Solving Productivity Puzzles - on the Nature of Total Factor Productivity, Technological Change and the Explanatory Power of the Mismeasurement Hypothesis

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To my beloved mother.

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Part I

General Introduction

> "Productivity isn't everything, but in the long run it is almost everything. A country's ability to improve its standard of living over time depends almost entirely on its ability to raise its output per worker." (Krugman (1994, p. 11))

As the 2008 winner of the Nobel Prize in the field of economics clearly points out, economic development and the evolution of mankind is deeply interconnected with productivity and its trend over time. It not only defines the standard of living but also provides the conditions for the business environment by implicitly shaping the technological premises of production processes. By doing so, technology and productivity work as natural boundaries on the road to prosperity (OECD (2015b, preface)). Even more, they can significantly limit the growth path and the standard of living in the future. Representing a potential economic bottleneck, for economic growth it is of central concern to fully exploit the technological opportunities and productivity forces - so to speak, to unbound the prometheus[1].

Economic welfare, expressed as levels and growth rates of gross domestic product per capita, therefore roots in the productivity forces. Moreover, and as neoclassical growth theory has stated, in a steady state growth in income per capita is impossible without the existence of technological progress. Undoubtedly, implementing new and improved technologies in the production process, like in the course of the invention of the internal combustion engine by Jean-Joseph Ètienne Lenoir in 1858, has clearly raised overall productivity, output and therefore the wealth of nations. Griliches (1987, p. 1), in this context, defines (aggregate economic) wealth among others as the knowledge of how to convert the input quantities into the desired output goods. That point clearly describes what we would identify with technology - in some way, the 'blueprints' of the production process. Moreover and in order to quantify technological progress by the translation into aggregate economic productivity, Zvi Griliches states that:

> "Measuring technological change is of interest because, in a sense, it defines our wealth

[1] With regard to Landes (2003).

and puts limits on what we can accomplish." (Griliches (1987, p. 1))

Being confronted with the data for many developed economies nowadays, declining rates of growth in productivity have to be noted for (at least) the last two decades. Over time, average annual growth rates of gross domestic product per capita have been cut in half for Germany on a decade-by-decade comparison[2]. For other countries, similar patterns can be outlined. Decreasing productivity not only puzzles but exhibits the challenge to shed light on the forces faltering economic development. Otherwise, the fruits of economic well-being will be out of reach for future generations.

In order to contribute to the illumination of the productivity puzzles, the present study tackles the nexus of productivity, technology and economic development. The two main purposes include an exploration into the quantification of technology in economic theory and an elaboration on the implicit forces shaping productivity. The former question elaborates on the nature of the variable, commonly used to express technology - which is total factor productivity (TFP), the latter question discusses two potential strands of explanations for decreasing rates of productivity. Hereby, it asks whether real economic reasons contain explanatory power or whether the productivity puzzle is just illusory and a result of incorrect measurement in national accounts.

By doing so, the present study's aim and contribution are to analyse and possibly reduce measurement errors for the explanation of productivity puzzles. Moreover, it points on definitory problems of the exact content of the TFP-residual and finally evaluates on the environmental conditions for the German economy. The latter then offers potential for policy-makers to critically reflect on these conditions and execute appropriate policy actions.

In a first step (part II), the history and evolution of TFP are presented, starting with the works of Cobb and Douglas (1928) on production functions back in the 1920s. Works by Jan Tinbergen (1942) and Robert Solow(1956; 1957) then mark the next milestone in the history of growth accounting - the analytical framework to decompose economic growth into its contributors. As a result of the decomposition, TFP was calculated as a residual and since then seen as a representative of technology. The consecutive debate on the nature of this residual has formed the discussion on whether the TFP-

[2]As the empirical section of the present study will show, the average annual growth rate for 1971-1980 has been 2.8%, whereas nowadays it is only 1.4% for 2006-2015 (see chapter 8).

residual is an equivalent of technology, just related to technology or a melting pot of sources, which economic theory is not (yet) able to identify.

Assuming that TFP is related to effects of technology in any way, the second point of interest (part III) then shapes the discussion of two potential strands of explanation. On the one hand, there is the hypothesis of incorrect (or insufficient) measurement frameworks. If mismeasurement in national accounts can be corrected for, then the current productivity slowdown must be illusory. Of main interest is a study for the United States, set up by Chad Syverson (2016)[3]. Syverson tries to correct for certain aspects, national accounts are not able to measure, he claims. Especially in course of the introduction of (modern) information and communication technologies (ICT) into economic sphere, the slowdown has become stronger - so Syverson's analysis mainly focuses on potential leaks in the ICT sector. As a contribution, the present study applies his method on Germany and favours the same conclusion. Mismeasurement is a problem and it contains explanatory power, the gap of missing productivity, however, is simply too large to be explained. For the main explanatory content, other reasons must be inferred. In addition to potential mismeasurement in the ICT-sector, it is also discussed whether price deflation offers explanatory power (by making use of the so-called hedonic price correction method).

By adopting the revived[4] theory about so-called "secular stagnation", real economic causes play the lead. Secular stagnation, a term which describes a prolonged period of insufficient growth, is nowadays mainly associated with works of Larry Summers (2015b) and Robert Gordon (2012; 2014). Whereas the former focuses on the demand side of an economy, the latter analyses supply side effects. The present study then applies the supply side logic on Germany and asks whether deficiencies in the business environment in Germany provide explanations for the productivity puzzles. Hereby, it is structured by splitting the conditions into headwinds, which falter economic growth. It will be shown that some headwinds play a larger role, others a smaller.

The discussion does not claim to find one single reason but rather points on a combination of many effects, shaping insufficient conditions for the economy to prosper. Arguing in a sense of real economic

[3]For the current study, the working paper version Syverson (2016) was used (published later as Syverson (2017) with some minor modifications).

[4]Initially formed by Alvin Hansen (1939), it was Larry Summers (2015b) who reintroduced the debate.

causes, it relies on an empirical section at the beginning of part III. It provides a compendium of several variables, all of them related to productivity development. As the majority of studies in this field rely either upon TFP or labour productivity as central variables, the present study follows. For reasons of benchmarking and comparing, the United States plays the counterpart of the research object Germany. Not only does the mismeasurement calculation apply the same (mathematic) logic as in the US-study by Syverson, the empirical section as well as the headwind-discussion are presented in a sense of comparing German conditions with those of the United States, too.

With regard to the first of the two main purposes of the study, it is stated that TFP is related to technology but should not be treated as an equivalent. Any interpretation and application on economic policy has to be treated with a certain amount of care. For the second of the two main purposes of the study, it is shown that mismeasurement offers explanatory power but the gap of missing productivity is simply too large. Real economic reasons, combined as a nexus, are responsible for the productivity puzzle. Hereby, some aspects seem to be more significant for Germany (i.e. the demographic headwind), some seem to be of less concern (i.e. the educational system).

Part II

Total Factor Productivity - an Insufficient Measure of Technology?

1 Introduction

Nowadays, total factor productivity (TFP) is the most commonly used variable, derived from a specific economic framework to capture effects of technology for social accounting purposes. Robert Solow once stated, that

> "an important, usually, the most important, element in the growth of a modern economy is the sustained increase in total factor productivity" (Solow, 2009, p. 30).

Due to the residual nature of the TFP, one has to be careful in simply aiming for an enlargement of the TFP component. TFP is an outcome and not a cause (even though it is assumed to represent technology as the best proxy available). As the name says, total factor productivity captures the change in efficiency over time of all factors included in production. Efficiency in this context is a measure "used loosely to denote the ratio of output to any related input or class of inputs" (Kendrick, 1956, p. 2).

A change in productivity might result from many sources; part III of the present study explicitly deals with productivity puzzles and the (potential) causes for productivity development. Examples of what TFP[5] might cover too, include changes in management practices and organisational rearrangement. Further, it can include marketing, network and production effects, like (the value of) brand names or economies of scale, market competition or adjustment costs in the production process OECD (2015a, p. 12).

Even though many aspects might play a role in defining TFP, the notion is commonly devoted to

[5]Some sources, like the OECD, prefer the term Multifactor Productivity (MFP) over Total Factor Productivity (TFP). For example, see (OECD 2015a).

changes in technology. Due to this, the term is frequently used by economists as a proxy or even a perfect substitute for technology. For broader analyses, and due to the fact that economic theory lacks of a better alternative, TFP seems to be the best variable available for a quantitative approximation of technology. This first part of the study does not intend to substantially criticise the use but it tries to make aware of simply equalizing technology and TFP.

So, there is serious doubt on whether TFP can simply be used as an equivalent for technology and whether or not it captures all effects of technology in production processes. If one takes a deeper insight into the theory of TFP (with regard to definition and measurement), it can easily result in confusion. Even among the most famous economists and (early) works in this field of study, it is not clear what total factor productivity actually is.

Without any doubts, total factor productivity offers potential for several fields of serious controversies. The definitions range from simply promoting the equivalence of technology and TFP (in this case the simple correlation by neglecting any other sources):

"Improvements in technology - the invention of the internal combustion engine, the introduction of electricity, of semiconductors - clearly increase total factor productivity" (Law, 2000, pp. 6-7) or

"Economists tend to think of productivity as measuring the current state of technology used in producing the goods and services of an economy (or industry or firm), and want to interpret the changes in such a measure as reflecting 'technological change', shifts in the production possibilities frontier. For this purpose, it is usual to focus on one or another version of 'multi-factor productivity', where the list of inputs considered extends beyond labour and includes also measures of capital services and also, occasionally the use of materials and other inputs." Griliches (1987, p. 1),

admitting that,

"[...] conventional measures of productivity are only a distant and murky reflection of it. Changes in such indexes, especially sharp short-run fluctuations, should be interpreted with great care since they may have little to do with technological change proper." (Griliches (1987, p. 2))

to definitions, that there is no relationship at all:

"Since we know little about the causes of productivity increase, the indicated importance of this element [productivity increase, O.Z.] may be taken to some sort of measure of our ignorance about the causes of economic growth" (Abramovitz, 1956, p. 11).

When talking about an equivalence of total factor productivity and technology, this equivalence is often interpreted as a perfect correlation and/or causality (see Law (2000) above, who is well aware of the fact, that there is only a relation, no equivalence however, between the effect of technology and the residual).

The remainder of the first part of the study illustrates the evolution of the famous variable and provides a short mapping of the theoretical (measurement) framework. It also asks for the nature of total factor productivity. Following Carlaw, K. and Lipsey, R. (2003), three views of what TFP actually measures have been identified. A first one, which follows the idea of a (more or less) equivalence of technology and the TFP-residual, which can be labelled as the "traditional approach". A second one, which exactly criticises this equivalence and emphasizes the boundaries of human knowledge regarding the variables (the "ignorance view") causing growth and a third one, which on the one hand denies the equivalence but on the other hand accepts a linkage and relationship between the two notions.

The question, whether TFP can be seen as a technology-equivalent or not, shall not be answered completely (as it seems impossible to do so) but it is tried to shed some light on the discussion on the nature of TFP. One can, however, already anticipate, that - in contrast to (former) common belief - there is no simple and perfect equivalence.

2 Definitions and Early Research

2.1 Technology, Technique, Progress and Change

In economic theory, there are plenty of notions and definitions related to the general description of the growth process of an economy. For many variables, however, it seems like there is not 'the' right definition but rather a range exists (Godin (2015, p.3), Kennedy and Thirlwall (1972, p. 12)). Before proceeding, it seems appropriate to shortly decompose and discuss the notion of technological change and its siblings. It is important to reduce confusion, as still today economists often talk of different variables, notions or even approaches, when in fact often meaning the same thing. Accurately defining the relevant technological aspects is difficult, a fact Joan Robinson (1952) has clearly mentioned a long time ago: "Technical progress is difficult to discuss in precise language" (Robinson (1952, p. 36)).

A first potential field of confusion is the one that includes technology and technique and with respect to the more dynamic growth context technological progress and technical progress. When scanning literature, one finds a huge amount of notions describing a production process or even broader, the structure related to the transmission of (non-) physical inputs goods into output goods. In fact, there is confusion about the notions, whereas often they are used interchangeably without further interpretation.

In economic theory, a line of separation is drawn. However, in the Anglo-Saxon literature, it is not. Technical and technological are assumed to represent the same thing - the mechanical and operational knowledge, combined with physical units, like machines, to convert input goods into output goods. Everything, that is related to the production process is named as technology or technique. Blueprints, which capture the skills are meant as well as heavy machines, tractors and tools, necessary for the workers (which are themselves part of the production technology/technique). Outside the Anglo-Saxon sphere, there is a division between technology and technique. To become familiar with the complexity of technology and in order to have a more precise understanding, it is shortly shown, where the differences (might) lie between these notions.

Holwegler (2003) defines technology as the book of blueprints, available in an economy. It contains the knowledge and skills, available for the production process at a specific point of time. As a result of progress, the pages of the book of blueprints' increase - in other words: new production knowledge is available. Technique, then describes the application of the new knowledge, available due to inventions, the process of innovation and knowledge diffusion Holwegler (2003, p. 9).

For a more precise definition, the view has to be expanded to the microeconomic field - the firm-level in this case. Especially, the Schumpeterian trilogy is still famous and separates the development process (Kromphardt and Teschner 1986, p. 236 quoted after Holwegler 2003, pp. 9-10).

Three different stages of the development process are identified:

1. Stage of invention: An invention simply represents the evolution of ideas for new products and processes.

2. Stage of innovation: Following the stage of invention, an innovation stands for the knowledge, resulting from the initial idea. It then is the application of the early invention and describes the 'new' way, a product is generated.

3. Stage of diffusion: After having implemented the initial invention in the innovation stage, the 'new way' of producing (or the 'new good') is applied in other companies or industries. It diffuses through the economy, meaning that more and more production processes adopt the 'new way' of producing.

This trilogy can be transferred to and implemented into the general macroeconomic framework. Technological development can be related to the stage of invention, whereas technical development covers the stages of innovation and diffusion (Holwegler, 2003, p. 9).

These lines of separation match with those of Schmookler (1966), who defines technological change as "the rate which new technology is produced" as well as "change in knowledge", whereas a change in technique is rather " a change in practice" and therefore if a company "uses a method or input that is new to it" (Schmookler (1966, pp. 1-9) quoted after Godin (2015, p. 8)).

