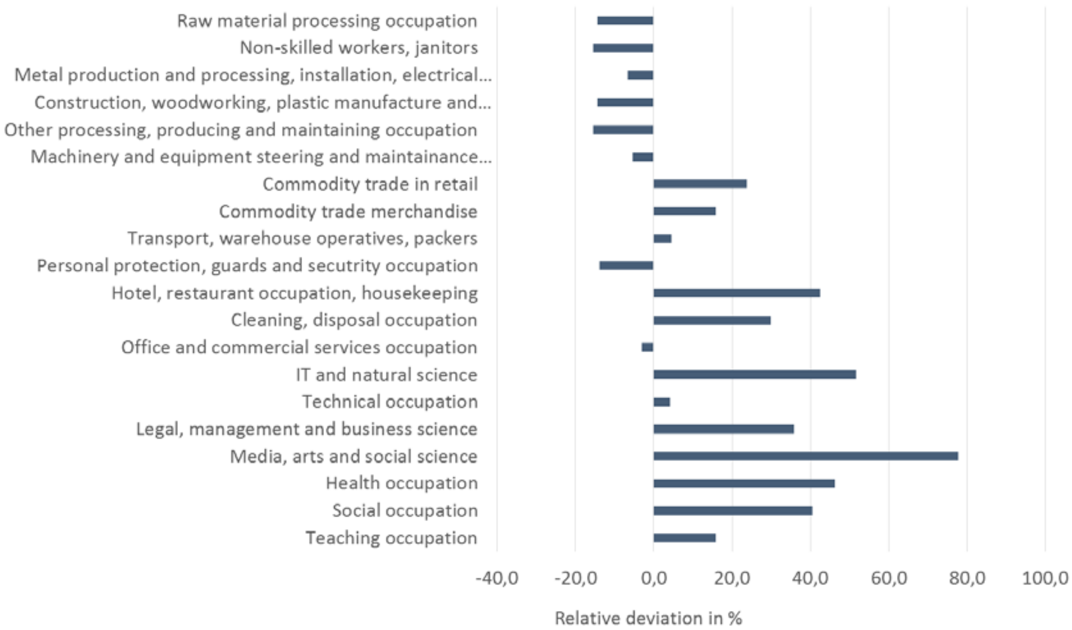
(4) BHF 17 Media, humanistic and socioscientific, artistic professions

(5) BHF 18 Health care professions

(6) BHF 19 Social professions

(7) BHF 20 Teaching professions

Figure 15
Number of gainfully employed persons by primary occupational fields from 1996 to 2013



Source: own diagram.

It is unknown how converting to Economy 4.0 will affect the composition of the occupational fields and their level of educational requirement within an industry. Assuming that as a result of transforming to Economy 4.0 especially highly routine functions will be cut and functions with little routine will increase (Author et al. 2013; Bonin et al. 2015; Bowles 2014; Brzeski and Burk 2015; Frey and Osborne 2013), one can estimate the potential effects digitisation will have on employment within the industries.

There now are a number of concepts and measurement methods for Germany to determine the degree of routine or replacement potentials (method box 4). Solely for better comparability with the previous study (Wolter et al. 2015), which uses the approach of Dengler and Matthes (2015), this concept is used below. However, another publication will be released soon which in addition to the level of routine of Dengler and Matthes (2015) also uses the routine index of Tiemann (Tiemann 2016a; Helmrich et al. 2016), the work capacity index of Pfeiffer and Suphan (2015) as well as a replicability index based on the BIBB qualifications panel (QPE) (Helmrich et al. 2016).

Method box 4: Degree of replicability

The degree of substitutability of Dengler and Matthes (2015)

The substitutability potential of Dengler and Matthes (2015) provides information on portion of the tasks typically carried out by a job could already have been carried out by computers in 2013. For this purpose three coders researched independently, whether duties – used in the expert data database of the Federal Employment Agency to describe the work tasks to be performed – could be entirely performed by machinery, robots or computer programmes. This allows the specifics of the German labour market and education system to be directly taken into account. It does not estimate future, only the current substitutability potentials. Dengler and Matthes further calculated the substitutability potentials by level of education requirement for the current scenario calculations.

Routine index of Tiemann (2016)

The routine index of Tiemann (2016) implements the extended definition for routine according to Frey and Osborne (2013). Thus, in assessing the routine of a job not only is the ability to program activities key, but also the (sensory) perception and handling parts and objects as well as creative and social intelligence required for the job. In order to include these different dimensions of routine, Tiemann (2016) takes into account that it is common for work processes and execution of work to be specified in detail, items to be repaired or serviced, processes to be improved and for work to include training, education or teaching. Based on the 2012 BIBB-BAuA Labour Force Survey, the characteristics listed are summarised to a factor using a factor analysis, with the factors describing the routine of the job of the person polled

The work capacity index of Pfeiffer and Suphan (2015)

In their work capacity index, Pfeiffer and Suphan (2015) strive to establish a relation to describe the work experience required for employment. They used data from the 2012 BIBB-BAuA Labour Force Survey, thus employing self-assessments of workers. The work capacity index is the means for three indicators describing the respective level of the so-called situational and structural requirements due to complexity as well as the situational imponderability of a job. In doing so, the index for situational requirement due to complexity for gainfully employed persons includes an estimate of how frequently the person surveyed solves problems at work, makes difficult decisions and needs to communicate with other persons. The situational imponderability of a job, on the other hand, includes the frequency of interruptions in the work flow, lack of information and/or knowledge when performing duties, simultaneous processes which must be monitored, and whether errors will result in great financial loss. This is again about how common time pressure is when performing duties. The last index on the structural requirements due to complexity determines changes in the work environment and the stress level of those surveyed. The work capacity index is further multiplied by training period required to perform the job.

QPE – a replicability index based on the BIBB qualifications panel

The QPE (detailed in Helmrich et al. 2016) approach is similar to that of Tiemann (2016) and applies the extended definition of routine according to Frey and Osborne (2013). For example it uses information about subject reference, the cognition and frequency of manual and repetitive activities in work for different employee groups in various industries to extract information about the replicability potentials of these groups using a principal component analysis. The 2015 BIBB qualification panel – an annual representative repeat survey of companies in Germany – serves as the database.

(Assumption 13) The higher the rate of non-routine duties of the occupational field and the requirement levels relative to the industry average, the more an occupational field and a level of educational requirement will benefit from transforming to Economy 4.0.

If the industry average of non-routine duties in an occupational field for example is 40 percent and is 80 percent for an occupational field in the same industry, when transforming to Economy 4.0 the Number of gainfully employed persons should decrease more in the occupational field with a higher level of routine. But since there are also many reasons speaking against complete adaptation according to the levels of routine, it is further assumed at best half the routine duties can be cut through technological progress. How much routine will actually be cut, however, cannot be determined beforehand, as there will be other changes to the occupation field structure endogenous to the model - e.g. due to different the development in wages - in addition to the assumption made (Maier et al. 2014b).

