From Secular Stagnation to a Technology-driven Upswing? A Comparison of US and German Productivity Data

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Abstract

Digitalisation of production – cyber-physical production systems, additive manufacturing, big data and more – promises to serve as a new basic innovation that changes production radically and thus promotes productivity and automation. This is in stark contrast to economic debates on secular stagnation. Empirically, historical and recent data seems to confirm stagnation tendencies, not an upsurge of productivity. The paper depicts key indicators of productivity and focuses on two countries, USA and Germany, which are self-proclaimed forerunners of digitalisation. Neither at the level of the total economy nor for selected sectors with a high affinity to digitalisation an upwards trend of productivity can be identified. Sluggish productivity despite digitalisation is explained by a combination of time lags of implementation, problems of measurement and data availability, and an unfavourable macroeconomic environment in recent years.

Keywords: Digitalisation, productivity, technological change

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1. Introduction

Recent debates in economic communities on secular stagnation (cf. the contributions in Teilings/Baldwin [eds.] 2014, Gordon 2015 and 2016, Hein 2016) contrast sharply with bright prospects of digitalisation seen by academics in the field of business studies, computer science and engineering (Rajkumar et al. 2010, Berman 2012, Petrick/Simpson 2013, Schuh et al. 2014). Economists basically stress the negative impact of the financial market crisis on global GDP growth trends and focus on the decline of GDP productivity growth since the 1970s. Other scientists but also voices in economics identify digitalisation as a supply-side game-changer which is going to revolutionise the economy by product and process innovations (OECD 2017). This view is supported by business and politics. Initiatives like the Industrial Internet Consortium (USA) or Industry 4.0 (Germany) promote a fast and thorough implementation of digitalisation (Industrial Internet Consortium 2018, Plattform Industrie 4.0 2018). However, recent empirical data indicates that a radical change has not materialised yet (Nordhaus 2015).

The phenomenon of digitalisation covers a broad range of new technologies like cloud computing, additive manufacturing, big data, internet of things or cyber-physical production systems (Geisberger/Broy 2012, Plattform Industrie 4.0 2014, Evans/Annunziata 2012). The impact on the economy could be revolutionary, indeed. In Gershenfeld's (2012) vision, we, the prosumers (consumers with the ability to make products themselves), will be able to create nearly all products at home, based on basic ingredients (filament) and some prefabricated components. The characteristics of products are specified by digital blueprints, which are offered as open source to everyone. Other researchers foresee fully automated plants in which sensor-equipped and connected machines or smart devices communicate with each other in order to produce all kinds of products customised for every taste one can think of (Rajkumar et al. 2010, Petrick/Simpson 2013, Monostori 2014). Even if those visions can be realised only to a certain extent in the near future, such a digital (r)evolution should lead to a huge increase in productivity. It reduces transportation, it shrinks machinery, it makes labour redundant, and it creates new products and value (Schuh et al. 2014). However, the data so far does not show such an increase in productivity.

Therefore, the paper investigates why we currently do not see the expected increase in productivity. As will be depicted in the paper, data availability is limited which restricts analyses mainly to descriptive statistics and an explorative approach. A focus is on the USA and Germany as two forerunners of digitalisation. If the fruits of digitalisation evolve then its impact should appear in the data of those two countries. At the same time this comparison sheds light on country differences despite the – at least potentially – global availability of digital technologies.

The paper continues in chapter 2 with a review of the literature on digitalisation and then compares the results of this strand of literature with debates on stagnation and long waves. Five hypotheses are derived from this. Chapter 3 then discusses the data and presents stylised facts of productivity developments in the USA and Germany. The last chapter concludes.

2. Digitalisation or secular stagnation?

Digital production covers a broad range of new technologies. Firms outsource their datacentres and store and compute data in the cloud. Firms acquire huge amounts of data to analyse the behaviour of their customers. Fintechs enrich traditional services with easier access and algorithm-based support. Information is now 'at your fingertips' (an old marketing slogan by Microsoft), i.e. easily available and available at low costs. In manufacturing, adjustable digital blueprints, 3D printing and cyber-physical production systems make mass customisation at low costs possible. 3D printing (or additive manufacturing) means that a single raw material (plastics or metal) in the form of filament or granulate is used to print an object layer-by-layer (Petrovic et al. 2011). Objects can vary in form, size and complexity limited by the size of the printer, statics and the material which is used. Moulds or punches are therefore not required which simplifies the production process. 3D printing also allows for very complex forms which have advantages in weight and thermal characteristics compared to conventional production methods (Reiher/Koch 2015). Due to the fact that the whole design process takes place in software, redesigns are relatively easy and customisation – up to the famous lot size one – is in reach at low costs (Petrick/Simpson 2013). Although conventional technologies allow for mass customisation as well, production processes based on such technologies usually assemble a limited number of prefabricated components but the design itself cannot be changed by the customer. This technology is no longer used for rapid prototyping only but also for production. For example, some components of airplanes are nowadays fabricated by printers in order to save transportation and storage costs (Triebs et al. 2015).