Moreover, for the two notions of 'change' and 'progress', many works do not explicitly separate. Even though the notion 'progress' implicitly exhibits a positive, forward-looking character, there might be in fact, backwards-looking development as well. Technically, this should be captured by the notion 'regress'. 'Change', therefore, has a more neutral underlying, compared to 'progress' and its negative form 'regress'.

As innovations, usually, only find their way into production processes of an economy, if they in some way raise efficiency, they can be considered as improved or superior. Due to this superiority, compared to the existing production structure, it seems fair to think of an inter-changeability of 'change' and 'progress' in this context. Any other technology (and therefore technique) would not be applicated, when producing less, with the same amount of inputs or produce the same output, requiring more inputs.

2.2 The Aggregate Production Function

Modelling production processes requires a theoretical understanding of the transmission process of input goods into output goods. The nature of the (development) process is hereby determined by the technological premises. Combining capital K and labour L - the two relevant factors in production - is usually executed by either a specific production technology A, describing the nature of the transmission process and hereby implicitly representing limitationality or substitutionality of K and L, or a form in between (substitutionality is explained in the remainder of this section, examples for limitationality is the Leontief production function. For an explanation of the latter see i.e. Csontos and Ray (1992)).

Many starting points in the history of accounting for economic growth are reasonable; the present study chooses to start with defining the very basic production structure. A common one, if not 'the' most common, is the so-called Cobb-Douglas-production function (Felipe and Adams (2005, p. 428)). In the late 1920s, the economist and senator of Illinois (1949 - 1967) Paul Howard Douglas and his mathematical fellow and friend Charles Wiggins Cobb developed their own vision of a production structure (Cobb and Douglas, 1928), aiming for a way to theoretically describe the conversion of input goods into output goods on an aggregate level. It is interesting to note that the authors hereby implicitly brought up the later growth accounting theory as they claimed to have found a way to examine

"whether this increase in production was purely fortuitous, whether it was primarily caused by technique, and the degree, if any, to which it responded to changes in the quantity of labor and capital." (Cobb and Douglas (1928, p. 139)).

Even though Cobb and Douglas (1928) are associated with the works on the production function, it is noteworthy that the origins go back to the work of Knut Wicksell in the 19th century (Wicksell (1896), Wicksell (1900)). The "reward" for its formulation has at least to be shared with Wicksell. See Samuelson (1979, p. 923) for example, who reckons Wicksell's merits and Malinvaud (2003) for a more detailed review on Knut Wicksell's contributions.

After having set up indexes of the amounts of capital, labour and production, the authors define the theoretical construct (Cobb and Douglas, 1928, p. 152 ff.). Based upon their empirical part, the actual production function (homogeneous of degree one) takes the following form[6]:

$$P' = 1.01 L^{\frac{3}{4}} C^{\frac{1}{4}} \tag{1}$$

Aggregate, actual output P' is produced by capital C and labour L and a constant (here: 1.01 and in the more general case $P = bL^{\frac{3}{4}}C^{\frac{1}{4}}$), with b, as independent from labour and capital input. It is a catch-all variable, including all forces, which have not been measured or were not able to be measured (Cobb and Douglas, 1928, p. 155) - a shifting parameter of technological taste.

Certain features apply (i.e. partial elasticity of output due to incremental changes in labour equals $\frac{3}{4}$, and in capital $\frac{1}{4}$ respectively). In contrast to other production functions, the Cobb-Douglas framework enables the user to substitute for the production factors. Capital and labour can be exchanged for each other, when respective factor prices are allowed to be flexible, too. Substitutionality allows to preserving the output level. If, for example, wages rise and labour becomes more expensive (in relation to capital), then it is substituted by a rise in capital use, keeping the production level constant.

Such a simple but useful framework has paved the way for separating for the technology component, in order to isolate and emphasize the role of technology in production. The Cobb-Douglas-production function has become one of the most (if not the most) relevant production function in economic theory. Paul Samuelson acknowledged the Cobb-Douglas-function as "part of every economist's toolbox"

[6]The authors first set up the actual production function P', derived from actual values of the period 1899-1922 for the US manufacturing sector. The mathematically derived form later is modelled and named by P.

(Samuelson (1979, p. 924)). Its simplicity, however, requires some special properties ("Santa-Clause-properties" Solow (2007, p. 13)) and assumptions, which might limit its general appliance. This been mentioned, the practicability and acceptance was and still is huge so that it is a "wonderful vehicle to generate informative examples" (Solow (2007, p. 13)).

Neoclassical growth theory, and its starting point - usually associated with the works of Robert Solow in the 1950s - uses the Cobb-Douglas framework as its theoretical underlying. It enables the user to set up a simple but useful framework to theorize a production process. In fact, however, the present study will argue, that besides the contribution of Robert Solow[7], it was a study by Jan Tinbergen (1942), which first modelled and expanded it into a more dynamic structure.

2.3 Notion of Efficiency and the NBER-program

The notion of efficiency, a.k.a. 'total factor productivity', can be traced back to a research program of the National Bureau of Economic Research (NBER) in the 1940s. It includes the works of George Stigler (1947), contributions from Solomon Fabricant (1959; 1954), John Kendrick (1956; 1961) and Moses Abramovitz (1956) - just to name a few of them, who paved the way for a detailed analysis of the sources of economic growth. In the centre of the study and consecutive debate is the general dichotomy of investment (leading to capital deepening, increasing capital per labour input and similar definitions; generally the increase in input quantities) and technological progress (with positive effects on productivity) and its relevance for economic performance of a country. Stigler (1947), however, has worked on productivity analyses independently from the later works of Jan Tinbergen (see chapter 3.2).

Even though many have contributed to the evolution of early productivity measurement, it was Kendrick (1961), who brought up one of the most pioneering (empirical) studies. His book on productivity measurement has not only offered a step into a mainly unexplored theoretical field; even more, it has provided (one of) the most detailed works on empirical productivity measurement and is still considered as one of the major surveys on national accounting and productivity measurement in general.

[7] And the works of Trevor Swan (1956).

It is remarkable, to which extent Kendrick has traced productivity trends and taken care of their relationships with other variables - a merit, many have acknowledged (see for example Kavesh (1962) or Fabricant (1961)). The latter has once labelled the book as "the most comprehensive survey of productivity trends in the United States ever made" Fabricant (1961, p. lii).

The book itself consists of more than 600 pages of detailed and carefully collected data on the time period of 1889 to 1959 for the United States. Not only does it provide a catalogue, similar to a goldmine for researchers, it also aims to overcome the shortcomings of other efficiency measures - an issue, Stigler (1947, p. 43 and p. 49) has already emphasized. Stigler (1947, p. 49) criticizes efficiency measures, which only rely on one single production factor - mostly labour - which, according to him, are incomplete measures of economic progress.

Compared to labour productivity, Kendrick prefers an index, which covers all factors included in production. This index, later made famous as total factor productivity, was meant to overcome the shortcomings of (simple) labour productivity measurement in order to account for technological progress. Again it was Fabricant (1961) in the foreword of Kendrick (1961)'s survey, who labelled the "new" notion of efficiency as "the best currently available approximation to a measure of efficiency" Fabricant (1961, p. xli). Without exaggerating, it still is the most commonly used (and probably the most suitable) tool for productivity measurement and still works as a representative for technological progress.

For the purpose of this study, one can thankfully rely on the excellent introduction of Fabricant (1961), who has summarized the main findings of Kendrick (1961)'s work (even a chapter "The Facts in a Nutshell" exists). Shifting the focus to total factor productivity, Kendrick finds that its annual growth rate for the covered period of time (1889-1959) is 1.7% in the US private domestic economy (see also Kavesh, 1962, p. 835 for a review of Kendrick (1961)). Real private domestic product instead grows at roughly 3% to 3.5% (Fabricant, 1961, p. xxxvii). So, about one half of economic growth is caused by effects of increasing efficiency, the other half can be traced to the effects of an increase in input factors (forming the already mentioned "dichotomy" of productivity effects versus effects of an increase in input factors). Whereas Kendrick's opus magnum is probably the most important one in these times (mainly due to its excessive data work), other contributions of the NBER-program of the

1940s have contributed, too.

For the covered period of time, 1899-1939, Stigler (1947) finds a rising trend in output, measured by national income in certain industries. Output in the relevant six[8] industries has almost trippled over time. The average working amount of hours worked per worker, however, has declined but employment, measured by the number of workers, has risen by around one-third over time so that in total the amount of hours worked in the US has remained almost constant. As chapter 9.2.4, in course of the theory of secular stagnation, will show, several effects on labour markets contribute and potentially neutralize each other (i.e. an increase of the amount of people employed can be counterbalanced by a reduction of the average amount worked per week).

Even though Stigler emphasizes the necessity to include all factors of production in the productivity measurement, he focuses only on the labour input (expressed as output per worker). According to his data-set, output per worker rose at around 3% per annum. Abramovitz (1956) finds productivity as the main source for economic growth for the covered period of time (1869-1953), by using data from the work of Simon Kuznets (1952), as well as from Kendrick (1961)[9]. The study and findings will be discussed in detail later on (see chapter Abramovitz' Measure of Ignorance and a Reaction). General (empirical) developments with regard to productivity are provided in more detail in chapter 8. The notion "total factor productivity" can be derived from the work of Stigler (1947) (Stigler calls it a "changes in the efficiency with which all resources are used" Stigler (1947, p. 49)) , the exact notion, however, is from the work of Kendrick (1956).

[8]Agriculture, manufacturing, mining, gas and electric utilities, and steam railroad are the six industries covered in his analysis. He focuses on these industries, as they have initially employed around two-thirds of the national labour force (1899) and produced around 90% of national output in the US.

[9]See the acknowledgements of Abramovitz (1956, p. 5).

3 Growth Accounting

3.1 Origins of Growth Accounting

In economic theory, the notion and concept of "total factor productivity" (TFP) is commonly used to describe the role of technology in the production process. It hereby captures the effects, not resulting from a simple increase of the input quantities of the respective production factors (i.e. Hulten (2001), Ganev (2005)).

The theoretical framework, which is normally chosen to identify and calculate total factor productivity, is the so-called "growth accounting approach"[10] (Cadil (2007, p. 347)). Accounting for the sources of growth in a tighter definition stands for separating the individual production factors and their respective contributions to output growth from each other. Usually, the factors are captured by capital input, labour input and the technology component.

After accounting for capital input growth, labour input growth and the resulting growth in output, there is a residual left over, aiming to represent technological progress - the growth of total factor productivity. As the present study is about the linkage between productivity, technology and more broadly the development path of an economy, this section provides insight into the modelling structure and the underlying theoretical framework of the commonly used variable (TFP) to capture the effects of productivity (and technology).

Even though the notions "growth accounting", "the residual", "total factor productivity" and similar ones are usually assigned with the works of Robert Solow in the late 1950s[11] (Solow (1957)), it was the Dutch economist Jan Tinbergen (1942), who has originally set up a framework, in order to separate for the causes of economic growth.

The initial version of the mathematical underlying, the Cobb-Douglas production function, did not contain a dynamic perspective. In other words, a time-index was required, in order to provide a framework for a more dynamic approach. It was Jan Tinbergen, born in 1903 in The Hague (Nether-

[10] Alternative approaches to define and measure TFP are (i.e.) the "Index Number Approach" or the "Distance Function Approach" (for example see Carlaw, K. and Lipsey, R. (2003)).

[11] Whereas Solow (1956) sets up his vision of a neoclassical growth model without technological progress, it was his 1957 paper (Solow, 1957) which enriches this neoclassical model with a technology component. This technology component then is measured as a residual and has later become famous as "Solow-residual".

lands), who took a step further and developed a time-indexed, dynamic framework on the base of the Cobb-Douglas production function (Tinbergen (1942), Oppenländer (1976, p. 15)). Tinbergen allowed for comparing specific points of time with regard to their respective production process. By doing so, he provided the possibility to compare the efficiency levels of the production process of an economy. More precisely, if one compares the production function of say yesterday $(t-1)$ to that one of say today (t), one can examine the (change in the) efficiency level of how input factors are converted into output goods. Even more, by fitting the model to the data, it is possible to check whether an economy's ability to efficiently convert input into output has improved or worsen.

The beginnings of (neoclassical) growth theory are usually associated with the works of Robert Solow and the independently developed growth model of the Australian Trevor Swan in 1956 (Swan (1956)). Pointing into the same direction, the approaches of Solow and Swan slightly diverge and differ in detail. Solow i.e. provides a graphical exposition in dependency of the capital-labour-ratio, whereas Swan uses the output-capital-ratio instead, which allows to directly observe the effects of technological progress from the illustration (in the basic Solow model, technological progress can only be observed by the roundabout of calculating efficiency units). Swan worked out one single contribution to form his growth model, including aspects of technology, whereas Solow separately modelled technological progress (Solow (1957)) and expanded his 1956-paper by the role of technological progress (Solow (1957)).

It is often discussed, why the neoclassical growth model is commonly referred to the works of Solow and not to Swan likewise by the same extent. In an article by Swan's daughter, Barbara Spencer (see Dimand and Spencer (2009)), she argues on a number of reasons but also emphasizes the kindness of Solow, who recalls Swan's contribution to neoclassical growth theory regularly. Aspects, which separate the two approaches from each other do not only include the role of technological progress or the issue on production technology (CES production technologies or only using a special case out of it - the Cobb-Douglas production function (see Dimand and Spencer (2009, pp. 118-120)); these aspects also include geographical obstacles and the lack of modern communication possibilities back in the 1950s. Whereas Swan has published his entire work in Australian journals only (besides the reluctance to publish in general due to his high standards of work (Dimand and Spencer (2009, p. 119))), Solow's articles were accessible to economic public quite more easy.

Both works form the base for the growth accounting approach. However, it was Tinbergen, who independently had employed the very first model and enriched it with data, years before the neoclassical theory was born. Tinbergen not only developed a growth modelling environment, but he also provided a wider catalogue of different subtypes of production processes (technologies). He was also motivated by the general problem of combining theoretical aspects and approaches with data. Statisticians, he stated, do not completely rely on an underlying theoretical concept and on the other hand, serious trend movement theory has not yet given a (reliable) database. His goal, therefore, was to provide a "very simple quantitative theory of the trend of production, employment and real wage rates" (Tinbergen (1942, p. 513 and p. 547)). A little later and "for having developed and applied dynamic models for the analysis of economic process"[12], the Dutch mathematician and economist then in 1969 received the first Nobel Prize in economics together with Ragnar Frisch.