The changes to the occupational field structure arising in line with converting to Economy 4.0 have consequences: A dispersal toward more complex duties the share of higher wage occupations will also grow. Therefore the industry average of wage costs will increase.

As with the estimate of cost and profit structures, it is again assumed the companies will not implement any changes which will reduce their profits. The assumption 14 therefore implies labour productivity will increase another 0.23 percent by 2025. The 0.23 percent correspond to the rise in labour costs in the industries with exclusive restructuring of the occupational fields.

In other words: The occupational fields where the level of routine is considerably higher than the industry average will decrease, occupational fields with a relatively low level of routine compared to the industry average will increase. Overall, however, employment in the industries which invested will decline at the same rate due to the assumed increase in labour productivity.

Table 5 shows a fictive example of an industry with four occupational fields to explain the process.

Table 5
Inclusion of the level of routine, sample calculation

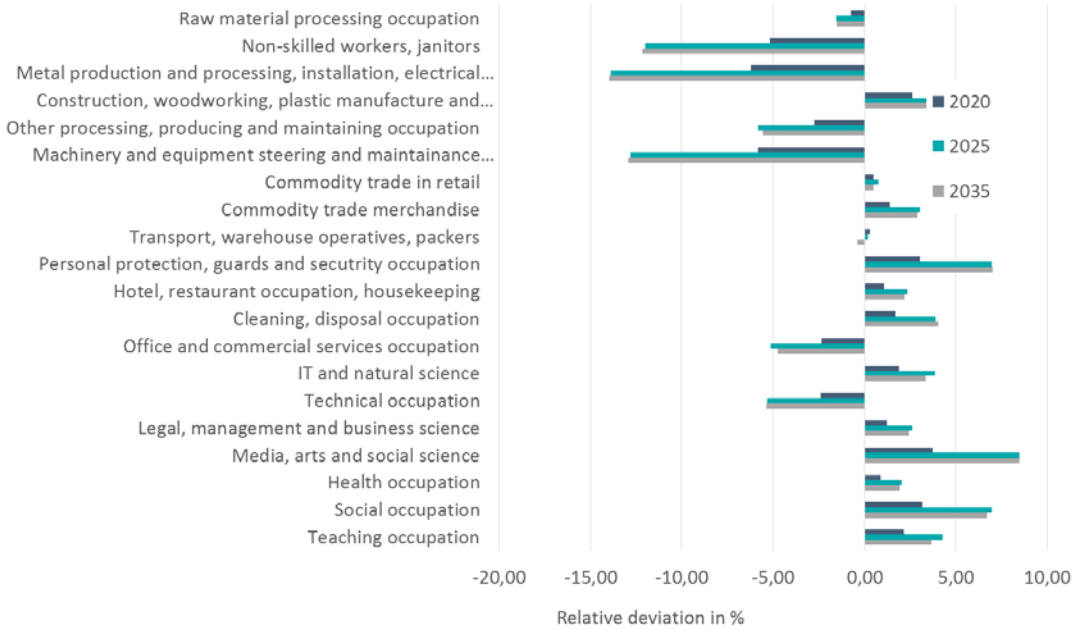
		Occupational fields 1	2	3	4	Total	Average
Gainfully employed in 2015	in individuals	1000	1000	3000	5000	10000	
.. in %	in % of total	10	10	30	50	100	
Routine percentage of the job	in %	10	70	80	90		77
Halving of the routine percentage	in %	5	35	40	45		
Percentage of the complex jobs at halved routine percentage	Anteil in %	95	65	60	55		61,5
Bonus/malus: In relation to the industry sector average, scaling factor	Faktor	1,54	1,06	0,98	0,89		
Employees considering the bonus/malus factor in 2025	in individuals	1545	1057	2927	4472	10000	
Considering the increase of labour productivity by 0.23%	in individuals	1541	1054	2920	4461	9977	

Source: own diagram.

These are compared with the above scenario in order to show the consequences for the occupational field. Figure 16 shows the changes in the primary occupational fields which solely trace back to the assumptions ⓭ and ⓮ .

It clearly shows that Machinery and plant control and maintenance professions (BHF 6) in particularly will decrease; these will lose up to 12 percent over the course of the transformation. Compared with the previous movements in the occupational fields over time (Figure 15), however, this change is still comparatively low, although it should be noted Figure 16 only shows scenario-effects beyond the basic development of the reference scenario. IT and scientific professions (BHF 14) and building trades (BHF 4) will benefit the most.

Figure 16
Partial scenario 4 – Number of gainfully employed persons by primary occupational fields compared to partial scenario 3



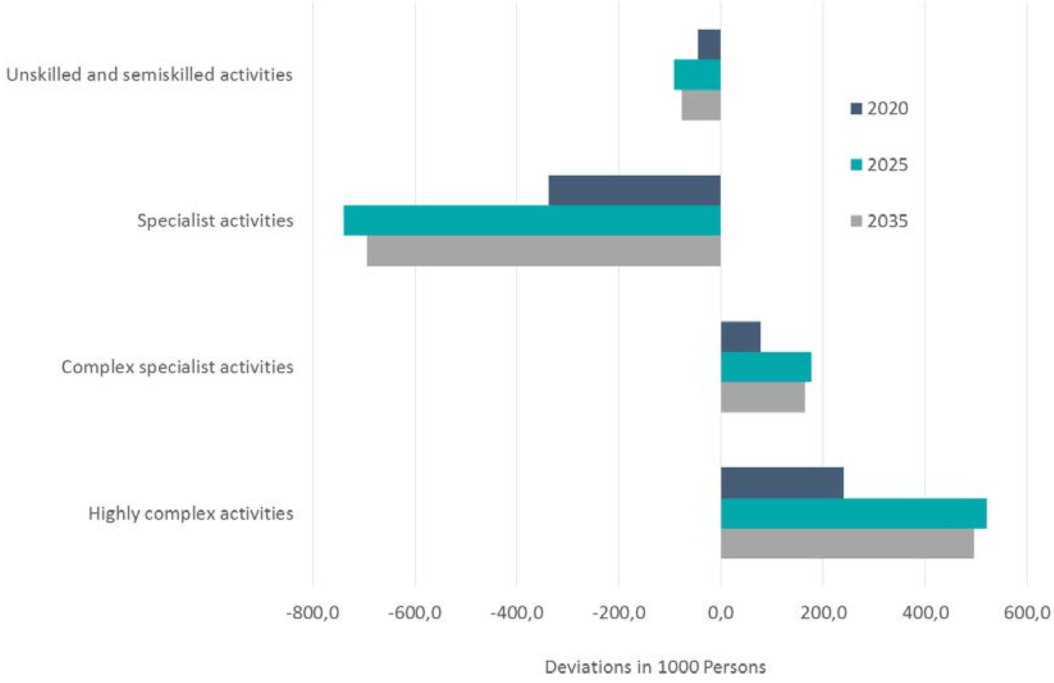
Source: own diagram.