3D printers can be integrated in factories with cyber-physical production systems (Rajkumar et al. 2010, Broy 2011, Broy et al. 2012). Such highly autonomous production systems make use of sensor-equipped and programmable machinery and devices. Those systems are able to process a huge amount of sensor data and the components are able to interact in real time through common communication protocols. Subsequently, they can adjust to a changing environment and changing purposes and they are able to cooperate in order to achieve a common goal, may this be based on heuristics, machine learning or other forms of AI (Sha et al. 2008, Monostori 2014). Consequently, the level of complexity and quality that can be achieved is much higher compared to conventional production systems due to the autonomous negotiation processes between the devices and the automated analysis of data (Baheti and Gill 2011, Bangemann et al. 2014). This holds for production itself and the products of cyber-physical production systems. Moreover, customisation and simplification of creation is not at the expense of a decline in productivity. On the contrary, experts foresee a massive rise in productivity (Schuh et al. 2014).

Digitalisation promises firstly to add value by creating new products and services and by offering a tremendous variety of products. Secondly, the costs of production are going to decline. Thirdly, the required amount of inputs would decline or inputs could be recycled. Ideally,

> "assemblers will be able to create complete functional systems in a single process. They will be able to integrate fixed and moving mechanical structures, sensors and actuators, and electronics. Even more important is what the assemblers don't create: trash. […] [A] product assembled from digital materials [i.e. the atoms and molecules of the quote above, AK & TN] need not be thrown out when it becomes obsolete. It can simply be disassembled and the parts reconstructed into something new." (Gershenfeld 2012: 52)

According to this vision, all kinds of products could be created at a fingertip with a minimum of resources or recycled resources. However, although part of this is already reality, most of it is still in its infancy, especially when it comes to mass production. An open question is, to what extent productivity increases have already been realised or will be realised in the future. Two aspects have to be considered: whether the new technologies have the potential to increase productivity substantially and whether the new technologies will be used throughout the economy. The review above has demonstrated that many authors are quite optimistic. They have in common that they firstly stress the importance of technology and secondly they focus on a potential long-term upswing of the economy due to digitalisation.

Economic contributions, although not ignoring the supply-side factor technology, take a broader view and acknowledge a variety of factors that drive an upswing in productivity, even if the main driver is technology. Already the classical contributions by Schumpeter (1934: 74–94, 1942: 82-85, 1947) points to the role of organisational and social factors for process and product innovations – entrepreneurs have to make use of technologies and they have to organise its implementation. From a Keynesian point of view, one could add that implementation requires investments, and investments require trust in future sales. Moreover, economic debates about the impact of new technologies stress the cyclicality of business activity and the combination of different types of cycles – short, medium, long (Bernard et al. 2014). Schumpeter (1939), based on work by Kondratieff (1926), identified long waves driven by basic innovations and shorter waves caused by other factors. Such a conceptual framework covers both different factors and up- and downswings, which is a difference to the view presented above that rests on long-term upswings without taking into account the cyclicality of growth periods.

Against the background of this sketch of potential factors that impact on productivity, empirical research allows for an at least tentative answer to the question whether an upwards trend in productivity can be identified. Nordhaus (2015) uses US data to put the idea of a technology-driven 'singularity', i.e. a boundary of production after which GDP and productivity will sharply rise and accelerate, to a test. Automation would affect both the demand and the supply side. From a demand-side point of view, it would drive down prices and thus foster consumption in some sectors – which in reference to Baumol Nordhaus calls 'Baumol's cost euphoria' (Nordhaus 2015: 9) – and would consequentially lead to falling relative productivity rates and increasing relative prices in other sectors, i.e. Baumol's cost disease. From a supply-side perspective, the focus is on substitution of capital with 'digital' capital, to be more precise: information capital, which would push productivity and GDP growth upwards. Based on a neoclassical growth model, Nordhaus' analysis shows that GDP growth would tend to increase indefinitely (information produces information produces information…) and wages – for those who still are employed – would grow as well. Most of the empirical indicators, however, do not point to an acceleration of productivity and GDP growth. Only a rising share in (information) capital substantiates the idea of a singularity although nothing indicates that this is a near event (Nordhaus 2015: 8-29).

Similarly, the work by Gordon cannot verify a forthcoming upwards trend. On the contrary, at least in retrospective the data substantiates secular stagnation, not a rise in productivity and economic growth. Based on US data from 1920 to 2014, Gordon (2015) identifies four different phases of which the first two are characterised by high productivity increases. Since the 1970s, the trends of productivity and real GDP decline as well as annual growth rates of aggregate hours and total factor productivity, which is used as a proxy for technological progress (cf. table 1). Gordon interprets the time period from 1996 to 2004 as an exception and explains the upsurge by the dot.com revolution (or bubble), not contradicting the declining trend.

Table 1 Depiction of annual growth rates by Gordon (2015)

	Real GDP	Aggregate hours	Output per hour	TFP
1920–1950	3.58	0.61	2.97	2.17
1950–1972	3.89	1.24	2.65	1.79
1972–1996	3.01	1.63	1.38	0.52
1996–2004	3.32	0.81	2.51	1.43
2004–2014	1.58	0.36	1.22	0.54

Note: 2004 and 2014 data refer to third quarter of each year.

Source: Gordon (2015: 55)

Table 1 also points to a correspondence between high [low] productivity and high [low] real GDP growth. Gordon's GDP growth projections for the USA are pessimistic and in clear opposition with respect to a forthcoming long-term economic upswing caused by technological innovations (Gordon 2016: 634-639). Mainly, his argument is that much is already achieved, progress because of that difficult, and four headwinds, as he calls it, will reduce GDP growth in the future.