Tinbergen modelled the same properties as in the subsequent basic neoclassical model - production, employment and wealth on the aggregate level, influenced by capital accumulation processes, population growth and technological progress. By doing so, he explicitly stated the necessity to distinguish between short-run developments (cycles) and long-run movements (trends) - an issue, still present in today's economic discourse. Whereas short-run movements are merely triggered and influenced by speculation or business- cycle developments (Tinbergen (1942, p. 511)), long-run developments, the issue Tinbergen is more explicitly dealing with in his paper, consist of movements in a time period of decades or even centuries.

As population, production potential or technical development are usually considered as (more or less) rigid over shorter time horizons, they do play a significant role in the long-run. His aim, therefore, was to focus on these long-run developments and how they affect the long-run growth performance of an economy (Tinbergen (1942, p. 512)).

However, the original 1942-paper did not receive the deserved attention. Probably due to the fact, that the world was stuck in the middle of World War II, or maybe simply because its original version was written in German [13]. Due to this, the first approaches in growth theory were not associated with

[12]See www.nobelprize.org for further details.

[13]The original version of the 1942 paper was later translated into English (Tinbergen, 1959).

Tinbergen, but with the works of Roy Harrod (1939) and Evsey Domar (1946)[14]. Both economists aimed to extend the ideas of John Maynard Keynes' General Theory (Keynes (1936)) into the long-run.

Harrod and Domar, two of the most famous post-Keynesian growth economists, faced instability problems in their approaches - a property especially of the Harrodian paper, which was later often labelled as "knife-edge"-growth[15]. A coincidence of the natural rate of growth, representing growth in labour, and growth in capital is just considered as a situation of a lucky coincidence. Imbalances and the resulting state of (an ongoing) disequilibrium result from the technological properties of the post-Keynesian model. Whereas the later neoclassical model consists of a production function, which is composed of substitutionality of production factors and flexible factor prices, the post-Keynesian models of Harrod and Domar are expressed through limitationality in production[16]. Even though Harrod and Domar developed models with different aspects, they are often summarized under 'the' Harrod-and-Domar model, which is the "genealogical ancestor from which neoclassical growth theory claims to descend" (Punzo (2009, p. 89)).

It took 17 more years for the translation of Tinbergen's original paper when it was again outshined by the breakthrough works of Robert Solow (1956) and Trevor Swan (1956), both forming the birth point of neoclassical growth theory. What Harrod and Domar, under the assumption of a rigid production technology (limitationality of the production factors), were not able to solve, is considered as the major achievement of the Solovian model. By replacing limitationality in production with a flexible production framework (substitutionality of the production factors), a stable balanced growth path became possible and not lucky coincidence any more (Solow (1956)). Solow then, only one year later, enriched this neoclassical model with a technology component (Solow (1957)). As chapter 3.3 will show, the model made it possible to separate for the sources of economic growth - the major approach which led to the methodology nowadays known as "growth accounting".

In fact, the formula, which has later become famous as the "standard growth accounting equation",

[14]Solow, when discussing his precursors refers to Harrod (1948) instead (see also Punzo (2009, p. 89)).

[15]The notion "knife-edge"-growth was initially used by Solow (1956) and later by several other economists. So it was later immortalized by Prescott (1988); very much to the dislike of Harrod, who wanted to get rid of the notion or being associated only with the "knife-edge"-growth issue (Hagemann (2009, p. 84)). It is interesting to note, however, that Solow has admitted not having fully understood the entire model, when writing his famous papers in the 1950s, particularly, the twofold (in-)stability problem of the Harrod-model (Solow (2000, p. xiv)).

[16]For a more detailed discussion of the properties of the postkeynesian approaches and the relation to Solow's neoclassical model see Hagemann (2009).

can originally be traced back to Tinbergen (1942, p. 543). Tinbergen in contrast to Solow, Swan and the post-Keynesian precessors Harrod and Domar claimed for a production technology in between the two extrema (limitationality of the post-Keynesian flavour and substitutionality of the neoclassical strand). Additionally, to Tinbergen's main focus on the Cobb-Douglas production function, he also provided a wider catalogue, composed of various subtypes of production technologies.

In Tinbergen's paper, the breakdown for the sources of economic growth resulted in an expression, representing effects of technology and related ones, all summed up as a change in efficiency. The simple expression "technical development" (Tinbergen (1959, p. 193)) measures technology (original German expression: "Rationalisierungsgeschwindigkeit" Tinbergen (1942, p. 543)) as the residual, resulting from output growth minus growth of capital and labour input. So, the birth of the growth accounting approach, which is often associated with Solow (1956; 1957), Swan (1956) and the birth of neoclassical theory in the 1950s, origins in the works of Tinbergen, set up more than a decade before the works of Solow (1956) and Swan (1956).

Even though Tinbergen has originally provided the relevant framework to measure technology as a potential source of economic growth (in the line of the growth accounting approach), it was Solow (1957), who was responsible for the dissemination and making known the growth accounting approach. It is highly speculative, whether Tinbergen's work would have been known nowadays without the works of Solow on that field. In order to understand the relevance and evolution of the growth accounting concept and the nowadays famously known residual, and in order to compare Tinbergen's theory to its ancestors, a short description shall be provided in the next chapter. I hereby focus on the structure of the 1942 original paper.

3.2 Tinbergen as the Origin

For the basic Tinbergen-framework, a one-good economy (like the famous Ricardian "corn-economy", an economy consisting only of one commodity (Ricardo (1815))) is assumed, removing the necessity to introduce monetary variables (i.e factor prices and goods prices). The commodity can either be used for consumption or investment purposes. Tinbergen's model relies on the production function, modelled by Paul Douglas and Howard Cobb (Cobb and Douglas (1928)). The exponential production function exhibits constant returns to scale (as the respective input shares are summed up to one).

Following the original notation, a good u is produced by a transformation process, using capital K and applied labour a as inputs. A third production factor, land, is assumed to be constant and can be thought of implicitly represented by the factor capital. The functional relationship is then adjusted by the efficiency parameter "technical development" (Tinbergen (1959, p. 193))ε^t, which represents Tinbergen's extension of the Cobb and Douglas (1928) production function[17]. Interestingly, the efficiency parameter has a time-indexed superscript, providing the possibility for a change in efficiency and allowing the introduction of technological progress in a modelling structure. Tinbergen, in his paper, emphasizes the distinction between technological progress and growth in [labour] productivity as potential sources for economic development (Tinbergen (1942, p. 540)).

Growing labour productivity is either the result of a change in the underlying (type of the) production function, implying technological progress, or the effect of using more capital relative to labour. For his study, the former case is ruled out, by assumed the underlying production function to be constant over time for the respective time periods covered.

Even though Tinbergen talks about the second case (rising capital intensity) as technical progress, he relativizes this claim. A rise in capital intensity - and therefore a rise in labour productivity - of a given production function, is obviously accompanied by a decline in capital productivity. Only if both factors in production experience an improvement in terms of efficiency, it is technical development (represented by ε^t) (Tinbergen (1942, pp. 521-522)). It shows that Tinbergen was well aware of the confusion regarding technology, its measurement and the fact that all factors included in production have to be considered in productivity analyses - he explicitly points out the necessity to define technological change due to a general confusion about the nomenclature (Tinbergen (1942, p. 516 and p. 521)). More generally, he also states that technological progress is meant to be defined as "a reduction of the real costs" (Tinbergen (1959, p. 193)).

Real (overall) costs in production logically do not only represent labour input. Situations of rising labour costs are possible as well as stated above; however, only if accompanied by an overproportional

[17] Cobb and Douglas (1928) production function is represented by the following (Tinbergen) notion: $u = ca^{\lambda}K^{\mu}$. Note that c is the constant, now being replaced by the technical development component in Tinbergen's analysis.λ and μ stand for the shares of the production factors.

reduction of the respective capital costs. According to his work, technological progress, therefore, cannot work as a simple equivalent of growing labour productivity, in order to explain productivity trends in general.

One apparently realizes all the recurring statements and debates on the nature of technological progress and its relationship to economic growth in the forthcoming growth theory literature - i.e. the general dichotomy of capital intensity and technological progress for the explanation of growth in labour productivity (and wealth) by Robert Solow, or the subsequent studies (i.e. the research programme by the National Bureau of Economic Research (NBER)).

Cobb and Douglas (1928) did not allow a production function to change regarding their technical properties (there were no such technical development parameters like ε^t, as Tinbergen has introduced). The definition of technological progress by Cobb and Douglas (1928) therefore, was reduced to an ongoing flow of capital formation (capital deepening), whereas in Tinbergen's theory the rise in overall efficiency is named "technical development" and therefore meant as a synonym for technological progress (Tinbergen (1942, p. 521 f.)).

At first, Tinbergen sets up the representative production function. He compares different types of underlying production functions, whereas his main focus is on a Cobb-Douglas-type, which Tinbergen adjusts by the efficiency parameter ε^t of technical development. Following Cobb and Douglas (1928), the Tinbergen production function for growth accounting purposes then takes the form of:

$$u = \varepsilon^t a^\lambda K^{1-\lambda} \tag{2}$$

Technical development is adjusted by a time-index, whereas the superscripts of the input factors represent the shares in production and therefore the shares of how economic income is distributed on capital and labour. Following Cobb and Douglas (1928), the empirical results show $\lambda = \frac{3}{4}$, so that the more specific production function can be written as:

$$u = \varepsilon^t a^{\frac{3}{4}} K^{\frac{1}{4}} \tag{3}$$

A feature of the Cobb-Douglas type is perfect substitutionality of the input factors capital and labour. Despite having some doubts on this in reality, Tinbergen adopts it for his main example ("We are not certain that this complies with the facts [...]", in original Tinbergen (1942, p. 522) and Tinbergen (1959, p. 194) in the English translation). Moreover, he provides a catalogue of different production scenarios. A production function of complete complementarity is offered as a second main case, aiming for limitationality in production processes, when input goods have to be used in fixed proportions.

In a next step, the demand side of the economy is defined. Assuming that both production factors earn their respective marginal products, the demand equations for capital and labour can be modelled as follows (marginal product equals respective factor price) [18]: demand for capital $\frac{3}{4}\left(\frac{K}{a}\right)^{\frac{1}{4}}\varepsilon^{t} = l'$and demand for labour $\frac{1}{4}\left(\frac{a}{K}\right)^{\frac{3}{4}}\varepsilon^{t} = m'$, with m' as the market interest rate, l'as the wage rate. For the supply side, the amount of labour supplied not only depends on the wage rate but is additionally a dependant of wage-flexibility λ[19].

Wage flexibility λ is an important feature, as it offers various interpretations. It would be intuitive that, if wages rise, people tend to supply more labour (wage-flexibility greater than zero). It is, however, possible as well, that people of a specific age, gender or region offer less labour in course of rising wages - this would be the case if they consider their goal in earning a specific amount of money, which enables them to satiate their needs.

By assuming that the supply of goods determines production, the demand for the production factors labour and capital does equally represent the supply equations for the final goods - a feature, which is ultimately linked to Say (1803)'s law (Tinbergen (1942, pp. 527-529)). The set-up of the Tinbergen model of growth and its derivation of an equation, that accounts for separating for the sources of

[18] Note that the following equations represent the demand for capital and labour on the aggregate level.

[19] The corresponding supply side of the economy is set up as supply of labour being $l' = \left(\frac{a}{b}\right)^{\lambda'} l^{\circ\circ}\lambda^{t}{}_{\circ}$ and supply of capital being $\dot{K} = \chi u$. Supply of labour a generally depends on wages l'. The amount of labour supplied, relative to the entire population b, depends on the wage rate l', relative to a wage rate l°, which is considered to be the "normal" wage rate: $\frac{l'}{l^{\circ}} = \left(\frac{a}{b}\right)^{\lambda}$. Defining the movement of the "normal" wage rate over time (l°=l°° $\lambda_{\circ}{}^{t}$) as a function of a constant ($l^{\circ\circ}$) and the annual rate of change ($\lambda^{t}{}_{\circ}$) and adding the growth of population ($b = b_{\circ}\beta^{t}$, with $b_{\circ}$ as the initial population and β^{t}as the relation of population of the past period, compared to the period covered) one gets the supply of labour: $l' = \left(\frac{a}{b}\right)^{\lambda'} l^{\circ\circ}\lambda^{t}{}_{\circ}$. Supply of capital is a less complex function and does not offer much potential for empirical analysis to discuss. Capital accumulation is the sum of all current accumlated amount of capital. The law of motion for the accumulation of capital seems rather simple, as a specific amount of economic output u (expressed by the marginal prospensity to save χ) is saved.

economic growth, logically makes him the ancestor of the theory of growth accounting.

3.3 Solow and the 'Second Date of Birth'

As already stated, however, the growth accounting approach would not be that famous without the works of Robert Solow. Whereas the Solow (1956)-paper was about setting up a (neoclassical) growth model, the 1957-paper added technological features and focussed more on the role of technology in the process of economic growth. Robert Solow received the Nobel Prize in economic sciences in 1987 for "[...] his contributions to the theory of economic growth"[20]. His neoclassical vision of economic growth and his studies on the sources of economic growth in the US still represent some of the major breakthroughs in the field of economics in the twentieth century. The nowadays commonly used neoclassical growth model (allowing for household optimization in contrast to the basic "Solow-model") is built upon the base of Solow's approaches in the 1950s, mainly based on the two popular papers (Solow (1956, 1957)).

Besides forming the neoclassical growth model, the Solow-model implicitly includes the growth accounting approach. The basic idea was to find a method of separation for the growth of national (gross) product into its contributors. Solow was interested in distinguishing output changes, caused by technological progress from those resulting from the effect of capital deepening (Solow (1957, p. 312)).

Applying the theoretical approach to the data, he found that nearly seven-eighths of total output growth in the US (over the covered period of time of 1909-1949) was caused by a not-yet explained force, conjecturing effects in productivity and/or technology. The other one-eighth resulted from a simple increase in capital intensity, meaning more capital per labour unit; generally speaking an increase in the factors of production. In his famous paper, Solow (1956) first provides a mathematical explanation of his view of the aggregate production process. He defines the aggregate production function as a simple input-output relationship, in the tradition of Cobb and Douglas (1928).

The input factors are narrowed down to capital K and labour L. A third production factor A is identified and defined as technology, more precisely as neutral[21] technical change. In terms

[20] See <<https://www.nobelprize.org/prizes/economic-sciences/1987/press-release/>> for further details.