The industry- and occupation-specific structural changes will also result in new requirements in the workplace. Numerically speaking, however, digitisation will affect support jobs less (Figure 17). Compared to the QuBe baseline projection, there will primarily be less demand for professional work and more demand for highly complex activities.

Finally, we will take another look at gross flows within the occupational fields. Whilst deflections among primary occupational fields in the partial scenario 3 is still lower than among industries, the partial scenario 4 shows significantly higher deflections (Figure 18).

In 2025 and 2035 the assumptions made will affect about 2.2 million or 2.0 million jobs. The net total for these years shows a loss of 130,000 or 110,000 jobs. This drop can be attributed to the macroeconomic consequences of the redistribution of professions and labour productivity once again increasing.

Figure 17
Partial scenario 4 – Number of gainfully employed persons by requirement levels compared to partial scenario 3



Source: own diagram.

Figure 18
Partial scenario 4 – Number of jobs eliminated and newly created jobs by occupational fields compared to partial scenario 3

Source: own diagram.

3.5 Demand (partial scenario 5)

The following includes consumer demand from private households and export demand in the scenario. The development of increased demand from private households can arise based on the new opportunities Economy 4.0 presents.

(Assumption ⑮): The government's consumer spending will increase by 5 percent in the area of cyber crime or cyber warfare to handle the new risks resulting from digitisation.

In the differentiation of the national accounts, the government's consumer spending can be broken down by scopes of activity. Two scopes of activity are looked at more closely: Defence particularly includes the government's personnel expenses for the German army. According to forecasts of the Federal Ministry of Defence, 14,000 persons will be hired for cyber warfare. This corresponds to about 1.4 billion Euro or 5 percent of the current budget with a cost per person of 100,000 Euro.

An equivalent increase of 5 percent is assumed for the German federal police (scope of activity public safety). According to the German federal police it currently has 40,000 gainfully employed persons. So 5 percent higher expenses means that an additional 2,000 persons will be hired in 2025. Both are entered under government accordingly.

After 2025 expenses will continue to increase until 2035. It is assumed expenses will increase by 20 percent (2 percent per year) for both scopes of activity. This increase roughly corresponds to the rate of price increase.

(Assumption ⑯) The demand for goods increase by 2 percent until 2025 and that for services by 3 percent.

Private households are interested in the new opportunities for consumption which will arise after converting to Economy 4.0. Products can be customised, the interest in new items and accelerating networking existing end devices with e.g. the residence or the car may be the cause. The dynamics and the extent of these additional demands are difficult to estimate. Another result of the company surveys specified above, however, was that companies also expect increases in turnover from new goods or services due to investments in newer technologies. Since this expectation is greater among companies in the service industries than among those in the manufacturing industry, it was assumed the demand of private households for new goods will increase by 2 percent and 3 percent for services. This should not be viewed as an increase in volume for existing products but as demand for new or improved products and services the companies are able to offer due to their investments in 4.0 technologies.

These assumptions were applied in the model by increasing demand differently based on consumer utilisation. For the demand for goods the respective purposes follows the products produced by the economic sectors in the manufacturing industry, so those which have transitioned their production methods in line with the scenario analysis and can therefore actually produce customised products.

Table 6
Selection of purposes

	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

Foods and beverages, however, are an exception, as we do not assume additional food consumption. Consistent with the assumption of Germany being a pioneer, it is further assumed the new goods will only be available for purchase within the country and cannot be imported. For goods with a high import share it is therefore assumed the demand for imported convenience products will only increase starting in 2020. This applies to clothing, furniture and cars. The imported inputs (raw materials and semi-finished goods) were left unchanged, as it is assumed these will not improve and will first be processed within the country.

The purposes in blue (Table 6) are always goods describing the domestic consumption of private households. Goods and services cannot always be clearly distinguished. For example, the purpose "Goods and services for operating private vehicles" is not selected.

The purposes in yellow can be categories under service industries and increase by 3 percent. Rent and associated services or goods are not included for the service industry.

(Assumption 17) Based on the higher quality and customisation, the willingness of end consumers to pay will increase by 0.66 percent for goods and 1 percent for services by 2025.

Two assumptions are made in order to include the change in the quality of a product or service in line with a scenario: On one hand the customer will receive more, so adjusted for price, consumer demand will also increase but material or labour costs for manufacturing the new products will not change, as the products now have characteristics (e.g. custom layout) they did not have before. This can also be supported by the above company surveys: This not only shows clear results, as the utilisation of 4.0 technologies enables offering new products or services, but to also better satisfy individual customer requirements.

Consumer demands will therefore increase by a third, adjusted for price, over previous demand and the additional material and labour for this is corrected. It is further assumed the lower costs per piece will not be passed on to consumers but flow into the companies' profits.

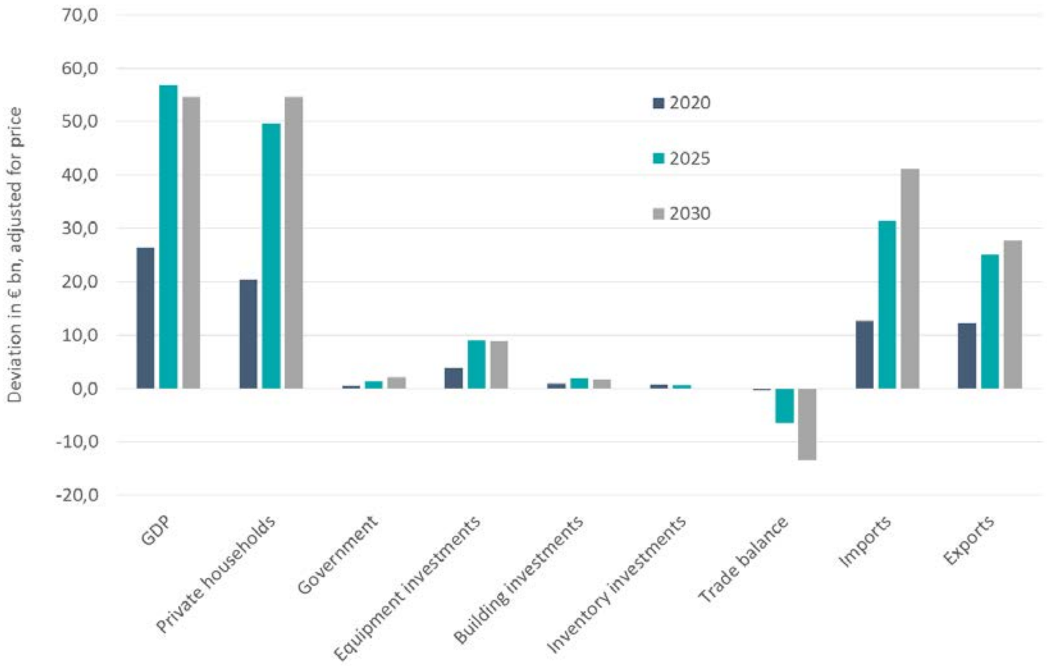
(Assumption 18) Germany has been a worldwide pioneer in the transition to Economy 4.0 and other countries are responding with a five year delay. It is further assumed the demand for new goods and services will not only increase in Germany, but worldwide, and that German export will grow accordingly.