> "Rising inequality has diverted a substantial share of income growth to the top 1 percent, leaving a smaller share for the bottom 99 percent. Educational attainment is no longer increasing as rapidly as it did during most of the 20th century, which reduces productivity growth. Hours worked per person are decreasing with the retirement of the baby-boom generation. A rising share of the population in retirement, a shrinking share of working age, and longer life expectancy are coming together to place the federal debt/GDP ratio after the year 2020 on an unsustainable upward trajectory. These four headwinds are sufficiently strong to leave virtually no room for growth over the next 25 years in median disposable real income per person." (Gordon 2016: 642).

Even if one does not to buy all his four arguments, his quote reminds the reader of factors besides technology that shape GDP and productivity developments. This was also a starting point of the whole debate on secular stagnation. After demonstrating that a simple extrapolation of old growth trends to project future GDP developments is useless, Summers (2014) identifies finance as both a driver of economic performance in the past and as a cause of the economic crises of 2007/8. If investment falls short interest rates cannot fall enough to stimulate investment again, and falling wages and prices will worsen the situation. Employment decreases and Ponzi financing increases. As a remedy, he recommends to strengthen public and private investment, promote business confidence and to maintain social protection. This is not a completely new insight. Hein (2016) reminds of the work of Josef Steindl on stagnation, who has analysed the stagnation period of the Great depression in contrast to the absence of stagnation in the so called golden age after world war II; which then again was followed by a period of stagnation since the late 1970s. Steindl highlights factors that shield against stagnation. Among other factors, he points to R&D spending and the technological catch-up process in Europe after World War II. However, he also stresses the role of stagnatist policies, i.e. restrictive fiscal and monetary policies, which contribute to stagnation. Backhouse/Boianovsky (2016) provide an overview on the historical debate on stagnation.

Derived from this review of the literature, five hypotheses will be put to a simple test based on descriptive statistics in the next chapter to explain the currently sluggish development of productivity despite plenty of new technologies:

(1) There is no increase in productivity right now but there will be a new Kondratieff, i.e. a rise of productivity in the future.
(2) The measurement of productivity is insufficient to cover productivity increases by digitalisation and thus undervalues the increase in productivity.
(3) There is an increase in productivity but it is restricted to specific sectors or products with a relatively low weight for the total economy.
(4) There is no significant increase in productivity because digitalisation does not raise productivity (much).
(5) The impact of technological change as a supply side factor hinges on the demand side, too, i.e. that changes in productivity depend also on a favourable macroeconomic environment.