[21] Neutral technical change improves both input factors in the same way and to the same amount and therefore leaves marginal rates of substitution unchanged. For deriving growth equilibrium in the basic Solow model, technical change is assumed to be Harrod neutral (labour-augmenting). The model itself uses a Cobb-Douglas production function (see equation $Q = A(t)f(K,L)$), which leads to the fact of a coincidence of the Hicksian neutral technological progress and

of production theory, this technology component stands for a mathematical shift-parameter of the aggregate production function. By defining the technology-parameter A as both labour- and capital-augmenting, the aggregate production function is expressed over time as:

$$Q = A(t)f(K, L) \tag{4}$$

Equation (4), providing the nature of the production process, describes the basic aggregate production function, consisting of the input components capital and labour, adjusted by technology and resulting in a stock of final goods. Note that here, Q represents output, whereas A, the technology component, works as a 'shifter' for the production function, including the input factors capital K and labour L.

Technology in a static, one-period case offers a description of the way an economy uses specific input factors, like capital goods or labour units to receive a final good at the end of the production process. A production technology therefore implicitly defines several properties, for example, the technical configuration of a machine, the level of human education, the organizational structure of a company and many more.

Every economy has its own, specific way of extracting output from input-factors. These "blueprints" then can be named technology. However, the way of producing changes over time due to innovations in machinery, organization, labour skill and others. A serious classification of which innovations contribute most, what kind of innovations shall be considered or neutrality-vs.-non-neutrality-aspects of innovations, in general, shall be neglected at this point. If one, however, changes the average production concept of an economy ("blueprint"), it means nothing else than technological change. Such a change of the average technology in use might result from more firms in the economy, shifting to better technologies ("technology diffusion"), less productive firms withdrawing from economic activity or (and especially for the long-run), if the generally available technology has improved due to R&D, innovations and others.

A production concept becomes obsolete and gets substituted by another one, only when the former

the Harrodian one.

produces less efficiently. An economy, or a representative entrepreneur, only apply a new technology when the input-output-ratio is more in favour of the latter one. The term 'change' offers the possibility of using less efficient technology.

For an investigation on TFP, one has to keep in mind that scenarios of switching to inferior technology are possible as well (a discussion on the nature of the notion 'change' has already been set up in chapter 2). The result would be (if one assumes that TFP perfectly represents technology) negative TFP-values. For the purpose of the present study, the notion 'technological progress' suits, as well as 'technological change', if one keeps in mind that technological regress is possible as well.

In order to bring together theory and data, Solow sets up time derivatives of the output equation (4). After further simplifications and rearrangements, growth in output is on the left-hand side of equation (5). On the right-hand side, one finds the growth of technology component A and growth of the input factors K and L, both adjusted by their respective marginal shares $w_K$and w_L. These shares represent the output shares:

$$\frac{\dot{Q}}{Q} = \frac{\dot{A}}{A} + w_K \frac{\dot{K}}{K} + w_L \frac{\dot{L}}{L} \tag{5}$$

The method and resulting equations, Solow sets up, can be found in a similar way in Tinbergen's work. Providing an expression of output in terms of input and marginal shares, in fact, is a key component in Tinbergen's analysis (Tinbergen (1942, p. 523)), which again emphasizes the importance of Tinbergen's work and its similarity to the (more) famous successors.

Solow then in a next step defines the output per worker ratio (or labeled differently as labour-productivity, q), capital per worker ratio (capital intensity, k) and the relative share of capital (w_K) and assumes the function $f(.)$ of being homogeneous of degree one[22]. It follows that:

$$\frac{\dot{q}}{q} = \frac{\dot{A}}{A} + w_K \frac{\dot{K}}{K} \tag{6}$$

After having set up the theoretical base of his analysis, Solow links his concept to the data (Solow (1957, pp. 314 ff.)).

[22]It is: $\frac{Q}{L} = q$, $\frac{K}{L} = k$ and both shares added up to 1: $w_K + w_L = 1$.

The simple structure of the expression in equation (6) only needs three time-series to be computed and inserted: output per unit of labour, capital per unit of labour and the share of capital (Solow (1957, p. 313 f.)). His empirical computation is based on a data-set from 1909 to 1949 for the US. Especially data for private non-farm gross national product (GNP) per man-hour, like the labour-efficiency component, can be traced to Kendrick (1956) (appreciated explicitly by Solow (1957, p. 314))[23].

Solow makes use of private non-farm data on a gross level. The intuition is that it simplifies the analysis by restricting the measurement of government activity; the reason for using gross instead of net values simply lies in the availability of the data. Exact data on capital time-series are derived from Goldsmith (1955). Solow justifies its adoption: capital service data was not available to a sufficient amount. Instead, and in order to derive capital-in-use from the capital-stock data, Solow adjusts it by data for the labour force employed, which implies the level of utilization and therefore works as a proxy for capital services.

After having computed the time-series, one finds a steadily rising trend of - what is per Solovian definition technological progress[24] over time. The residual share has increased (Solow (1957, p. 315)), also stating the increasing importance of technology for economic growth in the United States and its implications for appropriate policy actions.

Solow's empirical investigation states that the major source of economic growth cannot be attributed to a simple increase in the factors of production- capital and labour. Variations in capital and labour only account for roughly one-eighth of total output growth, the residual (technology per definition) for around seven-eighth. These results exhibited a milestone in the analysis of economic growth and built the starting point of modern economic growth analysis. Input quanta, or put in other words, an increase in capital intensity (implying more capital per labour unit), plays a less significant role for long-run economic growth and an economy's growth path.

But what does the residual actually represents? For Solow, the residual was nothing else than "the technical change index" ((Solow, 1957, p. 313 and p. 316)) and therefore a variable, which includes the

[23]Other data sources, for example, are: Douglas (1953) for labour force related data, Goldsmith (1955) for capital stock related data (see Solow (1957, p. 315)).

[24]The fact, that A(t) rises constantly over time makes it easier to speak of technological progress instead of change.

change in efficiency in the production process of an economy. In advocacy of Solow, he was well aware of the fact, that a simple application of technological progress as residual and therefore a non-explained source of growth was not the be-all and end-all of everything:

> "...A(t) series, which is meant to be a rough profile of technical change, *at least looks reasonable*." (Solow (1957, p. 316)).

However, these results shattered economic theory as well as politics likewise. Long-run economic development and growth is not possible without technological progress. Moreover, capital accumulation cannot account for steady-state growth.

It is interesting to note that results of the discussed approaches in this chapter vary. The NBER-program finds productivity as the main source of economic growth; so does Solow, who labels the effects in productivity as technological effects. Tinbergen, however, suggests that capital and labour input are the responsible factors of economic progress. For sure, the disunity in the results might arise from covering different periods of time. They do, however, also arise from discordance in definition and measurement - the latter one of enormous interest for the present study on productivity puzzles.

If, in the sense of Tinbergen and Solow, technology is measured as a residual and accounts for the major part of economic progress, it leaves the problem of deriving policy implications almost untouched - providing an even larger "residual of ignorance". Even though many studies in the mid-end of the twentieth century have focussed on measurement problems and definitory issues, it was Abramovitz (1956), who first brought up his doubts. His study arose independently from the Solovian ones, expressing his dissatisfaction on the status quo.

4 Measure of Ignorance and Reactions on the Traditional View

4.1 Abramovitz' Measure of Ignorance and a Reaction

In course of the upcoming wave of interest in the origins of economic growth and the development path of economies, the works of Jan Tinbergen, Robert Solow and others have received attention. It was them, who intensively promoted the relevance of a technology component for the economy's growth process. Especially the breakdown of the individual contributors with regard to output growth, later known as the growth accounting approach, have defined the field. Theory and empirics were both set up, in order to find a representative for technology and to define and measure its contribution. Hereby, a residual term, later become famous as 'Solow-residual', did that job.

The conclusion, that more than 80% of output growth over time for the US (1909-1949) can be traced to technology seemed to be like a major breakthrough and important finding; and in some way it was. By separating for an increase in input factors and a rise in technology as an explanatory source of output growth, most studies argued for the latter one. It was Solow, however, who equated the rise in productivity with a rise or improvement in technology. This, in turn, has raised several doubts. Is the individual contribution of technology, in fact, more than eighty per cent accountable for economic growth and what does this mean for policymakers? Do they only have to stress the increase of the residual, in order to promote economic growth?

From nowadays, we know that a simple equalization of the (productivity-) residual and technology is not sufficient and not completely accurate. In addition, the residual is an outcome and not a cause, complicating the situation for economic policy. Aiming for a simple enlargement of TFP pushes the debate ad absurdum (see i.e. Carlaw, K. and Lipsey, R. (2003, p. 458) who emphasize the character of TFP as "lumped together as a residual left over factor").

The major starting point for a slight critique of the Solovian work (more precisely on the equalization of TFP and technology) was a study by Moses Abramovitz (1956). Even though the study came up independently from Solow's, it can easily be considered as a critique on some of the major predominant studies in these times.

Agreeing on the general method and modelling approach of the studies of Robert Solow, Abramovitz

(1956) denied a simple equalization of productivity and technology. Even more, he stressed the ignorance of the ingredients, assembled in the (technology-) residual. By doing so, he highlighted the residual's character as a catch-all variable, containing several unknown factors. Abramovitz' own study investigates, as almost all of the other studies of the NBER-related research programme (see chapter Notion of Efficiency and the NBER-program), developments of the time period of 1870 to the mid 1950s (here: to 1953) in the US. By doing so the author argues that net national product of the last decade of the study (1944-1953) is thirteen times higher, compared to the first one (1869-1878). It implies an average growth rate of roughly 3.5% p. a.. Tripling population over time makes it a per capita growth rate of 1.9% p.a, which then has led to a quardrupling of net national product per capita in the covered period of time. A tripling of the population and effects resulting from structural change (i.e. production shifting from agricultural to industrial production in these times) led to a remarkable increase of the labour force of 25% in total. It was, however, (more than) counterbalanced by a reduction in the average working hours per worker, so that aggregate labour input, measured in total hours worked, has remained constant (or even slightly declined, subject to interpretation of the results).

Compared to labour input, (physical) volume of capital, on the other hand, has increased even overproportionally, leading to a (net) rise in the capital per worker ratio (representing capital intensity in production). In the next step of his calculations, Abramovitz compares for a (hypothetic) situation, in which the efficiency levels would have remained constant, inputs however grown at the actual rate. It enables to isolate for the effects in productivity. The result of the analysis is quite interesting, as it traces only around 14% of the increase in net national output to the effect of capital deepening - a rather small portion. Eventually, productivity has to account for the rest of the increase in net national product of this hypothetic scenario[25].

In the general dichotomy of whether capital deepening or rising productivity accounts for economic growth, Abramovitz favours the latter one - however also admitting the lack of knowledge when it comes to the explicit sources of productivity and to the exact definition of the residual:

[25] It is furthermore discussed, how the change in the underlying base year changes the results. Abramovitz admits that a change in the base year of the empirical analysis leads to other results. It, however, does not change the shares of productivity and capital deepening strongly, so that the conclusion remains the same.

> "Its source [of the increase in national product, O.Z.] must be sought principally in the complex of little understood forces which caused productivity..." (Abramovitz (1956, p. 6)).

Two more points are noteworthy here. Firstly, capital inputs and productivity do of course have a relationship. There is, however, a yet unexplored connection in between, so that rising inputs have in some way contributed to economic growth, too. Secondly, Abramovitz emphasizes (general) possible measurement problems, which might lead to a bias in tracing the sources of economic growth. Measuring labour input seems to be quite straightforward, capital a bit more complicated. The author hereby paves the way for the later debate on mismeasurement and definitory debates, which have defined the research area from the 1960s onwards and will also form the remainder of the present study. Even more, Abramovitz also reckons, that due to potential biases in the measurement process, generally the observed trend in productivity might be overstated (Abramovitz (1956, p. 12)).

What does this imply? If productivity change is mainly unexplained, the relationship to the effects of capital deepening remains unexplored, too, and a separation of both effects with regard to economic growth becomes complicated. It then follows that:

> "Since we know little about the causes of productivity increase, the indicated importance of this element may be taken to be some sort of measure of our ignorance about the causes of economic growth..." (Abramovitz (1956, p. 11)).

It is of central concern, to find the appropriate source(s) of productivity growth (see also OECD (2015b, p. 32 f.)). If productivity and its ingredients are unexplained phenomena, we cannot simply (re-)label it as technology (or technological progress) - a hypothesis, Jorgenson and Griliches (1967, p. 52) shared later on. Abramovitz' study has, among others, emphasized the role of productivity for economic growth. In order to shed light into the analysis on the actual sources of productivity, the present study contributes by exploring the role of the measurement problem as well as by discussing other potential explanations (which help to specify the linkage between input factors and productivity).

Contrary to former studies and conclusions, in 1967 Dale Jorgenson and Zvi Griliches have embossed a next era in the history of understanding the causes of economic growth (Jorgenson and Griliches

(1967)). Their emphasis is on the measurement problems of the variables, associated with the growth accounting theory. More precisely and according to their understanding, real national product and real factor inputs have been measured incorrectly (Jorgenson and Griliches (1967, p. 52)). If all input and output coefficients are measured correctly, then the residual (almost) vanishes. This, in turn, leads, in the sense of Abramovitz (1956), to a "measure of ignorance", that growth in output is mainly explained by growth in input. The ingredients, we do not know, shall be explained, defined and (correctly) measured and not summed up in a catch-all variable. Not only measurement problems, but definitory problems are raised as well as:

> "Simply relabeling these changes [changes of 'The Residual' or 'The Measure of Our Ignorance', O.Z.] as Technical Progress or Advance of Knowledge leaves the problem of explaining growth in total output unsolved." (Jorgenson and Griliches (1967, p. 52)).

Their own definition goes along with the growth accounting approach - growth in output as a result of the separation of growth in input and growth in total factor productivity. In fact, Jorgenson expanded the basic Solow Model mainly by measurement innovations (Jorgenson (1963)). This separates the Jorgenson and Griliches (1967)-approach from the traditional one(s) so that it is considered as being different from the traditional Solow Model and its ramification. For Solow, the production theory involved in the growth accounting approach functioned as a tool, whereas Jorgenson and Griliches stated its ultimate relationship (Hulten (2001)):

> "For Solow, the aggregate production function was a parable for the measurement of TFP; for Jorgenson and Griliches it was a blueprint." (Hulten (2001, 14)).