International demand for machinery and measuring technology will begin five years later (so 2020) than in Germany and will then also last fifteen years. For a plausible increase in export demand it is assumed increased investments in this scenario (approx. 3.6 billion Euro) will be in relation to domestic production: In 2013 the production value for machine construction and electronic products combined was approx. 340 billion Euro. Since the additional demand for investments particularly aims at these two industries, this will increase production by about 1 percent.

In addition, the assumptions on the consumption of private households is expanded by their international dimension: It is assumed that not only domestic private households, but also households in other countries will change their consumer behaviour and utilise the new options for customisation. When also assuming an average growth of 2 percent in consumption among the largest trade partners, the TINFORGE trade model shows an increase in German exports of a little over one percent. With this model it is therefore assumed that with an increased propensity to consume, export for German companies will also increase.

When illustrating the sole effects changes in demand will have on components of the gross domestic product, we have Figure 19.

Figure 19
Partial scenario 5 – Changes in the gross domestic product and its components compared to partial scenario 4

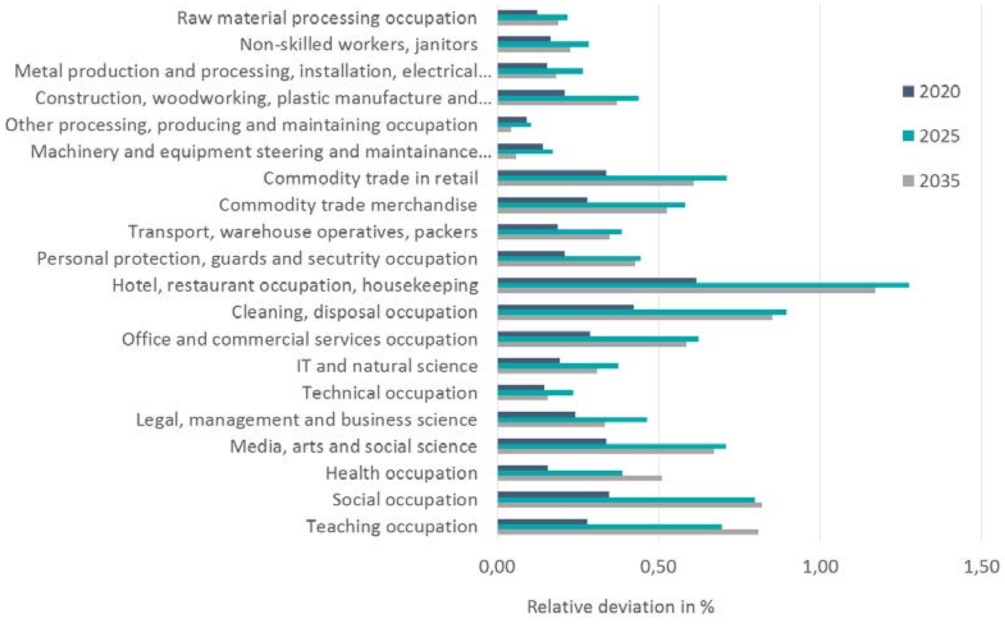


Source: own diagram.

Imports grow considerably, as e.g. many audiovisual devices are not produced in Germany and therefore need to be imported. Furthermore, the demand of private households for services with considerable domestic effect (e.g. rent payments or personal care) are not directly affected by the scenario assumptions. After all, the additional export also entails additional imports. Despite growing export, overall net export is negative compared to partial scenario 4.

The consequences partial scenario 5 has on the primary occupational fields is far more vague than the previous (Figure 20). Based on private households consumptions the demand for "Food service professions (BHF 11)" will see the most growth. Overall, service professions are in greater demand than professions in the manufacturing industry.

Figure 20
Partial scenario 5 – Number of gainfully employed persons by primary occupational fields compared to partial scenario 4



Source: own diagram.

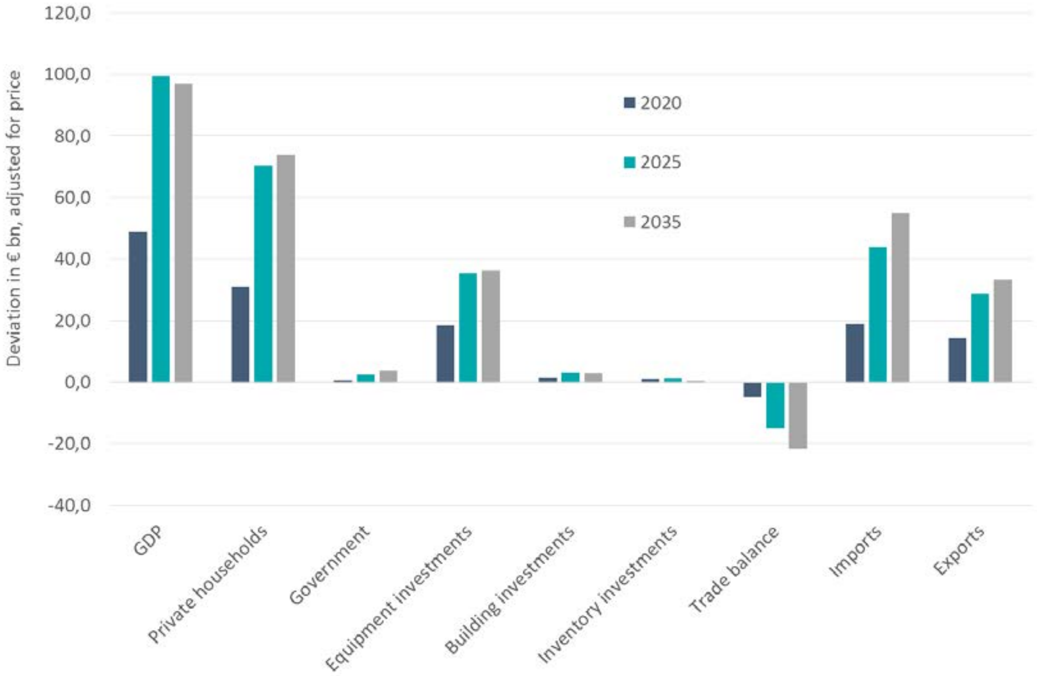
The assumptions made on increased demand as a result of new, improved and customised goods and services ultimately result in a total of 220,000 more gainfully employed persons in 2035 than in partial scenario 4.