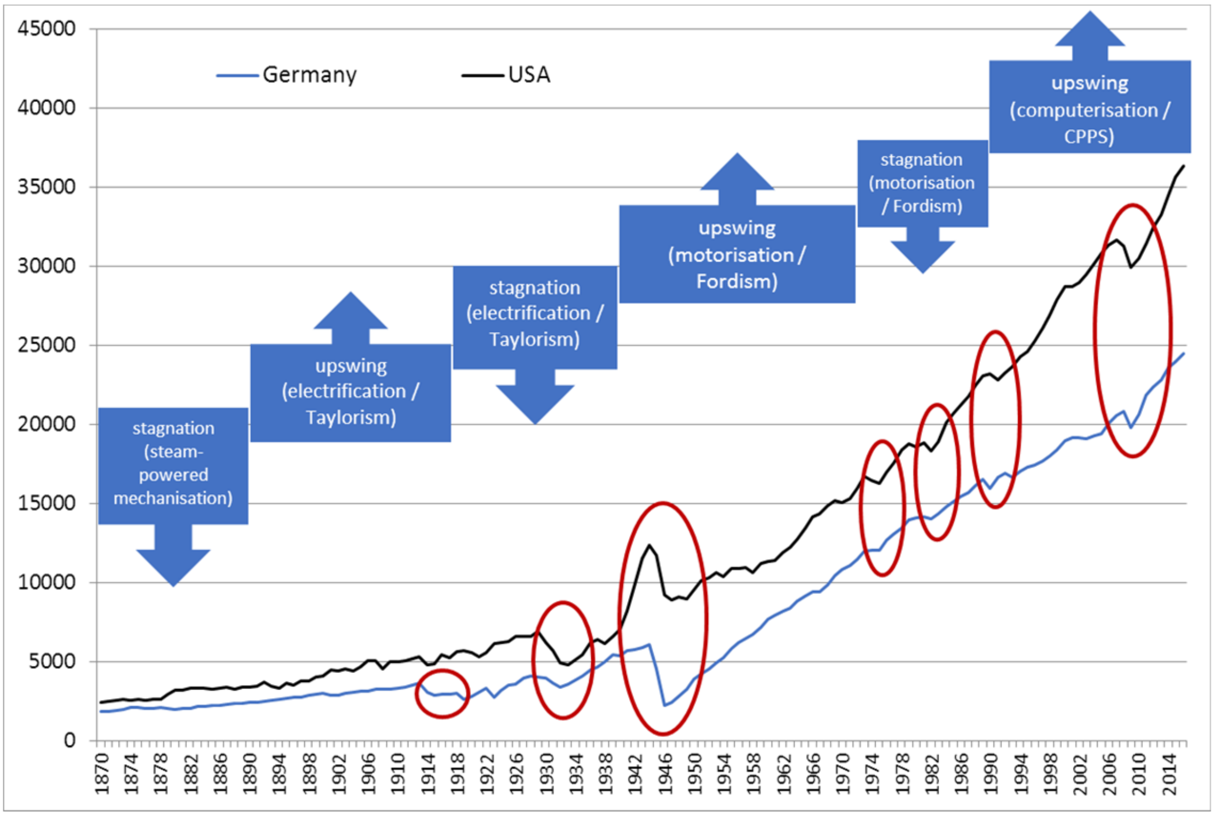
3. Data and findings

Productivity growth can be interpreted as an outwards shift of the production possibility frontier. Potential causes are better organisation and management of inputs, learning effects and improvements in education or better technology but also a stimulation of investment which usually makes use of the state of art of capital goods raising productivity in relation to the existing capital stock. The most common indicator for productivity is labour productivity because in the end all improvements should lead to an increase in output and value in regard to the labour used for production. Labour productivity is measured by value added per employee or hour; because of differences in working hours per year and person labour productivity per hour is the preferable indicator. In line with a standard production function approach capital deepening, i.e. increase in capital per labour hour, contributes to an increase in output. Land as a production factor is ignored because it is assumed that it is limited and cannot contribute to productivity increases. All value added which cannot be traced back to labour and capital is summed up in a third indicator, usually called total factor productivity (TFP). TFP is often referred to as technological improvement which is (only) valid if neither capital and labour inputs nor their elasticities change. An important issue here is that changes in human capital, i.e. education and training, are reflected in the TFP, not in labour productivity because it is assumed that labour is homogeneous. Therefore, an increase in university degrees of employees leads to a higher TFP which means that the influence of technology is overestimated. In order to increase labour productivity more capital or better technologies could be used which is the reason why the OECD interprets capital deepening and TFP as growth contributions to labour productivity (OECD 2018a: 52).

Both levels and growth rates are provided in common data sources. Often data at sectoral level is available, too. However, longer time series are rare. This paper uses mainly data from the OECD and Eurostat, in particular the OECD productivity database (OECD 2018b) and EU KLEMS (2018). Both databases include productivity data for the USA and Germany (cf. for an in-depth analysis of German productivity developments Ademmer et al. 2017).

In retrospective, if technological revolutions have had an impact on the economy and have had caused long waves then we should be able to see significant changes in the living standard of the people over time that correlate to technological basic innovations. Real GDP per capita can serve as a proxy for the change in living standards. Pronounced upswings should be followed by phases of stagnation or even downturn. For the USA and Germany from 1870 to 2015 (figure 1), at least this indicator tells a different story. An upwards trend of GDP is disturbed by some pronounced peaks and troughs. And those peaks and troughs are related to crises, not to technology-caused long waves: World War I in Europe; the Great Depression; the war economies of the late 1930s/early 1940s and the fall in GDP afterwards; less pronounced the oil crises 1973 and 1979 and the 2nd Gulf war 1990; finally the financial market crisis.

Figure 1 Real GDP per capita in PPP, 1970-2016



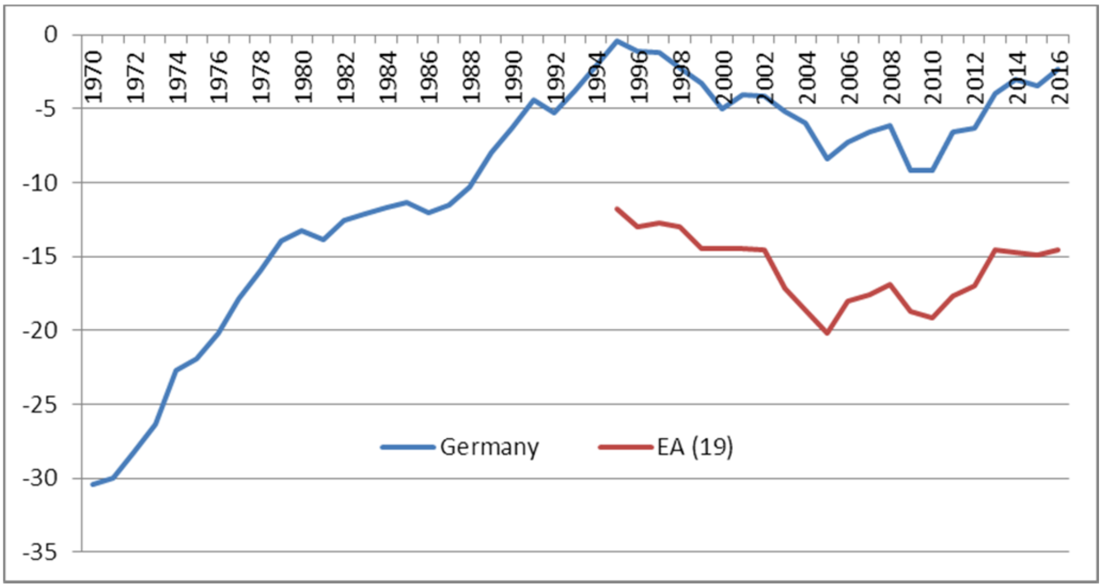
Source: JST database

This points to a rather steady diffusion of technology disrupted by crises, not caused by technological changes. But maybe a closer look at productivity levels and growth rates is able to highlight changes caused by technological improvements.