The interpretation of Jorgenson and Griliches (1967) is in line with the "spill-over" and "free-lunch" view, which will be discussed in chapter 5 of the present study in more detail.

4.2 Correcting the TFP-Formula - a Potential Solution?

Among several other studies following Jorgenson and Griliches (1967), it again was Zvi Griliches in the late 1970s and 1980s (i.e. Griliches (1987, 1988)), who summarized several deficiencies of the TFP-measurement and definition and pushed the 1967-approach further. Despite a doubtful side-effect of the economic debate, drifting to minimizing the residual generally (no matter how), it is being considered as an important step to analyse the character of the residual and its relationship to technology. Griliches not only outlined several deficiencies, associated by the quantification of the residual, but also provided a - to his understanding - 'corrected' formula of the TFP-residual.

In accordance with his previous works with Dale Jorgenson, he set up a 'corrected' version of the residual. His goal was to take into account all deficiencies, identified with the definition and measurement of total factor productivity. From his perspective, the main stumbling blocks, the advocates of the 'traditional'-view of the residual encounter, can be divided into the following subcategories (Griliches (1987, pp. 2 ff.)):

1. A relevant capital concept (i.e. the debate on net vs. gross values)
2. Measurement of real output (i.e. including discussions about the right price deflator)
3. Measurement of input (i.e. quality-aspects are usually untouched. See chapter 9.3.2 for further details)
4. R&D and public infrastructure (i.e. how to treat them in national accounts)
5. General data problems (missing or incomplete data; i.e. the amount of hours worked in total is a variable, which is extremely complicated to measure, as chapter 8.2 will also debate on)
6. 'Weight'-problems (i.e. the existence of shadow prices)
7. Aggregation over heterogeneity (with regard to various types of input factors)
8. General theoretical assumptions (i.e. what kind of production function, what kind of inputs)

Griliches among others, dealing with conceptual and measurement errors, however, was aware, that in general, the problems are subject to overlapping and incompleteness. Their original formula of the residual ($TFP = Y - sK - (1-s)L$) was obviously not sufficient[26](Jorgenson and Griliches (1967)). Extensions and changes of the formula could help to allow for a better and more accurate understanding, what the residual actually consists of and accounts for. So, Griliches (1987) himself set up a 'corrected' version of the residual. His purpose was (at least) to show the limitations and incompleteness of the approach, going back to Solow (1957). According to the list of stumbling blocks (points 1.-8.), the unexplained part of economic growth - the total factor productivity - can (and should) take the following form (Griliches (1987, p. 3)):

$$TFP_{correct} = s(k* - k) + (1-s)(n* - n) + (s* - s)(k* - n*) + h[sk* + (1-s*)n* - f] + \alpha_z z + u + TFP_{incorrect} \tag{7}$$

The rewriting of the 'incorrect' Solow-residual allows for a more exact but also a more complex definition of the unexplained part of economic growth. The variables, denoted with asterisks represent the correctly measured inputs. The first term represents errors of capital measurement ($k * -k$), weighted by the share s of capital on the overall index. If there were no errors in capital measurement, the term would easily vanish, as the measured value k would be equal to the correct value $k*$. The same logic applies for all the remaining terms. Please note that n represents labour input, s and respectively $(1-s)$ account for the shares. The final term $TFP_{incorrect}$ stands for the old, incorrectly measured residual.

Connected to definitory problems, as well as to the capital input component, is the issue of utilization. For productivity analyses, it is important, that the rate of utilization of machinery (any other capital good would do) is not affected by business-cycle-effects as this might lead to potential biases. If, however, the rate of utilization is influenced by business-cycle-trends, then this might lead to an over- or understatement of efficiency and misleadingly provide wrong implications for the path of technological progress.

Labour input, or more precisely the correction for labour input, is represented by the second term ($n * -n$), weighted by the respective share. Problems with the measurement of labour input arise from

[26]The calculation is pretty straightforward and simple. When subtracting capital input K, labour input L- both weighted by share s - are subtracted from output Y, this yields the residual.

aggregation issues over heterogeneous agents, like young vs. old, male vs. female or the very important separation between educated and uneducated labour. Moreover, aggregation issues result from a price bias, too. If individuals' marginal prices do not correctly display their individual productivities, this ultimately leads to wrong implications about efficiency levels of specific labour cohorts, as well as for the aggregate level.

Problems occurring due to wrong weights of the input factors capital and labour are represented by the third term $(s * -s)$. If for example an economy experiences (a wave of) structural change or a change in specific industries, the relation between capital use or labour use might change. If now, relative prices observed, get disconnected from their marginal products, efficiency estimates get biased as well.

The fourth term stands for economies of scale. The h hereby expresses the degree of elasticity of scale in production. If, for example, there are no economies of scale, it would not have an impact on the residual and the fourth term would vanish. Note that the term would also disappear if the growth rates of inputs, weighted by their correct shares just equal the growth rate of establishments f (plants) of an economy.

The fifth term z stands for the omitted variable bias, adjusted by the 'true' elasticity of output for omitted variables. If its value would be positive, then factors contributing to residual growth were not listed or recorded in the conventional input factors capital and labour.

Omitted variables play a significant role in certain industries, for example for the sector of agriculture, fishing and forestry (AFF). Natural resources and their use do not enter the production function of most growth accounting approaches (if the production function is denoted as $Y = Af(K; L)$); in theory, these natural resources find their way into the production function implicitly via the capital component K. Rainfall is absolutely crucial for plant growth in agriculture. AFF-industries more likely suffer from too little rainfall (compared to a situation of excess rainfall). Too little rainfall would diminish economic growth, without showing up in the production function. In terms of a production function $Y = Af(K; L)$, one could come to the (wrong) conclusion, that this might result from a decline in efficiency (or technological regress) (for example see Kulys and Topp (2014)).

The sixth term u represents the output part. More precisely, definitory problems of output measurement, not further specified by the author and therefore summed up as a 'catch-all'-variable u. As for some questions, it is hard to find an exact definition like 'where do final goods start?' and 'where to draw the line between them and simple intermediate goods'. As a potential but rather general claim, Griliches asks for a more serious "border of economic activity" (Griliches (1987, p. 3)). It is remarkable that current debates in the 21st century about the appropriate framework for national accounts in order to capture economic activity correctly have already bothered economists long time ago.

Other problems might include the question of how to treat pollution, underground activity, home office work or the effect of outsourcing. If a mother decides not to employ a nanny, but take care of their kids by herself, how does this service enter the aggregate production function? In terms of market transactions and market prices, an 'outsourcing of parenthood' raises national GDP and affects productivity measurement. If the mother, in turn, raises her child by herself, there is no market transaction. National productivity measurement remains untouched. As initially stated, a general problem results from separating goods, services or units into their respective price and quantity component.

For productivity analyses, it is crucial, that prices reflect their marginal costs in equilibrium. If prices are regulated or controlled by governmental institutions, an adjustment of goods by constant prices seems impossible. Even more, if for example prices are subsidized by governmental institutions, then this may lead to a biased view of productivity. Depending on 'external activity' (all activity except market activity), one might come to a wrong conclusion about the change in efficiency.

5 Spill-overs, Super-Normal-Profits and the 'Free-Lunch-View'

In theory, and if in reality TFP is measured as a residual, it might capture the effects of technological progress. As already stated, however, there are serious doubts on the extent (i.e also see OECD (2015b, p. 32 ff.)). Technological change is, at least in part, already embodied in capital goods (K), which has to be taken into account. Hence, for measuring TFP some caution is necessary. If technological progress is already embodied in capital goods, then another interpretation of TFP is, that it will account only for the disembodied part of the innovation. This can include network effects, more efficient practices in general, the impact of brand names, organisational change and general knowledge (diffusion) (OECD (2015a, p. 32)).

Emphasizing that TFP does not and even cannot measure technological progress entirely, Carlaw, K. and Lipsey, R. (2003) state that TFP is (at best) only related to technology. In fact, the authors maintain a rather sharp point of view by stating that "productivity is not a measure of technology"[27]. The confusing terminology of TFP among economists makes it problematic to speak of both notions in the same breath.

Their own definition of TFP is described by the notion of so-called "super-normal-profits" associated with technological change. TFP, or the residual, then captures "contemporary returns, that are in excess of the normal rate of return on investing in known technology" (Carlaw, K. and Lipsey, R. (2003, p. 457)), but not technological progress itself. Moreover, only under certain conditions, TFP can capture these "excess returns".

By rejecting the simple equality of TFP change and technological progress, they also provide criticism on the disembodiment-hypothesis and exogenous technology treatment of former studies. Technological progress is not the result of spontaneous events (the often cited 'manna from heaven'; i.e. see Davenport (1983, p.139) on the exogenous character of technological progress in traditional approaches) but a result of intensive resource-using activities. These resource-using activities are composed of more than just simple R&D-costs. They are represented by the entire "development costs" of a new technology set, which also include "installation costs, acquisition of tacit knowledge about the

[27] Chapter 2 of Carlaw, K. and Lipsey, R. (2003, p. 458) is titled accordingly.

manufacture and operating of the new equipment, learning-by-doing effects in making of the product, and learning-effects by using it, plus a normal return on investment of funds in development costs." (Carlaw, K. and Lipsey, R. (2003, p. 467)) - broadly speaking, anything related to the introduction of a new set of technology into the economic sphere.

Carlaw, K. and Lipsey, R. (2003) follow the line of Jorgenson and Griliches (1967). More precisely, they adopt the "excess returns"-logic (Carlaw, K. and Lipsey, R. (2003, p. 467)) described in the 1967-study.

5.1 Jorgenson and Griliches 1967

By following Abramovitz (1962), and under the assumptions of constant returns to scale and the respective shift in the production function, according to Jorgenson and Griliches (1967), this shift is identified as "the effect of 'costless' advances in applied technology and managerial efficiency, and industrial organization" (Jorgenson and Griliches (1967, p. 250) quoting Abramovitz (1962, p. 764)). Put together, any advance in production, which is costless in terms of market transactions, is identified with changes in total factor productivity. Characterizing TFP as "costless advances" represents a "spill-over"-character from technology. Moreover, the authors' understanding form the basis of another potential view of how to interpret TFP.

If then, all variables are measured correctly, output growth is (or should be) mainly explained by growth in inputs. In their own calculation, the authors then correct for several deficiencies, i.e. aggregation errors, errors in investment and goods prices, errors in relative utilization, errors in aggregating capital services and aggregating in labour services. Initially, 52.4% of output growth is explained by inputs and the respective counterpart of 47.6% by the effects of productivity (TFP)[28]. After correcting for the (measurement) errors, there is an increase in the explanatory power of input growth to 96.7% and a reduction in the productivity residual to only 3.3%. For the time period covered (1945-1965), a 3.59% increase in output p. a. is noted and productivity effects account for only 0.10 percentage points (Jorgenson and Griliches (1967, p. 270 f.)).

[28]The results might puzzle, if compared to the Solovian analysis. Jorgenson and Griliches focus on a different period of time in US history, namely from 1945 to 1965, which obviously complicates a comparison.

The result confirms their hypothesis, that after correcting for all measurement errors (which arise from mis-exploitation of economic theory), growth in output is mainly explained by growth in input. As the remainder of the present study will show (especially chapter 9.3), a reliable and correct quantification of measurement errors is not only complicated but also subject to critical and discussable assumptions.

Having established a new view on how to think of TFP, Jorgenson and Griliches have not only encountered approval. An important reply has been set by Edward Denison (1972). Denison's studies have confirmed residuals significantly differing from zero, emphasizing the importance of productivity with regard to the underlying methodology - the opposite of what Jorgenson and Griliches have found. By applying his own methodology, Denison finds, that the proposed (almost) zero-residual is a false statement (Denison (1972, p.1), Hulten (2001, p. 13)). For 1950-1962, Denison (1972) finds that 1.37 percentage points of the growth rate of output can be explained by output per unit of input, which is productivity, compared to only 0.3 percentage points as provided by the Jorgenson and Griliches (1967)-study; see Denison (1985, p.1 f.) and the results of Jorgenson and Griliches (1967, p. 270 f.)).

It can be suspected that differences between the two studies have arisen mainly due to the problem of different covered time periods, the definition of output in the two studies and the types of sectors included in the calculation, different labour and capital shares and as well different measures for deflating nominal values.

Heterogeneous assumptions and definitions represent general issues when comparing studies and their respective implications. Whereas Jorgenson and Griliches refer to real gross national product per unit of input in the private sector as the relevant data source, Denison takes real national income per unit of input for the entire economy (Denison (1972, p. 2)). It seems problematic to calculate under different assumptions and a comparison between the studies (or mutual criticism) should be treated with care. As an example, Denison calculates shares of capital and labour of 21.4% and 78.6% for the whole economy, measured as part of national income. Jorgenson and Griliches instead, take gross national product at factor prices just for the private sector and receive 29.2% and 70.8% respectively (Denison (1972, p. 4)). In addition, Jorgenson and Griliches (1967) have calculated and adjusted capacity utilization by the help of electricity (proxy-solution), which in turn led to further differences.

However, being aware of the different set-ups of their calculations, Denison (1972, p. 1) also admits that even "[a]fter allowance for these differences, most of the large discrepancy between our measures of output per unit of input remains".

5.2 Super-Normal Profits and Super-Normal Benefits

Carlaw, K. and Lipsey, R. (2003) are of the opinion that TFP captures only the gains, that are over and above the development costs in production. This understanding merely follows the logic of Jorgenson and Griliches (1967). Only if technology generates returns, that exceed their costs, TFP growth is positive. They consolidate their view by providing an example of three possible scenarios (see "A thought experiment", Carlaw, K. and Lipsey, R. (2003, pp. 467 ff.)). An entrepreneur faces development costs and the value of a product of the new machine so that three possible scenarios arise: costs equal value, costs being smaller than value, costs being larger than value. In all three cases, there is technological progress, embodied in the new machine. Only in the scenario (scenario three) of returns exceeding development costs of the machine, however, TFP growth is positive, which apparently rejects any equalization of TFP and technology.

Free-lunches or any other externalities, arising from technological change are a result of the assumed framework of a perfectly end-state equilibrium, which necessarily equates all lines of returns - those from an investment in new technology to those from the investment in a new capital good of the existing ('old') technology. Under conditions like these, additional returns would only arise due to externalities. The authors prefer the term "super-normal-profits" or "super-normal-benefits" over "free lunches of externalities" (which Jorgenson and Griliches (1967) prefer to make use of). Even though the notion "free-lunches of externalities" is associated with benefits accruing to third parties, there is a slight divergence to what TFP measures (Lipsey and Carlaw (2004, p. 1128 f.)).