3.6 Economy 4.0 scenario (Overall scenario 1-5)

The result of the Economy 4.0 scenario overall is comprised of the five partial scenarios addressed above. It describes the effects of all assumptions of Table 2 (❶-⓲) on the economic development and the labour market.

This results in positive changes: Consumption, investments (particularly equipment) and net export are positive over both periods examined (Figure 21). However, the benefit of declining imports will be lost due to additional demand (partial scenario 5).

Figure 21
Overall scenario 1-5 – Components of the gross domestic product compared to the QuBe baseline projection



Source: own diagram.

The result only arises from joint examination of the partial scenarios (Table 7). For example, the overall scenario has a positive effect on the consumption of private households, which will be triggered by the growing demands (partial scenario 5) and effects of the income cycle (partial scenario 1 & partial scenario 3). Government consumption can achieve an overall positive result during the second period. In the partial scenarios the effects are quite minimal, a positive effect only unfolds in the synopsis.

Equipment investments will either be pushed directly (partial scenario 1) or will grow based on the correlation of cycles (partial scenario 5). The overall result is positive. Building investments, in contrast, only see noteworthy positive values in partial scenario 2 (to 2018). The changes in stock are not part of a scenario and also will not yield positive results through indirect effects.

Overall, imports will expand considerably. However, partial scenario 4 clearly shows decreases due to the lower demand for raw materials and semi-finished goods. This can allow for an overall change in the net export, as except for the first partial scenario, exports consistently show positive results.

Table 7
Overall scenario 1-5 Effects on the components of the gross domestic product in the partial scenarios and overall

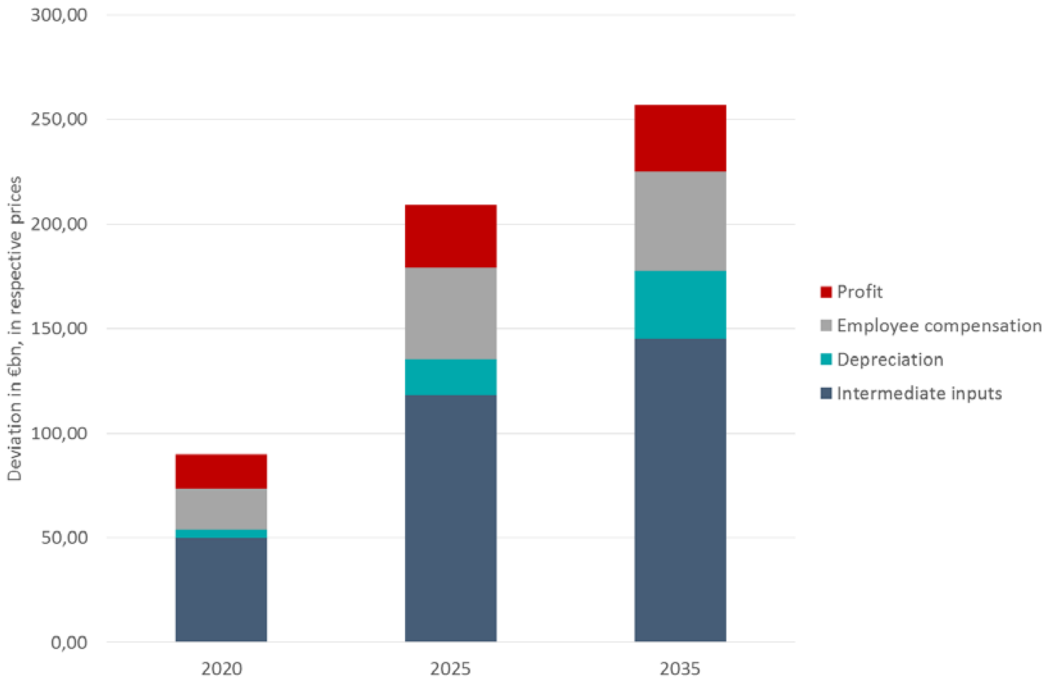
	Equipment investments Partial scenario 1		Building investments Partial scenario 2		Material and personnel costs Partial scenario 3		Occupational fields Partial scenario 4		Demand Partial scenario 5		Industry 4.0 1 to 5	
	2016-25	2026-30	2016-25	2026-30	2016-25	2026-30	2016-25	2026-30	2016-25	2026-30	2016-25	2026-30
Gross domestic product	+	-	+	O	+	+	O	+	+	+	+	+
Private households	O	-	O	O	+	+	O	+	+	+	+	+
Government	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
Inventory investments	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: own diagram.

Figure 22 shows the effect on production. By definition, production consists of the inputs produced and the added value generated. This in turn can be broken down into employee wages, depreciations and net operating surplus (profit). Overall production will grow over the years. 2020 it can increase by approx. 90 billion Euro – 2025 and 2035 even by more than 200 or 250 billion Euro. Whilst demand will initially increase and the cost structures will change, as of 2025 all effects are simultaneously and consistently active.

Figure 22
Overall scenario 1-5 – Primary inputs and inputs compared to the QuBe base-line projection

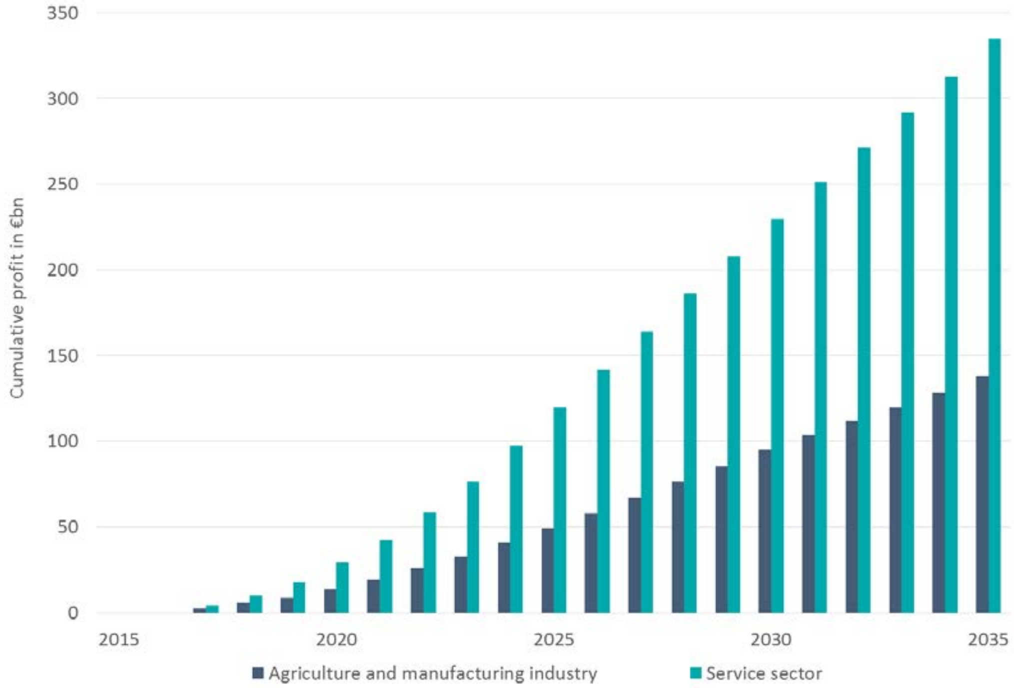


Source: own diagram.