Even between advanced countries there might be differences in productivity levels, especially after World War II. An empirical study based on OECD productivity data by Wolff (1994) demonstrates that the USA has been the leading economic country after World War II in terms of productivity but most OECD countries were largely able to catch-up in the period from 1970 to 1988. The data Wolff presents indicates that technology spreads and that it leads to a conversion of productivity levels at the level of the total economy, measured in labour productivity and capital deepening, whereas total factor productivity shows a more disparate development. After conversion, productivity growth rates for the total economy – and also for the reference country USA – slow down but they are not fully synchronised among countries. Moreover, the evolution of productivity is characterised by an uneven development of productivity growth rates at sectoral level within countries.

A catch-up process can be very well identified for Germany from 1970 to the mid-1990s (see Figure 2). Since 1995, productivity levels are nearby but below the US level, which points to an exhaustion of the 'advantages of backwardness' (Wolff 1994: 107). Data for the euro area is only available since the mid-1990s. For this time period, the productivity levels are below the German and US levels, and the data does not indicate a catch-up process in terms of productivity levels.

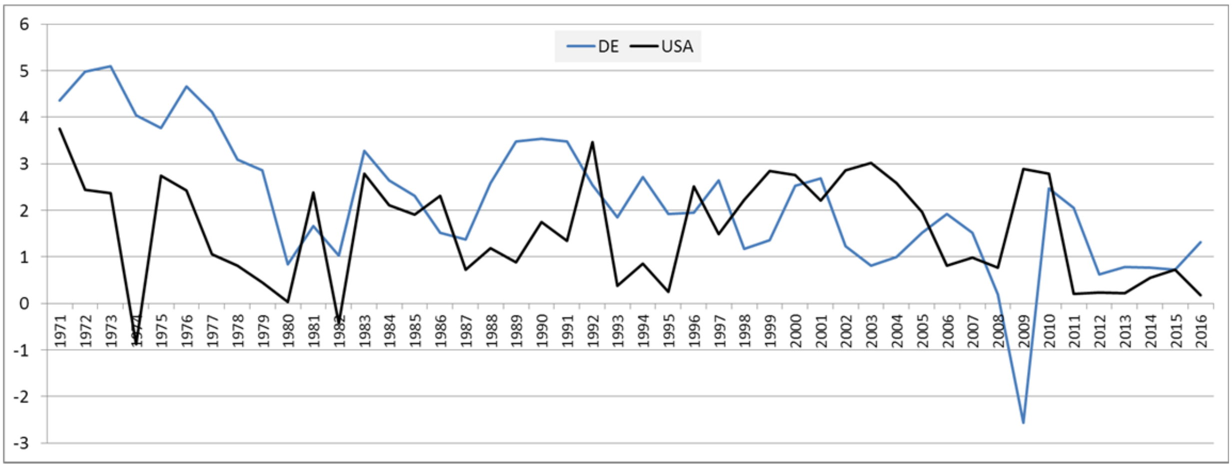
Figure 2 Productivity levels measured by gap in GDP per hour in respect to the USA



Source: OECD productivity database

Labour productivity growth rates for both countries since 1971 confirm the German catch-up process (Figure 3). Until the 1990s growth rates in Germany are higher than in the USA. Over the whole period, we see a slightly negative trend for Germany, and for the USA a rather constant trend although there are heavy and unsynchronised fluctuations, not only during the financial market crisis. Differences in growth rates between the countries can be explained by a different sectoral structure due to differing specialisation and differences in economic regimes. For example, the striking contrast between the development of the US and the German productivity in 2009 is a result of two different labour market regimes. In the USA a lot of producers responded to the downturn after the financial market crisis with dismissals, which technically increased productivity if value added does not drop too much. In Germany, firms were able to hoard labour because of the German system of industrial relations that allows for paid training, temporarily reduced working hours and subsidies by the state in times of crisis (Herzog-Stein et al. 2010). It resulted in a temporary decline in productivity until the economy recovered again.

Figure 3   Labour productivity growth rates (per hour)

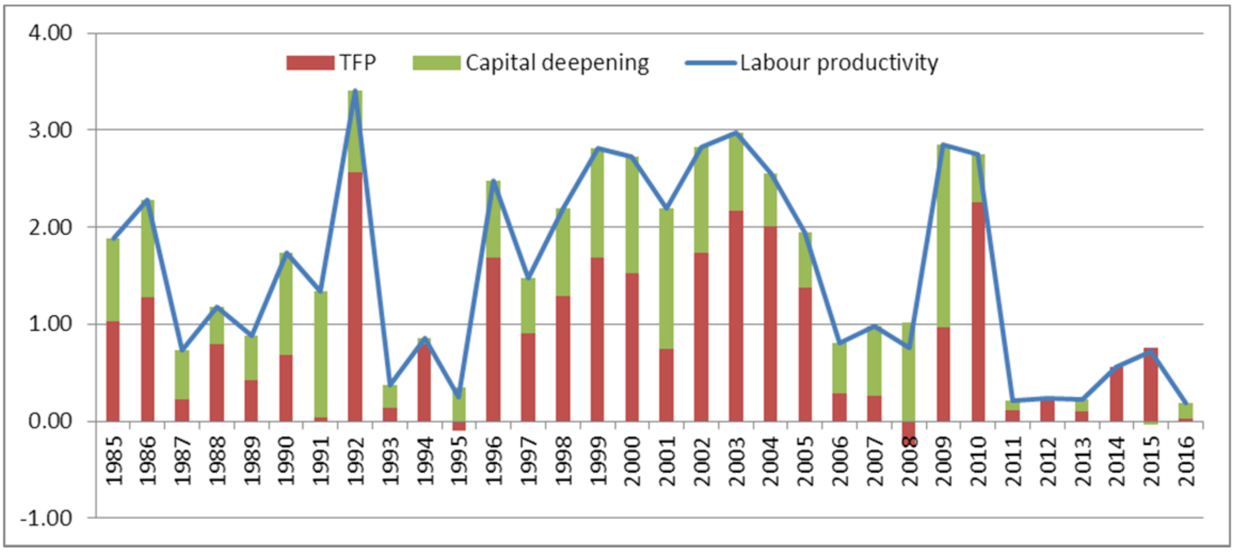


Source: OECD productivity database

Recent years are characterised by slow growth rates in both countries and not a strong upswing as the advancing implementation of cloud services, 3d printing, smart devices, cyber-physical production systems and so on would suggest.