Providing a scenario with the emphasis on different implications of risk and uncertainty ("Knightian uncertainty"), problems, associated with a "free lunch"- notation can occur (Carlaw, K. and Lipsey, R. (2003, pp. 469 ff.)). Frank Knight (1921) famously distinguished between risk and uncertainty, whereas uncertainty is a state, not measurable and not possible to be calculated. In such a "real world"-scenario there exist additional profits due to the commitment of undertaking risk. Profits arising from this commitment, which are over and above development costs, might appear - but they are not genuine free-lunches. The appearance of these profits represents incentives to persuade entrepreneurs to undertaking innovative expenditures. They are premia, which do not stand for a free-lunch, but some kind of extra-return due to taking over uncertainty. If the resulting innovations take over forms of general purpose technologies (GPT), like electricity, the steam engine, computers or innovations in turn of the information and communication technology (ICT), then their characters change to externalities for any other entrepreneur in this world. GPT are genuine free-lunches.

In order to avoid misleading implications, associated with free-lunches, Lipsey and Carlaw (2004) use "super-normal profits" as "the difference between the firm's return to [the effort of, O.Z.] innovation and the return that can be obtained by investing in capital embodying existing technology" (Lipsey and Carlaw (2004, p. 1129)). Moreover, "super-normal benefits of technological change" as "the sum of all associated output increases and cost reductions accruing to anyone in the economy minus the new technology's development costs" (Lipsey and Carlaw (2004, p. 1129)). Whereas the former definition is rather associated with the entrepreneur's behaviour, the latter one is a more aggregate view for the entire economy.

In addition, the authors discuss scenarios, in which the TFP-residual does not capture these 'super-normal benefits' (Carlaw, K. and Lipsey, R. (2003, pp. 470 ff.), as well as Lipsey and Carlaw (2004, pp. 1133-1141)). Interestingly, these scenarios can be interpreted as potential measurement errors in the process of measuring productivity growth accurately. A question that will accompany the present study over the next parts and chapters.

Timing of the appearance of the invention is important. If technological change spreads its effects over different time horizons (in their example at once compared to a spread over 20 years), the effects regarding TFP and free-lunches can differ. More precisely, as free-lunches represent a reduction in the production costs they can diverge from the TFP measured, due to a difference in the contribution of cumulative costs.

Another important issue is the treatment of R&D in national accounts. If costs for R&D are reported as costs only, they do not lead to an effect on output (and productivity, therefore). It is a general problem, associated with the set up of national accounts in terms of how to treat certain variables. For Germany, the Statistisches Bundesamt has corrected this inadequacy in course of a major revision in 2014 and since then there is an explicit treatment of R&D as part of capital formation (see i.e. Statistisches Bundesamt (2014), also discussed in chapter 8 of the present study).

Natural resources are usually assumed to be included (implicitly) in the input factor capital. Any incorrect measurement ("omitted variables") of these input factors can either over- or underestimate output and productivity. If natural resources (such as land or minerals) are underestimated according to their implicit treatment (in K), then TFP and the "excess returns" diverge.

Omitted variables and more general aggregation problems are similar to the general discussion about measurement errors, as provided by Griliches (1987) (see chapter 4.2). Last but not least is the measurement problem of general purpose technologies (GPTs). Their effects on productivity might still be large, even though the respective date (or period) of innovation, invention and also diffusion has already been taken place decades (or even centuries) ago. For example, without having discovered electricity, modern production technology and the high level of efficiency still gain from this invention (though, its innovation costs do not show up anymore). It seems that measurement problems, one of the main aspects in the present study, appear and have appeared in many studies and debates before. Its potential for the explanation of missing numbers in data turns up to be reasonable.

6 Concluding Remarks Part II

Technology and productivity are the main drivers of human development, wealth and output (i.e. Herzog-Stein et al. (2017, p. 5)). So, it is of central concern to capture technology from a quantitative perspective in order to theoretically model it accordingly. In the majority of studies and approaches, this is total factor productivity (TFP), representing the degree of efficiency of all factors included in production. It is calculated as a residual in a growth accounting framework - a possibility to decompose economic activity regarding its contributors.

For the evaluation of productivity of the individual input factors, there are the variables of labour productivity or capital productivity. Both rely on the evaluation of the efficiency of the respective input factors. For an overall analysis of efficiency, the concept of total factor productivity is inferred - and if all factors are evaluated regarding efficiency, this represents or at least is related to technology.

Even though the common approach to model technology in terms of total factor productivity has some merits, it also contains several points, which are open for debates. More precisely, three potential views on how to interpret the TFP-residual are provided in this first part of the present study: a traditional one, stating an equivalence between TFP and technology; an alternative one, aiming to assign the unknown ingredients of the residual to input factors and a "third-way", which interprets the TFP-residual as some kind of economic externality.

There is a long-lasting history for the exploration of the causes and explanations on economic development. In order to theorize and theoretically discuss economic progress, an analytical modelling framework was required. Back at the beginning of the 20th century, the base for it was set. By providing the possibility of the theoretical conversion of input goods into economic output, in 1928 the Cobb-Douglas production function was developed.

Based on, and enriched with, a time-indexed property, the studies by Jan Tinbergen in the 1940s form the origin of the growth accounting approach, which purpose it was, to separate economic growth into its contributors. Hereby the general dichotomy between an increase in input factors and effects resulting from productivity is outlined - the latter traditionally associated and equalized with (effects of) technology.

Independent works from Robert Solow and Trevor Swan in the 1950s - the starting point of neoclassical growth theory - then form the next milestone in the debate on the causes of economic growth. As a result, Solow discovered a residual - the "Solow-residual" - being responsible for the bulk of US economic growth - and he labelled it as technological progress. As the consecutive studies and approaches have argued, however, there is far more behind a simple equalization. Rather the residual is to be understood as a variable, composed of unknown ingredients - a measure of ignorance, as Moses Abramovitz has once labelled it.

This second view of how to see and interpret the residual was later shared by works of Dale Jorgenson and Zvi Griliches in the 1960s and 1970s, who aimed to improve measurement and hereby minimize the residual - they were on the quest of turning the ignorance into real and reliable economic explanations. By doing so, they unknowingly formed a debate, the present study is dedicated to: what explains productivity puzzles - real economic causes or poor measurement?

Another potential view, the "third way", as provided mainly by Richard Lipsey and Kenneth Carlaw, on how to interpret TFP, is to understand it as the amount of "super-normal profits" or "super-normal benefits" with the character of an economic externality. Only those gains, which are not yet embodied in the stock of input factors show up as residual. And only under specific conditions, these disembodied effects represent technological progress.

Even though these points of scepticism exist, there is no better variable such as TFP, describing the contribution of technology in an economic framework. Having started from a simple equivalence, the external-effect and spill-over approaches became quite common. Usually, in modern growth literature, there is no serious nomenclature-debate, as it seems there is no necessity. If, however, one talks about technology and total factor productivity in one breath, one has to keep in mind that disturbances might exist, which might lead to a biased measurement and therefore to biased policy implications.

Without doubts, the main driver for the development of an economy is technology; however, it is hard to capture in a quantitative approach. If one correctly assumes a relationship between technology and (total factor) productivity, then it is of central concern for an economy to stress on a positive trend in the productivity statistics. The remainder of the present study will draw an image on the trends in productivity with a special focus on Germany and discuss potential channels and linkages. Moreover, it will discuss the declining trends in productivity and provide a two-fold line of explanation - real causes on the one hand, and mismeasurement on the other.

Part III

Mismeasurement or Real Causes? - Implications for the Explanation of Productivity Puzzles

7 Introduction

Productivity and its development over time are of central concern for economists and politicians likewise. Part II has already indicated that technological progress and productivity growth are linked to each other. They are connected and therefore intercorrelated with the development process of an economy. In course of the debate on declining rates of labour productivity in the 1970s (as a ramification of the two oil-price shocks), Nordhaus (1982, p. 131) once stated that:

> "The recent slowdown in productivity growth constitutes the major economic ailment of modern industrial countries today. More than any other ill - higher oil prices, deteriorating terms of trade, volatility of financial or foreign exchange markets, high inflation - low productivity growth is the root of the arrest of growth in living standards as well as the political malaise in the West."

Without taking a deeper insight into the data, one is easily confronted with shrinking rates in productivity in many countries over the last years (decades), varying to the extent, however. Not only regarding extent; economic conditions and explanations suspect that Germany is a special case, compared to other developed economies (Elstner et al. (2018, p. 34)).

Superficial research instantly confirms the view, that over the last years productivity growth has decreased (or in some categories at best stagnated), depending on the respective productivity variable considered. Growth in labour productivity and total factor productivity in Germany has slowed down over the past decades as illustration 1 shows. One is immediately reminded of the 1970s and the underlying debate over the reasons for the (global) decline in productivity (see chapter 9.1) and the worldwide recession back then.

Since the 1970s, growth rates of hours worked and persons employed have (more or less) remained stable over time, whereas GDP growth rates have declined in the latest past. Numbers of employment growth, measured as persons employed, can be found in between an interval of ±2%, except some (stronger) cyclical variations, like in the aftermath of the two oil-price shocks in the 1970s (i.e. -2.5% in 1975) or in course of the era of the German reunification. The latter has led to a so-called 'German Sonderkonjunktur' (i.e. +3.2% in 1990 and +2.8% in 1991), implying outstanding economic performances, at least for the (two) consecutive years after Reunification.

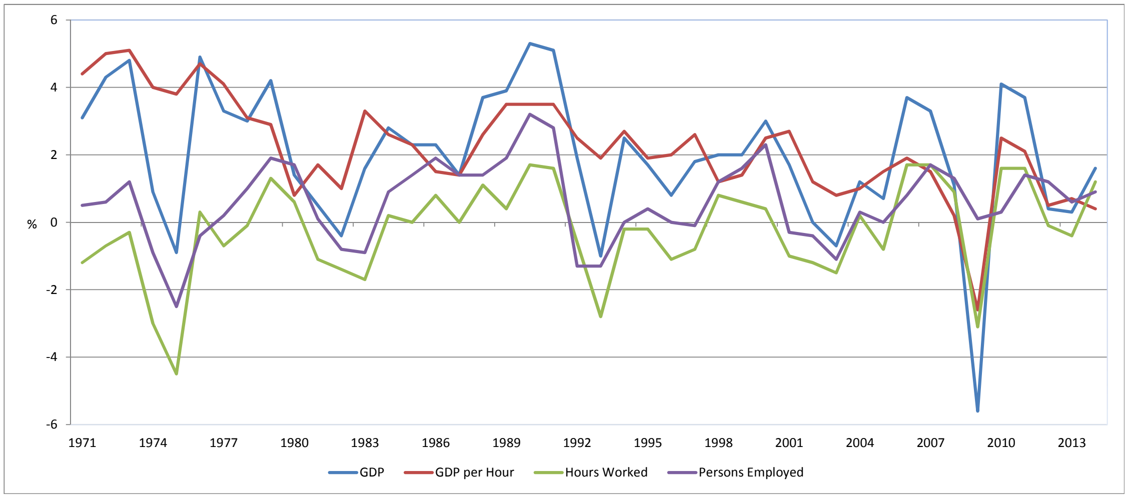
Likewise, employment volume by per capita measurement has remained stable. Following the same trend as employment, measured as per person, the growth rates can be found in between an interval of ±1% (also subject to cyclical swings in course of the oil crises in the 1970s, the German reunification 1989-1991 and the global financial crisis 2007-2009).

At first glance, this implies a declining growth ratio of output per unit of input (denominator constant, decreasing enumerator). The red line in illustration 1 shows the efficiency parameter of GDP per hour worked.

In the 1970s GDP per hour worked has experienced growth rates of about 5% p.a. (i.e. 1973: 5.1%). In the 2000s then, these values have dropped below the 2%-mark (neglecting cyclical phenomena in course of the financial crisis or others shocks; strong negative growth rates of -2.6% in 2009 have been compensated by years of moderate recovery in 2010 (2.5%) and 2011 (2.1%)).

Since then, growth rates have almost reached the zero bound, implying some kind of stagnation phenomenon. Their declining trends, and as the empirical section of the present study will show, therefore confirm the supposition, that productivity growth in Germany has decreased over the last years (and even decades) and GDP growth rates have declined slightly in the 21st century so far. Prior to this, growth rates of around 2% to 4% (except the often cited strong effects in part of the German Reunification) are found; nowadays only temporarily overstepping the 3%-mark.

Figure 1: Labour Productivity Growth and TFP Growth in Germany (in per cent), 1971-2013. Source: OECD Statistics (2016); own illustration.



Typically, theories for explanation are categorised into the demand or supply side of an economy. A debate on weak effective demand hereby is often used to explain the decline. Recent statements by Larry Summers (i.e. see Summers (2014a; 2014b; 2015b; 2015a)), have re-activated a discussion on what is called (demand-side) 'secular stagnation'. Summers relates his studies on the origin of the debate - delivered by the Presidential Address of Alvin Hansen back in 1939 (Hansen (1939)). Since then, 'secular stagnation' has been revived as a potential strand of explanation for decreasing rates of productivity (i.e. Aksoy et al. (2015)).

The main objective of the debate on (demand-side) 'secular stagnation' is the shortfall of effective demand in the long run. Whereas the majority of issues dealing with effective demand usually connects to the short run and the business-cycle-view, the debate on secular stagnation has shifted and extended the discussion to the long run.

Moreover, weak capital spending plays a role - withholding the latest and technologically advanced capital goods for the workers. Capital spending, especially in the public sector, provides the required framework for economic progress (mainly infrastructure). Besides the income effect, capital spending creates capacity for future economic performance and works as a "diffusion-machine" for technological progress. The impact on productivity growth is similar, like a high level of government spending, i.e. represented by regulatory issues[29]. A discussion of potential reasons is found in chapter 9. As weak capital spending also provides potential for a discussion, the empirical section provides data and trends on general investment behaviour, especially for Germany. Germany currently experiences a debate on whether there is a lack of investment in the economy ('Investitionslücke', engl. 'investment gap'). See section 9 and the listed studies for a more detailed discussion.