Considerable increases in the employee wage payments can be seen. The reduction of routine duties and the increasing labour productivity in the manufacturing industry benefits occupational fields with a higher level of educational requirement and higher wages. With the companies having a performance-based wage policy, the assumed increase in labour productivity will result in wage increases for the labour force.

Ultimately depreciations will increase over time: Even after the final investments have been made, depreciations will continue. Since depreciations accumulate for the investment years (vintages), the highest depreciations will occur after investments peak, so after 2025 during the second period. At first the additional profits appear minimal. However, macroeconomically past profits are also less than half as high as employee wages.

Figure 23
Overall scenario 1-5 – Development of cumulative profits in agriculture and the manufacturing industry as well as the service industry compared to the QuBe baseline projection

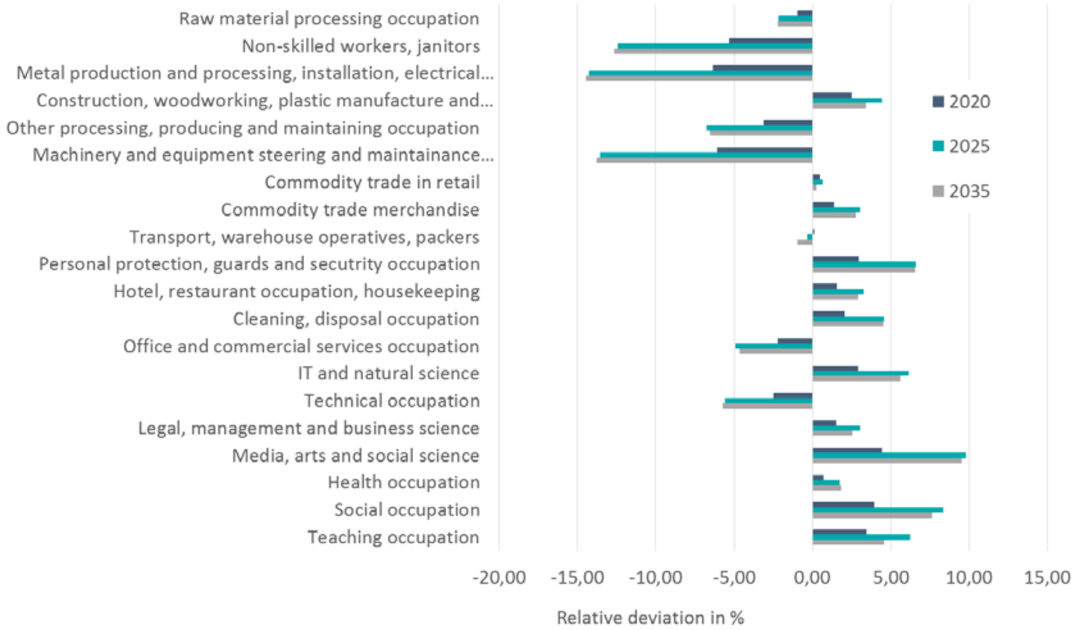


Source: own diagram.

Earnings performance is examined separately (Figure 23). When calculating deviations from the QuBe baseline projection, positive profits can consistently be seen over the entire period, and cumulatively this will yield a cumulative difference in profits of about 340 billion Euro in the service industry and 140 billion Euro for the other industries by 2035. In the years after 2025 profits can then be increased more: The transition has taken place and the momentums of demand persist.

A review of the primary occupational fields shows that professions which are particularly found in the manufacturing industry (particularly "Machinery and plant control and maintenance professions") will be negatively affected despite implementing additional demand (Figure 24). Even the increased demand of partial scenario 5 cannot compensate the results of the changed Input supplies and the changed occupational field structure. The professions benefiting the most from the scenario are in the technical-scientific sector (BHF 14), the social professions sector (BHF 19), teaching professions (BHF 20) and security and guard professions (BHF 10). The positive effects on the Media and humanistic professions (BHF 17) are related to the demand for design and are shaped by the general macroeconomic development.

Figure 24
Overall scenario 1-5 – Number of gainfully employed persons by primary occupational fields compared to the QuBe baseline projection

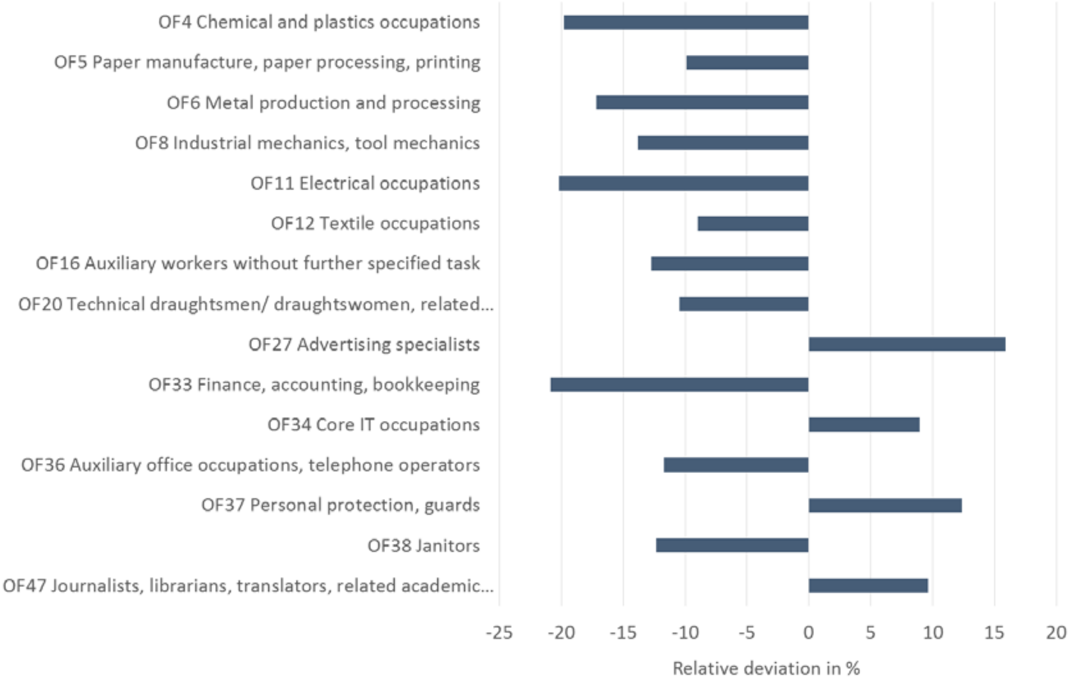


Source: own diagram.