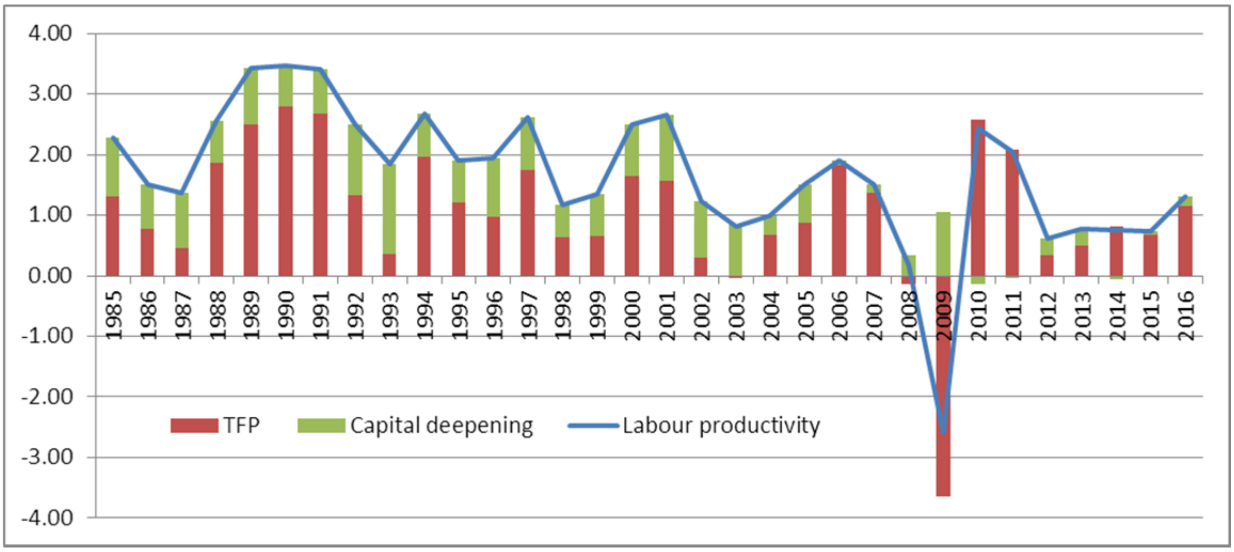
For a shorter time period, data for TFP and capital deepening is available, too. Figures Figure 4 and Figure 5show the contributions of TFP and capital deepening to labour productivity.

Figure 4   Contributions to labour productivity in the USA



Source: OECD productivity database

Figure 5 Contributions to labour productivity in Germany



Source: OECD productivity database

Although for many and also recent years TFP dominates labour productivity no upwards trend can be identified. Note that TFP does not exactly measure technological progress because it is the residual of what is not explained by labour and capital. Therefore, the negative development of TFP in Germany in 2008/09 does not reflect a massive decline in technological capabilities but labour hoarding at this time.

EU KLEMS data allows analysing disaggregated data. Figure 6 compares the total economy with the so called market economy, which excludes all sectors like real estate and public administration in which deflators are mainly estimated because market prices are not available. Both market economies have a higher labour productivity growth rate than the total economy. Two sectors of this market economy, manufacturing and information & communication show especially high growth rates.

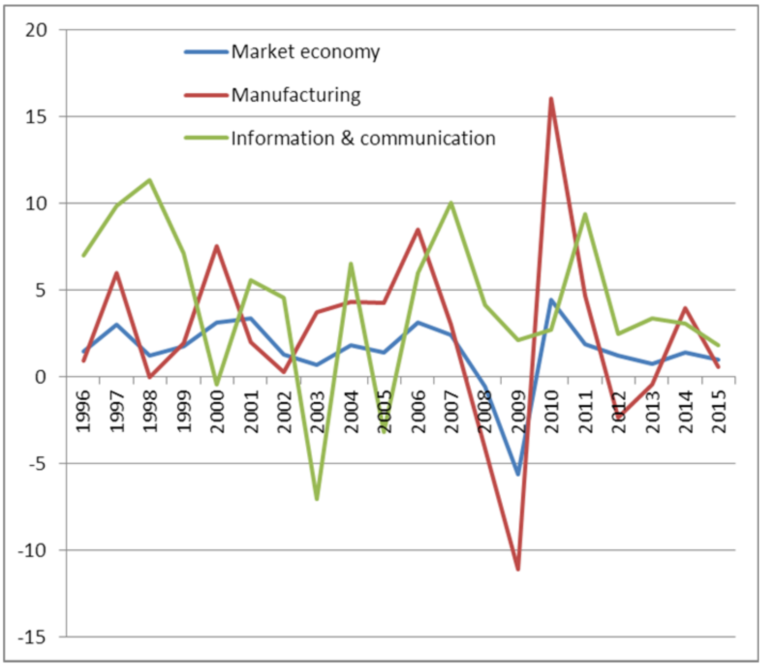
Figure 6 Labour productivity in the whole economy and selected sectors

	Average annual growth rate 1999 to 2015	
	USA	Germany
Total economy	1.3	1.2
Market economy	1.5	1.4
Manufacturing	3.9	2.5
Information & communication	4.5	3.4

Source: EU KLEMS, own calculations

However, differences in productivity growth rates between sectors are not a new development. On average, in Germany the growth rates of manufacturing and information & communication are both above the market economy but they do not start to move further away. There is no indication of an upswing in productivity due to digitalisation in those sectors that might be overcompensated by slow-performing other market sectors.