In contrast to demand-side phenomena, the supply-side provides explanatory power, too. The supply-side of an economy is associated with the (business) conditions and more general the framework for economic activity. As a substitute for a demand-side explanation (or a complementary?), Robert Gordon has formed an analysis, targeting potential obstacles in the framework of the regulatory sphere (i.e. Gordon (2012; 2015; 2016)). Whereas Gordon's major argument (less technological innovations) is subject to debate on, his minor arguments - the so-called "headwinds" - clearly focus on insufficient conditions in the environment of the United States, faltering economic growth.

This part of the study (part III) critically reflects on the development of German productivity variables. It asks whether Germany and other economies are experiencing a productivity slowdown from an empirical perspective and sheds light into the discussion about potential causes and explanations. One main focus hereby lies on the so-called mismeasurement hypothesis and general measurement problems- if there is a lack in the methodology and/or actual measurement process, this might account for the missing part in the data.

Syverson (2016), for example, recently has set up an analysis with regard to mismeasurement for the United States of America, spanning a time horizon over the last decades back to 1995. He concludes that mismeasurement cannot (entirely) account for the large gap in the productivity statistics but offers potential for further discussions and a deeper analysis. In fact, he discusses four different patterns, which counter the validity of the mismeasurement-hypothesis and (in sum) provide significant obstacles for its plausibility.

One of the issues discussed in the course of the mismeasurement hypothesis is the connection of ICT-heavy economies and labour productivity slowdowns (i.e. Syverson (2016, pp. 7-9)). In this

[29] The Wall Street Journal's May 2015 survey has proved results like these, available under <<http://projects.wsj.com/econforecast/#ind=gdp&r=20&e=1431549244029>>.

context "ICT-heavy" means, that the information and communication sector plays a decent role for the domestic economy, often measured by a ICT-to-GDP-ratio. In the course of the analysis of this section, country-by-country comparisons and the connection to the ICT-sector (and its size) are unfold. If mismeasurement is to account as a correct answer for the productivity puzzle in the US, then it should not be reflected in other countries as well (still subject to to discussion, as mismeasurement problems might occur simultaneously in various countries; at least they should not appear to the same extent or exhibit equal patterns). Data, however, show that a significant amount of other countries (other than the US) is experiencing low and declining numbers in productivity development, too (despite having different ICT-intensities).

Moreover, mismeasurement can also be related to the problem of changing quality or more generally - the composition of different types of goods and services. If products change regarding quality or their characteristics, then a quantitative comparison over time will be distorted. So-called "Hedonic Prices Indexes" have a long-lasting history and try to correct for changing product properties, in order to isolate the price effect.

This part, therefore, contributes in multiple ways. Firstly, it provides an evaluation of productivity indicators with a focus on Germany. Secondly, it separates for the two main strands of explanation - the productivity puzzle as a result of poor measurement or real economic causes. For the latter, Gordon's theory of (supply-side) secular stagnation is applied on Germany, evaluating the (economic) environment with regard to productivity development. For the argument of mismeasurement, the main focus is on Syverson (2016), and an application on Germany is provided. It will be shown that mismeasurement exhibits potential wisdom for the solution of productivity puzzles, its explanatory power, however, is simply too small. The reasons for shrinking rates of productivity, therefore, must lie in a nexus of real causes and maybe in the belief of having less (important) innovations in the 21st century.

8 Empirical Analysis

8.1 Preliminaries

General

What is so special about productivity variables and what can we infer for the general economic development path of a country? According to the first part of the present study, total factor productivity represents the best option available to capture technology in an economic framework. The growth accounting approach hereby divides economic growth into its relevant components. One can use it to display the relationship between productivity variables (namely labour productivity LP and total factor productivity TFP) and the effect of capital deepening (k):

$$\hat{LP} = \hat{k} + T\hat{F}P \tag{8}$$

denoted in growth rates, with $k = \frac{K}{L}$ as the amount of capital (K) per unit of labour (L).

Labour productivity growth is the sum of technological progress (if one accepts the TFP-notation) and the growth in the ratio of capital goods per unit of labour[30].

Any further specifications are possible - for example, in course of the rising relevance of the ICT-sector, a separation between ICT- and non-ICT-sectors regarding capital investment. It allows to evaluate the effects of changes in the ICT-sectors and non-ICT sectors separately (following Herzog-Stein et al. (2017, p. 6)):

$$\hat{LP} = a\hat{K}_{ICT} + b\hat{K}_{Non-ICT} + T\hat{F}P \tag{9}$$

with a and b as weights[31].

[30] Rearrangements are possible, so that (i.e.) technological progress is labour productivity minus the effect of capital deepening.

[31] These weights are expressed in percentages and are calculated as average over the last periods of time, regarding their weight to total capital input. Herzog-Stein et al. (2017, 4) follow the OECD-calculation method (see OECD (2015a), especially pages 69-70). The shares are computed by using data for the past two years and are calculated by the Tornqvist-method.

So, no matter which productivity indicator is chosen, one can derive implications for the counterpart. If one wants to explain declining incomes and decreasing rates of economic development, one has to confront the analysis at different points. Either one can find reasons for decreasing incomes (expressed as GDP or GDP per capita) due to less labour productivity growth, less technological change (represented by TFP) and/or by the effects of a lack of investment (per unit of labour).

It seems acceptable, taking labour productivity as central productivity variable due to better data availability, more studies dealing with it instead of total factor productivity and the easier and more straightforward approach with regard to measurement[32] (Griliches (1988, p. 10)). Labour productivity can be expressed as either per person or per hour worked (the former as rather a welfare indicator, the latter one usually preferred for efficiency analyses, like OECD (2015a) offers).

In both cases, it reflects an input-output-relation, which allows to evaluate efficiency and economic develoment. (National) income per person (=labour productivity as measured per person), the indicator for economic welfare and development mostly used, can be split into the following identity (Herzog-Stein et al. (2017, p. 4)):

$$\frac{GDP_t}{Pop_t} = \frac{GDP_t}{h_t} x \frac{h_t}{E_t} x \frac{E_t}{EP_t} x \frac{EP_t}{Pop_t} \tag{10}$$

with the components of entire population (Pop), amount of hours worked (h), persons employed (E), employment potential (EP) and gross domestic product (GDP). All variables are taken from the same period of time t. Gross domestic product (GDP) or national income per person then is derived as the product of four terms: GDP per hour worked ($\frac{GDP_t}{h_t}$) times average hours worked ($\frac{h_t}{E_t}$) times employment ratio ($\frac{E_t}{EP_t}$) times Labour Force Participation Rate (LFPR) ($\frac{EP_t}{Pop_t}$).

This separation allows tackling the individual parts individually. It also shows that finding one single explanation for declining rates of productivity seems unlikely, as a variety of potential reasons exists.

[32]Labour productivity erases complications from having more than one production factor in the calculation and it avoids the problem of aggregating over heterogeneity of capital stocks.

Data

In order to provide a reliable base for the consecutive discussion of the productivity puzzle, this chapter breaks down important stats and trends in productivity development. Several databases are possible to be taken into account, all of them slightly varying in detail and sometimes methodology. Many of the following illustrations of this chapter are based on the OECD productivity statistics[33]. The OECD also makes use of data provided by The Conference Board (2019), which itself collects data from OECD, national accounts like Eurostat or EU-KLEMS[34] (see i.e. OECD (2015b, p. 100)). Methodology and individual calculations for the OECD data are explained in De Vriees and Erumban (nd). If appropriate, calculations and methods are explained in more detail in the respective subsequent chapters. Also, if other sources differ in their data analysis, this will be noticed in individual cases.

National accounts are subject to regular minor and major revisions. To provide a common base and to make data comparable, country-specific data is based on the System of National Accounts (SNA). The SNA is an internationally agreed standard and includes a catalogue of regulations and recommendations for the quantification of economic activity. The current version in use is the SNA 2008, which almost all member states of the OECD have already adopted and implemented successfully. Switching from one to another system-version includes major changes. As the SNA includes several revisions, country-based comparisons have to be used with a certain amount of care, as differences in the data also might result from (minor) differences in the calculation method.

An important example for a major revision is the revision of national accounts in Germany in fall 2014. Beside including military goods in the investment category, R&D-activities are now part of the large investment category (counted to “other fixed assets”) and have changed the numbers significantly in this class.

The effect of including R&D was tremendous for the investment category. For Germany, the revised value for GDP in current prices in 2010 (taken as example) was an increase of 3.3% (or from €2.5 trn. to almost €2.6 trn.). Gross capital formation in total rose by 14.3% (around €2 bn.), the so-called “other fixed assets”, making almost €60 bn., which include the important R&D-expenditures,

[33]See OECD Statistics (2016) and the yearly published extensive compendium of productivity trends: OECD (2015a).
[34]More details on the EU-KLEMS project are provided at <<http://www.euklems.net/index.html>>.

now explicitly taken into account. In fact, including R&D-expenditures has increased gross capital formation by the largest amount ever (i.e. Statistisches Bundesamt (2014); Hagemann et al. (2016); Brümmerhoff and Grömling (2014)).

Another aspect noteworthy is the price-deflation of nominal GDP-data. Productivity is loosely defined as real output (enumerator), relative to the input used in production (denominator). To infer nominal output from the national accounts into real output, it has to be adjusted with prices. Various concepts to deflate nominal output are possible. GDP-deflators have the advantage over consumer-price-basket-methods in this case, as they represent all the goods and services being produced in an economy (consumer price basket methods value the change in the costs of living standard and also include imported goods and service). Capturing the change in prices of all goods, in this case, is superior to the basket-method, as all goods matter in an aggregate analysis of productivity. In order to quantify or evaluate (i.e.) the change in the standards of living, a consumer-price basket-method has to be chosen, as the change in some prices does not influence the consumption level. Moreover, as in the consumer-price basket imported goods are represented, they might distort the productivity analysis of the domestic country.

To make the results internationally comparable, however, a common standard has to be adopted and implemented. Here, the methodology of the purchasing power parity (PPP) is commonly used. It converts nominal values of all countries' currencies into US-dollar-standard by using the PPP-method (here: nominal GDP by market prices), in order to receive real GDP. Then, economic data, used to quantify and calculate productivity numbers, is linked to one unique base - US-dollar by having used PPP, which provides a common base for all countries.

Both methods, however, exhibit problems regarding the registration of quality effects. More precisely, changes in prices can also result from changes in the nature of products (and services) and their respective qualities. Section 9.3.2 discusses an alternative method to correct for quality-induced price changes - the so-called hedonic price index (method). The presumption is that increases in prices are overstated, leading to lower rates of productivities in the end. Hedonic price indexes indicate a lower change in prices, implying higher real values of output and productivity likewise. If executed correctly and the effects of the price correction are trustworthy, then it offers another potential for the missing part in productivity.

The empirical section of this study includes the analysis of the production factors in use. Hereby the inferred productivity concepts are linked to the actual factors in production. Used most frequently, this is labour productivity and multi-factor-productivity (MFP)[35].

8.2 Labour Productivity and Income Per Capita

Commonly, labour productivity is defined as the simple ratio of gross domestic product (GDP) and a denominator of some kind of labour input (i.e. Jorgenson (1986, p. 63)). Definitions, however, offer potential for debates, especially when confronted to the problem of aggregation over (heterogeneous) variables - within a country and/or by executing comparisons with other countries (in which definitions might deviate).

For the denominator of labour productivity, either persons or the exact working volume (expressed in hours) can be chosen (even more, persons can be understood as the entire population of a country, its working population or another fraction -a more detailed discussion can be found in section 8.2). Per capita rather provides information on the standard of living (represented as income per capita), whereas per hour worked is chosen when productivity is the issue (Ademmer et al. (2017, p. 31)).

Additionally, 'total hours worked' is the more appropriate denominator in use, as it is more robust to economic policy actions or structural labour market developments, like splitting full-time jobs into several part-time jobs or so-called "Arbeitsbeschaffungsmaßnahmen" (ABM[36], highly promoted by German labour market policy changes in course of the introduction of the "Hartz reforms" in the early 2000s[37]). The effects of the "Hartz reforms" and their implications for German productivity growth will be discussed in more detail in section 9.2.5.

Moreover, hours-based approaches have the advantage to derive propositions over more than one year. A quick view into economic history shows, that the average daily or weekly workload or time spent at work has slightly decreased within the last decades (i.e. in Germany after WWII from around

[35]Please note that in this context the terms multi-factor-productivity (MFP) and total factor productivity (TFP) are used synonymously.

[36]The ABM were abolished in 2012.

[37]By the implementation of small-scale employment models - for example so-called Mini-jobs and Midi-Jobs - unemployed persons shall be re-introduced to the labour market by roundabout, the so-called "secondary labour market".

10 hours per day to nowadays around 8 hours a day, see chapter 8.6 for details).

Measurements, using the person-denominator, cannot account for complete accurateness, like the hours worked concept can. A reduction in the average workload per person provides a downward bias in the productivity number (if total working volume is constant, less average workload per worker implies positive employment effects, which in turn lead to a larger denominator and smaller productivity, therefore). It should rather be understood as income per capita and the respective welfare indicator.

'Total hours worked', the productivity-indicator chosen by the OECD, includes the workload of employed and self-employed workers in production ("all persons engaged in production"). Productivity statistics should capture the actual amount worked, whether paid or not ("overtime", "unpaid work"), as every hour worked leads to output changes and therefore contributes to national GDP. 'Actual hours worked', though, differs from 'hours usually worked', 'hours paid for', 'contractual hours of work', 'overtime hours of work' and 'absence from work hours' (see OECD (2015a, p. 73)). In this context, it is interesting to note, that the OECD includes 'maintenance time', 'time used to travel to work or between working locations', 'waiting time', 'training time', 'cleaning time' and 'time spend on-call duty' for the calculation of the denominator.

Especially 'time used to travel to work' is discussable, as it is not ultimately linked to the production process and might be subject to possible biases. If, for example, in rural areas people require more time to travel to their working place, measured labour productivity is lower by the "extra-amount [necessary] to travel" (OECD (2015b, p. 73)), compared to urban areas, where people usually need less time to get to work, as there is a superior system of infrastructure. Does the productivity - or efficiency - of the 'rural' workers have to be considered as lower? Yes and no. Yes, as in a given amount of time the urban worker will extract more output and contribute more to national product, compared to the rural worker. No, in a sense, that their individual abilities and skills might be the same or even differ in advantage or the rural worker.