The following examines the level of the 50 occupational fields (Figure 25). To maintain clarity, we have only selected the 15 occupational fields which – relatively – deviate from the QuBe baseline projection the most. The deviations are greatest in the negative. These occupational fields can typically be categorised as manufacturing industry. The exception is occupational field 33 Finance, accounting, bookkeeping, which is affected the most. In relative terms there also are negative effects on electrical professions (BF11) and chemistry and polymer professions (BF 4). This comes as no surprise, as these occupational fields are greatly affected by restructuring the production processes as well as by changing the job constellation, as the substitutability potential is very high based on the concept according to Dengler and Matthes (2015) used here.

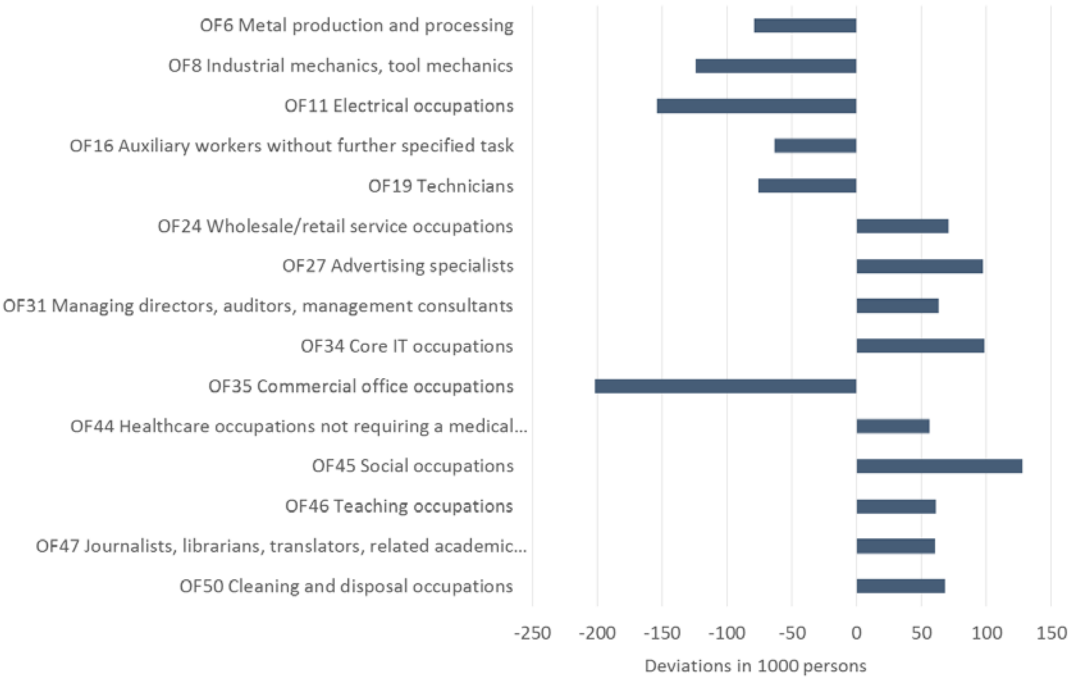
Although in absolute terms, primarily manufacturing professions are also affected by transitioning to Economy 4.0 (Figure 26), however from this perspective office and human resources professions (BF 35) are affected the greatest, since demand in an Economy 4.0 working environment will decrease by about 200,000 persons compared to the QuBe baseline projection.

Figure 25
Overall scenario 1-5 – Number of gainfully employed persons by select*) occupational fields compared to the QuBe baseline projection in 2035



*) Selection criterion: 15 highest deviations according to amount.
Source: own diagram.

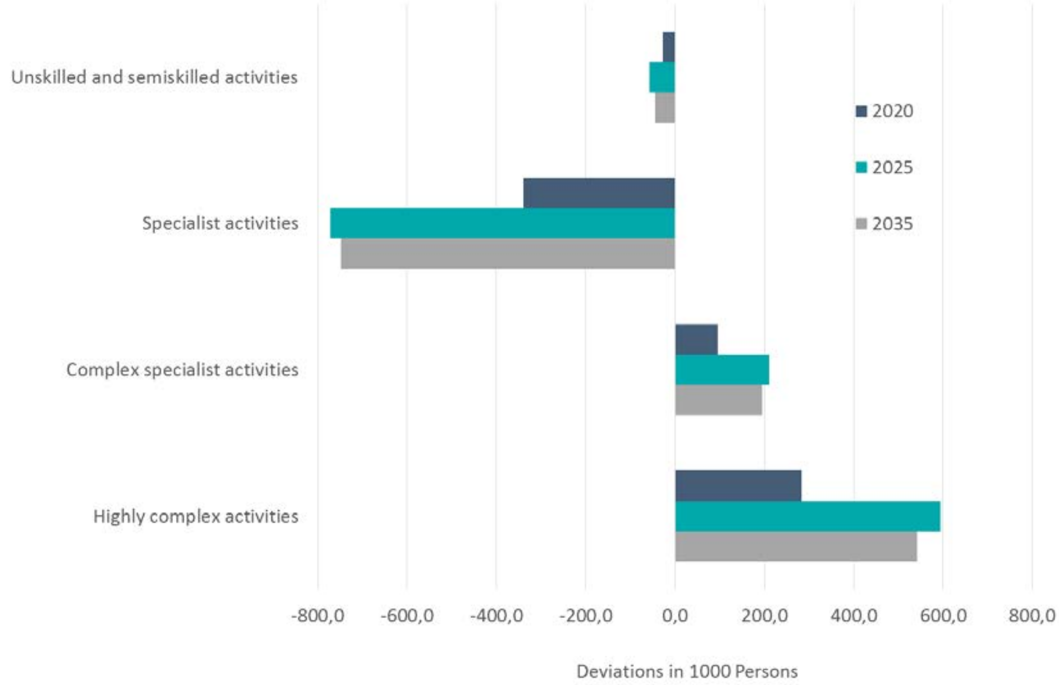
Figure 26
Overall scenario 1-5 – Number of gainfully employed persons by select*) occupational fields compared to the QuBe baseline projection in 2035



*) Selection criterion: 15 highest deviations according to amount.
Source: own diagram.

The industry- and occupation-specific structural changes will also result in new requirements in the workplace. However, in terms of numbers support jobs will be affected less by digitisation (Figure 27). Compared to the QuBe baseline projection there will primarily be less demand for skilled duties and more highly complex duties.

Figure 27
Overall scenario 1-5 – Number of gainfully employed persons by requirement levels compared to the QuBe baseline projection



Source: own diagram.

Comparing a completely digitised working environment (partial scenario 5) in 2025 with a world where technical advances by 2025 will be based on the previous trajectory of development (QuBe baseline projection), shows the effects digitisation has on the overall level of labour demand at minus 30,000 jobs and minus 60,000 in 2035 will carry no weight (Figure 28). However, these two working environments will clearly differ in the structure of the industry, occupation and requirements.