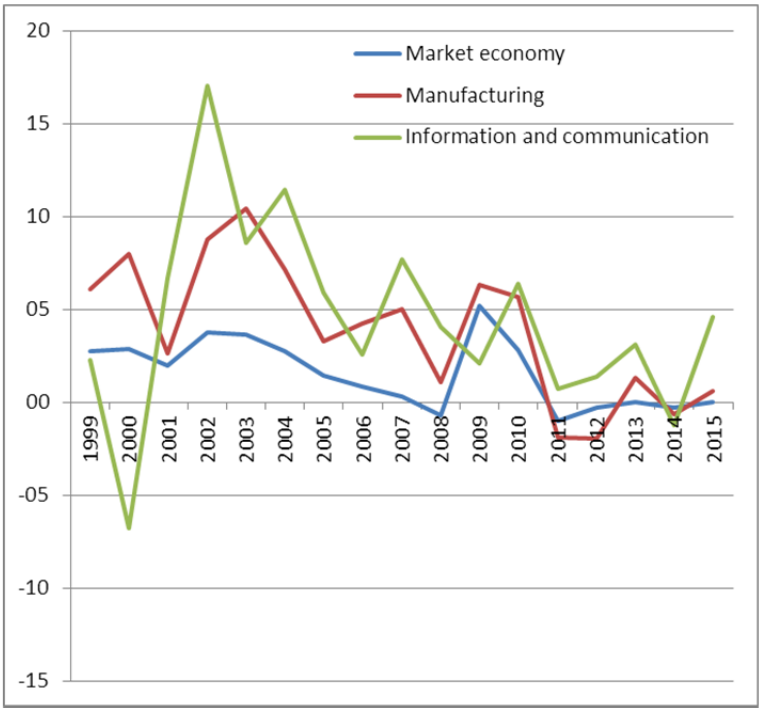
Figure 7 Labour productivity growth rates in the market economy, in manufacturing and in information & communication in Germany, 1996-2015



Source: EU KLEMS, own calculations

The time period for the USA starts only in 1999. On average, information & communication shows lower growth rates than the market economy. A negative trend is common to both the market sector and the two other sectors.

Figure 8 Labour productivity growth rates in the total economy, in manufacturing and in information & communication in the USA, 1999-2015

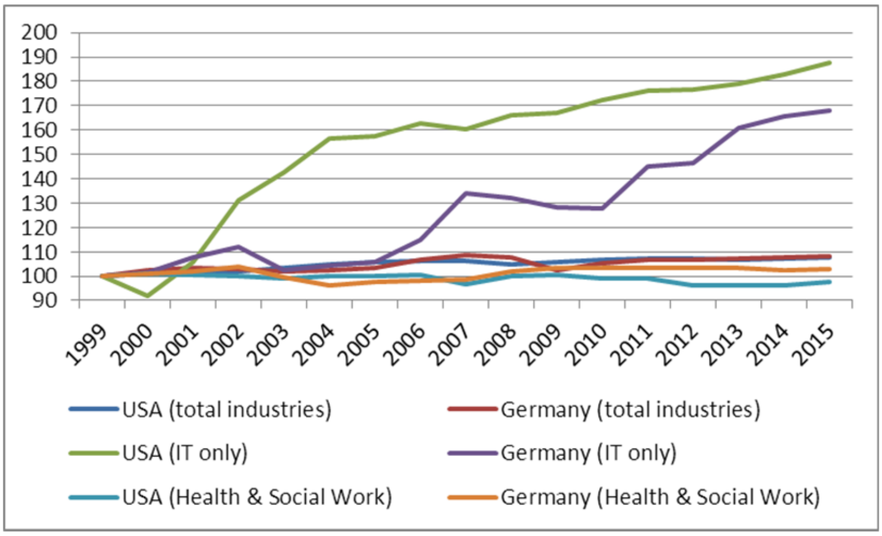


Source: EU KLEMS, own calculations

To sum up, sectors which should have a high affinity to digitalisation usually and in the medium term perform better in relation to the rest of the market economy but there is no indication of recent innovations that drive productivity in those sectors further upwards. On the contrary, productivity growth rates of the sectors in question slow down similar to the total economy.

In order to analyse further differences between sectors, Figure 9 depicts the development of selected sectors since 1999 measured by TFP as a proxy for technical progress. The IT sector, a sub-sector of information & communication, performs in both countries much better than the total economy and service sectors like health & social work which are focussed on direct human-human interaction. Digitalisation has become a reality in health care, ranging from internet-connected pacemakers to artificial animals for dementia patients (U.S. Food & Drug Administration 2017, Shibata et al. 2009), but still a lot services are time-consuming human-based care tasks which limits productivity increases. What might be more interesting is that productivity in IT moved away from the total economy not in recent years but in the USA in the early 2000s and in Germany from mid-2000s onwards.

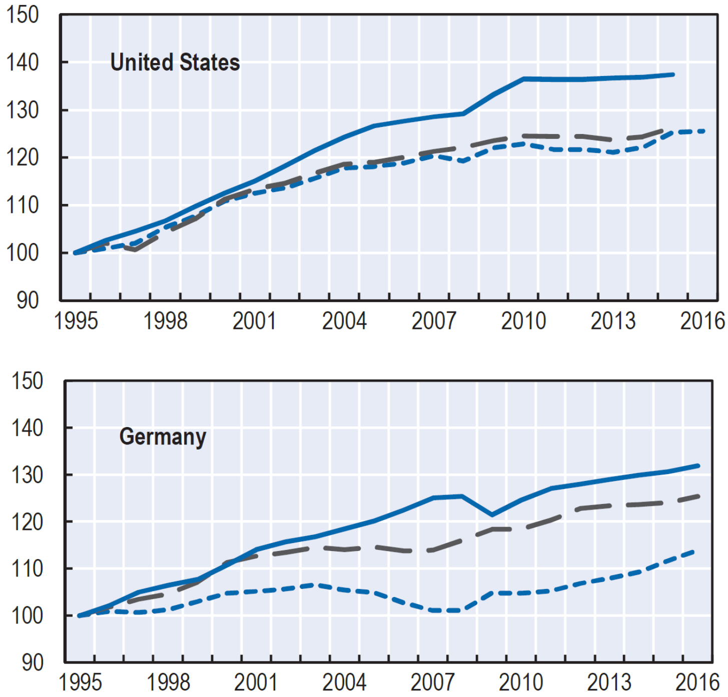
Figure 9 Total Factor Productivity per working hour, 1999=100



Source: EU KLEMS, own calculations

Suppose that digitalisation has potential because it offers a broad range of new technological tools that could, in principle, have a significant impact on production and productivity. If so, what explains that this potential could not be realised by now? Figure 10 highlights at least one aspect of this. In both countries the gains of labour productivity were unequally distributed and did not contribute much to an increase in wages of employees. Starting in 1995, the data demonstrates that real wages lagged behind labour productivity and could not catch-up afterwards. There is still a gap in both countries although real wage increases in Germany in recent years partly closed the gap. Especially the real wage deflated with the consumer price index, which is the relevant index for workers as consumers, points to an underperformance of real wages. From a macroeconomic perspective, low wages translate *ceteris paribus* into low private consumption. If so, this irritates business confidence and thus investment.

Figure 10 Development of labour productivity in relation to real wages (CPI deflated and GVA deflated)



Notes: blue line: labour productivity (gross value added per hour worked); dotted blue line: compensation per hour worked, CPI deflated; grey-dotted line: compensation per hour worked, gross value added deflator based

Source: OECD 2018a: 85-6

4. Conclusions

It seems that only a combination of arguments leads to an accurate depiction of the consequences of digitalisation for productivity. (1) Currently, digitalisation is insofar hype as an increase in productivity for the total economy but also for sectors with an affinity to digitalisation cannot be identified. On the contrary, advocates of secular stagnation and a declining trend in productivity can claim that they are much more consistent with the data. However, theoretical arguments demonstrate that digitalisation could change production in the future. Past experience also tells that it will take some time to implement and spread the new technologies which most likely is not a process of a few years but maybe decades (Brynjolfsson et al. 2017). It is an open question if this will happen and if digitalisation will serve as a new basis innovation with revolutionary potential. (2) One reason for the difficulty to measure the impact of basis innovations is that long-term time series on both productivity for a broader range of countries and indices of technological change do not exist. Moreover, there are many caveats that limit the interpretation of the existing data. The indicators, especially TFP, do not exactly measure what they promise to measure. Furthermore, the data is highly dependent on assumptions, estimations and the choice of the right deflator. Therefore, a careful interpretation is required. (3) Some sectors are performing better in terms of productivity than the total economy, like manufacturing and information technology and communication. However, increases in growth rates of those sectors date back to previous technological changes, currently a new upswing of productivity is not present in the data. Moreover, some services rely and will rely on human interaction in future as well which restricts productivity increases and will lead to unbalances developments. As a basic innovation, digitalisation should improve productivity in most of the sectors, not only in some, and it should change productivity for the total economy noticeable. (4) The data, which does not indicate a huge increase in productivity due to digitalisation in recent years, could be explained by the fact that digitalisation does not change productivity. Although anecdotal evidence stresses value added due to digitalisation aggregated data cannot confirm it. First research on firm-level data seems to show that some dominating firms, so called superstar firms, have a high productivity (Autor et al. 2017). Still the question is then why, if the superstar firms are dominating the market, the increase in productivity does not impact more on the total economy or at least on some sectors. (5) Finally, the macroeconomic environment has to be taken into account. An obvious candidate for the pronounced downturn of GDP and productivity growth in recent years is the financial market crisis. But this might only be a *pars pro toto* for the dependence of productivity on the macroeconomic environment. Or to put it simply: Innovations are only realised if investors have confidence in future sales. Fiscal retrenchment, austerity and trade wars do not foster sales, confidence and productivity. Supply of technology is not sufficient to start a new Kondratieff.

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