At an industry level, 320,000 jobs will be lost in 2025 compared to the QuBe baseline projection, whilst approx. 290,000 jobs additional jobs will be created by 2025 (Figure 28). The industries with job losses are in agriculture and the manufacturing industry. Overall additional demand for gainfully employed persons will primarily arise in the information and communication industry.

Figure 28
Overall scenario 1-5 – Number of jobs eliminated and newly created jobs by industries compared to the QuBe baseline scenario

Source: own diagram.

The redistribution between the working environments examined is greater at the level of the 50 occupational fields than on an industry level (Figure 29). With respect to the occupational fields, by 2025 about 1.22 million jobs total will be lost and 1.19 million jobs will be created in a different area.

However, both the analysis of jobs created and jobs lost at an economic sectors level as well as analysis at an occupational fields level no longer shows all redistributions. The expected in the labour force due to transitioning to Economy 4.0 become clearest when comparing the Number of gainfully employed persons for each level of educational requirement within the 50 occupational fields in the 63 economic sectors and including all 4 x 50 x 63 potential cells in the analysis (Figure 30).

Figure 29
Overall scenario 1-5 – Number of jobs eliminated and newly created jobs by occupational fields compared to the QuBe baseline projection

Source: own diagram.

Figure 30
Overall scenario 1-5 – Lost and newly created jobs by economic sectors, occupational fields and requirement levels compared to the QuBe baseline projection

Source: own diagram.

In the digitised world, on one hand 1.5 million jobs, which according to the baseline projection will still exist, will be eliminated in 2025. On the other hand, in the Economy 4.0 scenario there will also be 1.5 million new jobs which will not exist in the baseline projection. In summary, the digitised scenario deviates from the QuBe baseline projection by about 7 percent (= 3 million of 43.4 million jobs).

4 Conclusions

This study examines the effects the introduction of Economy 4.0 will have on the national economy and the labour market in Germany. In the process different working environments are compared in line with scenario calculations which build on each other. Unlike last year's study on the results of Industry 4.0 (Wolter et al. 2015), on one hand this also examines digitisation of all service industries. On the other hand we can now draw on the results of two online company surveys, the IAB/ZEW survey on Working Environments 4.0 and the IAB QuEst survey (Quality in Establishment Surveys), to examine, adapt and complement the assumptions made in the "Industry 4.0 Study".

When including all assumptions in the examination, a working environment which is fully digitised in 2025 (partial scenario 5) is compared with a world where technical advances by 2025 are based on the past trajectory of development (QuBe baseline projection). This comparison shows that at minus 30,000 jobs, the effects digitisation will have on the overall level of labour demand is relatively minimal. However, these two working environments will clearly differ in the structure of the industry, occupation and requirements. In the digitised world, on one hand 1.5 million jobs, which according to the baseline projection will still exist, will be eliminated in 2025. On the other hand, in the Economy 4.0 scenario there will also be 1.5 million new jobs which will not exist in the baseline projection. In summary, the digitised scenario deviates from the QuBe baseline projection by about 7 percent (= 3 million of 43.4 million jobs).

Digitisation will not only create a "new" working environment. Along the way this will also accelerate the structural changes. For example, despite holding a high share of added value in the gross domestic product, with respect to the labour force the manufacturing industry will continue to lose importance, whilst the "Information and Communication" and "Teaching" industries in particular will benefit from transitioning to Economy 4.0. The latter will particularly benefit based on education and continuing education playing a key role: With changing and higher standards, after initial training continuing education will be crucial to continuously improve skills (Weber 2016).

But not only the industry-specific structural change will be accelerated. By reducing routine duties, digitisation will also greatly impact the professional structure used to produce goods and services within the each industry. As it turns out, digitisation can therefore be an option for correcting imminent imbalance. For example, less workers will be used in manufacturing professions (including "Technical Professions"), where the QuBe baseline scenario shows shortfalls due to the demographic change. Service occupations, on the other hand, will need more workers than shown in the QuBe baseline projection. The current imbalances will only further increase in "Building trades, wood and polymer processing occupations" and "Office, commercial service occupations" due to the macroeconomic effects of digitisation.

The industry- and occupation-specific structural changes will also result in new requirements in the workplace. However, with respect to numbers, support activities will be affected less by digitisation. Compared to the QuBe baseline projection there will primarily be less demand for skilled duties and more highly complex duties. However, this development should not be considered a risk, but rather an opportunity. For example, currently over 35 percent of all highly complex activities are already being performed by persons without academic training (Maier et al. 2016). Despite the steadily growing portion of academics, in the long term there will also be professions in highly complex jobs – provided, they continue to advance their skills.

It is generally also conceivable the growth in labour productivity and improvements in input will be better than modelled. Likewise, the costs of digitisation taken into account may also be higher. Here we assumed figures to double in agriculture and the manufacturing industry, and to increase by two-thirds in the service industry, however, studies (as explained above) even assume figures will quadruple. The assumed changes in the occupational structures within the industries will result in considerable movements between the occupational fields. The assumptions can also be different here. For example, in addition to the studies of Dengler and Matthes on the levels of routine there also are other studies with in part different results (see e.g. Tiemann 2016a or Pfeiffer and Suphan 2015).[5] All three factors can at a minimum considerably increase the effect on turnover between new and old jobs. So far, the positive employment trend in Germany is occurring with less dynamics in economy and the labour market (Klinger and Weber 2014). So stronger growth in investments and productivity could strengthen the basis for this development.

The assumptions made and the modelling should therefore still be examined critically. If new findings on the transformation to Economy 4.0 arise, the scenarios would need to be adapted or extended. The scenario presented can therefore only be another step in showing the consequences Economy 4.0 will have on the labour market and the economy. Another more specific examination of the impacts implementing Economy 4.0 in other regions (USA, EU, BRICS[6]) will have on Germany as an industrial location could be made. But even the influence the replicability rate chosen will have on the future occupational structure should be examined in more detail. Another publication on this matter will be released shortly which in addition to the concept of Dengler and Matthes, also uses the routine index of Tiemann, the work capacity index

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[5] BIBB did a study on this on behalf of the Federal Ministry of Education and Research (BMBF) (Helmrich et al 2016, http://pt-ad.pt-dlr.de/_media/Projekt-des-Monats_2016-08.pdf).

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

of Pfeiffer and Suphan as well as a replicability index based on the BIBB qualification panel (QPE).

The scenario calculations and the assumptions made, however make one thing clear: There ultimately is no other way – if Germany's unable to implement Economy 4.0, other countries will still do so. And the assumptions which have a positive effect on Germany in the above scenario (pioneer, additional demand abroad, competitive edge) will then count against Germany as a business location. Decreases in production and further unemployment will result. Those are triggered by a loss in competitiveness and domestic demand shifting toward imported products. So the task must therefore be to make the transition as sustainable as possible.

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