The same logic applies for the separation between employed and self-employed workers. Self-employed workers usually make use of more time spent in home-office. Home-office does not lead to travel-time, so that these workers could offer higher productivity even though their abilities and skills are the same, compared to an employed worker. On the other hand, however, less time is spent with unproductive travel-time. It is a question of how to define labour input in general. One finds arguments on favour and against ex- or including 'travel time' or other parts as well.

Excluded in the OECD-statistics, however, is the time used for (longer) breaks at work, (public) holidays and/or educational training, which makes sense as this does not directly lead to changes in production. Longer absences from work and holidays are not related to the working activity and training/education is an investment in human capital and not an input factor in production. One might ask to ex- or include some of the listed aspects, as they are part of definitory questions. If there is a common standard, however, all countries considered will "suffer" from such a possible bias.

Biases, resulting from definitory problems, can be neglected if they occur in all countries by the same extent. Whereas the first point (in all countries) might be true, if the same institution is responsible for the calculations, the second point might cause problems. Countries usually differ significantly (even in the OECD) among cultural, economic, political and social aspects and more general in their structural composition and "way of life and work". A (specific) portion of the difference in productivity numbers could be derived from those biases and should, therefore, be erased as best as possible.

The actual measurement process of 'hours worked' offers potential problems and potential to debate. Usually and in most (OECD-) countries data is collected via direct measurement by using surveys. Additionally and if survey data is not available (or leads to disproportionally high transaction costs), so-called 'reference weeks' are taken into account. Upon a 'reference week', the annual workload is then extrapolated afterwards. Some countries, however, do not provide data via direct measurement and adjust the 'reference-week-method' by other sources and components (i.e. establishment surveys, tax registers or social security registers). Without any doubt, a method used uniformly in every country would raise liability and correctness of data. So far, it has to be taken into account that differences in productivity measurement can arise from different methodologies, used in different countries (OECD (2015b, pp. 73 f.)).

The empirical analysis of labour productivity and multi-factor-productivity is organized as follows. Deriving data from the OECD database, numbers for the measurement of the per capita, per hour worked and per person employed approach are provided. Additionally, this section also adopts a time interval separation from the OECD (2015b)-study, with regard to the global financial crisis of 2007-

2009 - a major structural change for almost every economy in the world. One interval represents the era, which is considered as 'pre-crisis' (2001-2007) and another one as 'post-crisis' (2007-2013). Both are compared to a 'default-interval' of the entire time (1995-2013).

Again, it is noteworthy, that any interpretation of trends in labour productivity should be used with caution. A country, or more precisely, its companies, might (differently) react to a decline in GDP-growth (may it be a business cycle- or long-run development), with a reduction of the working hours, in order to compensate for the lack of demand in markets. Such a pro-cyclical phenomenon is often identified in developed economies (see Okun (1962)). If then labour productivity is calculated by the 'per person'-method, rising efficiency in crises and declining productivity in expansions would be the result, even though skills and abilities have remained constant.

Also, if working hours are kept constant, labour productivity trends obviously might show a decline due to a negative trend of the GDP-enumerator, arising from other aspects like a lack of demand. This should not be interpreted as declining efficiency of the employee himself. This effect has to be separated from changes in the quality of a country's human capital stock.

For the analysis, the range of countries was chosen due to their economic significance, in order to display possible differences more accurately and of course due to data availability. As Germany (and the US) are the countries of major interest for this study, France is also taken into account as a reference scenario or benchmark. The French economy exhibits a similar structure (compared to Germany) and its economic performance has a similar standing in the European Union. Greece is added as a counterpart in order to show the negative business cycle developments (especially those) in course of the financial crisis 2007-2009. The members of the European Currency Union (ECU) are included, as it is assumed[38] to have a higher degree of similarity (homogeneity) among these economies, than among member states of the European Union (which do not share the same currency, monetary policy or other institutional endowments).

[38] At least in theory, ECU-members are expected to exhibit a high degree of homogeneity.

Per Capita

Labour productivity per capita breaks down (aggregate) GDP relative to a country's population, no matter whether employed (including self-employed) or unemployed. This calculation has to be considered with a certain amount of care. Firstly, changes in the size of the population matter, whereas changes in the structure of an economy's population remain unconsidered (demographic changes as discussed in section 8.6, as well as in section 9.2.4). Secondly, and if the denominator represents the entire population, comparisons between countries assume the same percentage of the working population (see section 8.2), relative to the entire population (more precisely, retirement age, schooling system and other labour market characteristics then necessarily have to coincide). As the separation in chapter 8.1 has shown, GDP per capita can be separated into four sub-components and is usually interpreted as a measure of income. GDP not only represents the amount of output produced in an economy, it also accounts for the incomes generated[39]. A change of GDP per capita can therefore be interpreted as a welfare indicator, as well as a productivity indicator.

Figure 2 shows the growth rates for specific countries from 1971 up to 2015, whereas figure 3 adopts the index-method. Hereby the value of 2010 is taken as base year. Every other year is then depicted in relation. Germany's growth rates of labour productivity per capita have just exceeded the zero bound by little within the past years (2012: 0.3%, 2013: 0.2%). The negative results of the year 2009 (-5.3%) can be neglected in some way, as most countries have suffered from such a collapse due to the aftermath of the global financial crisis. As already discussed, this (and the two consecutive years of recovery) represent a business cycle swing and a natural rebound afterwards. Even though business cycles matter (especially due to their potential of having implications for the long run), for the purpose of the present study longer trends play the more significant role.

A remarkable aspect of the German case is that, compared to the ramifications of the first oil-price shock in the 1970s (1973: 4.5% and 1974: 0.9%), growth rates have slowed down on average. A decade-by-decade comparison shows that the average annual growth rate in Germany for the decade of 2006-2015 is 1.4% compared to 2.8% in 1971-1980, implying a drop of 1.4% p.a.

[39] As the calculations of pattern four in the course of the mismeasurement analysis (10) will show, in reality GDP and GDI (gross domestic income) diverge due to statistical discrepancies.

So does the United States perform, which has experienced a similar trend like Germany. In the course of the supply-side shock due to the oil embargo of the OPEC in 1973 and its ramifications for the US-industry, the values shrunk from 4.6% for 1973 to -1.4% in 1974. Also, in the recent past, the US growth rates of labour productivity, measured as per capita, have declined (2012: 1.2%, 2013: 1.2%). The decade-by-decade comparison exhibits a similar pattern like the German case. From 1971 to 1980 the average annual growth rate in the US was 2.1%, whereas currently (2006-2015) it has reached a value of only 0.6%, implying a drop of 1.5% p.a..

Figure 2 also provides the remarkably volatile growth rate of Greece. The swings confirm the current economic situation in Greece: volatile development processes and a high degree of dependency on business cycle trends cannot be considered as a healthy environment for an economy. Especially the downturns in the 1970s, and in course of the global financial crisis in 2007-2009, which have hit Greece quite hard. The 14.4%-drop of the Greek growth rate in 1974 (from 7.6% in 1973 to -6.8% in 1974) is an outstanding example for an extreme (negative) swing.

Even the consecutive years after the crisis, in which many other countries were able to recover (at least) slightly, Greece has only reached negative values in income growth per capita (2008: -0.6%, 2009: -4.6%, 2010: -5.6%, 2011: -9.0% and 2012: -6.8%). The decade-by-decade comparison for Greece is even more remarkable, reaching from 3.7% (1971-1980) to -1.9% (2006-2015) and implying a drop of 5.6% p.a. on average.

Growth rates of the OECD and European Currency Union (ECU) are generally on a more moderate level (also because no values for the 1970s and 1980s were available). Noteworthy is the fact that in 2012 and 2013 the European Currency Union has suffered from negative growth rates (2012: -1.1%, 2013: -0.5%); the OECD in contrast only grew negatively in the year 2009 (-4.1%). As the OECD contains more countries, negative developments concern a larger area and not a single country only. Negative developments have to be taken even more seriously, as the economic significance concerns a vast area and many more citizens, compared to a single country.

Figure 2: Labour Productivity, (GDP per capita, total economy, percentage change at annual rate) 1970-2015. Source: OECD Database (2014); own illustration.

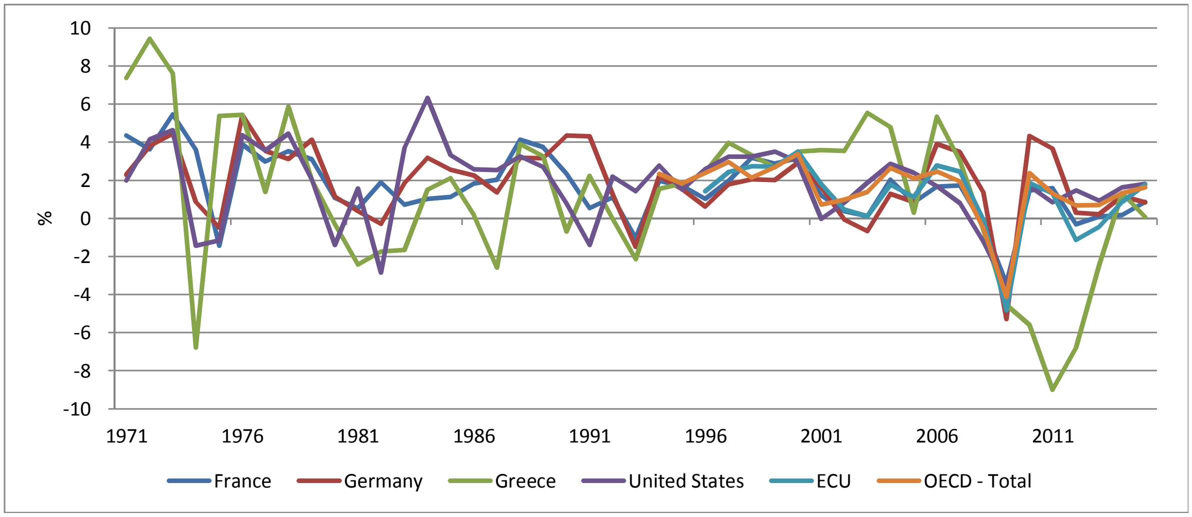
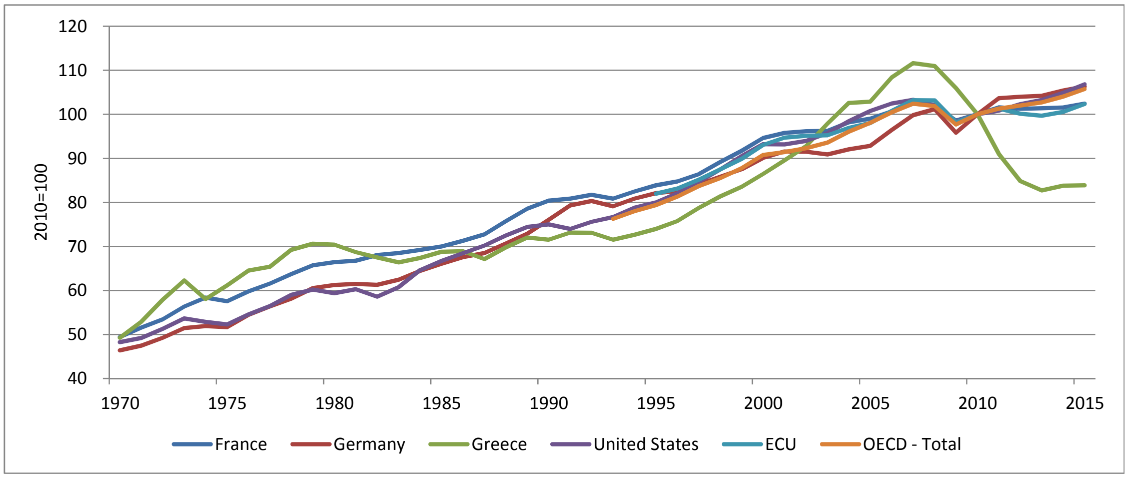


Figure 3 shows the labour productivity per capita development by making use of the index-method. Hereby, 2010 works as the base year for all calculations. The results of the index-method and the results from the growth rates expression converge. All countries or groups of countries have experienced a steady increase in labour productivity growth until the 2000s. Up from the beginning of the 21st century and especially after the global financial crisis the curve has become flatter, which implies slower rates of growth or even negative values. Again, the highly volatile Greek scenario (green line) can be identified.

Figure 3: Labour Productivity, (GDP per capita, total economy, 2010=100) 1970-2015. Source: OECD Database (2014); own illustration.



Per Hour Worked

The more precise tool for the quantification of economic efficiency regarding the input factor labour is the per hour method. It erases complications, arising from different labour market characteristics of the countries considered (i.e. different retirement ages). Otherwise the average working weeks, in terms of hours, have to coincide among countries, which is not the case for all countries. Furthermore, labour market politics distort the outcome. If an institution or company decides to cut down a full-time job into two half-time jobs, the amount of people employed is doubled in this scenario - the labour input in total (as measured in hours) however has remained the same. The per hour method, as mentioned, erases complications like these, but itself offers potential for criticism and biases (see chapter 8.1 for details).

As already considered in the introduction of this chapter (section 8.2), an accurate measurement of working hours is almost impossible. Mismeasurement due to false reports or the unwillingness of companies to provide the data are just two of the problems, that might occur. There is also the problem of how to define working hours. Do lunch breaks go into the calculation? Does travel time go into the calculation? And how is training-on-the-job being treated - fully equivalent to a standard working hour or only by a certain fraction? Even though labour productivity measured per hour worked is subject to uncertainty as well, it seems to offer the best methodology to compare countries regarding their efficiency (especially if one single "data-collector" like the OECD gathers the data. However, as the OECD makes use of the national accounts offices of the individual member states, a specific amount of care is still appropriate, as the methodology and data collection of the national offices diverges slightly).

Compared to the per capita calculation method, the decline of the considered growth rates (as illustrated in figure 4) is even sharper, which indicates either an increase in the entire employment volume (which is not the case for most of the countries) or an even sharper (overproportional) decline in output. Apart from the example of Greece, the numbers look less volatile, compared to the per capita calculation method. For example, German labour productivity growth rates per hour vary from -2.6% (2009) to 2.5% (2010) instead of from -5.3% (2009) to 4.3% (2010) of the per capita approach (both intervals ranging from 2006-2015).

Figure 4: Labour Productivity, (GDP per hour worked, total economy, percentage change at annual rate) 1970-2015. Source: OECD Database (2014); own illustration.

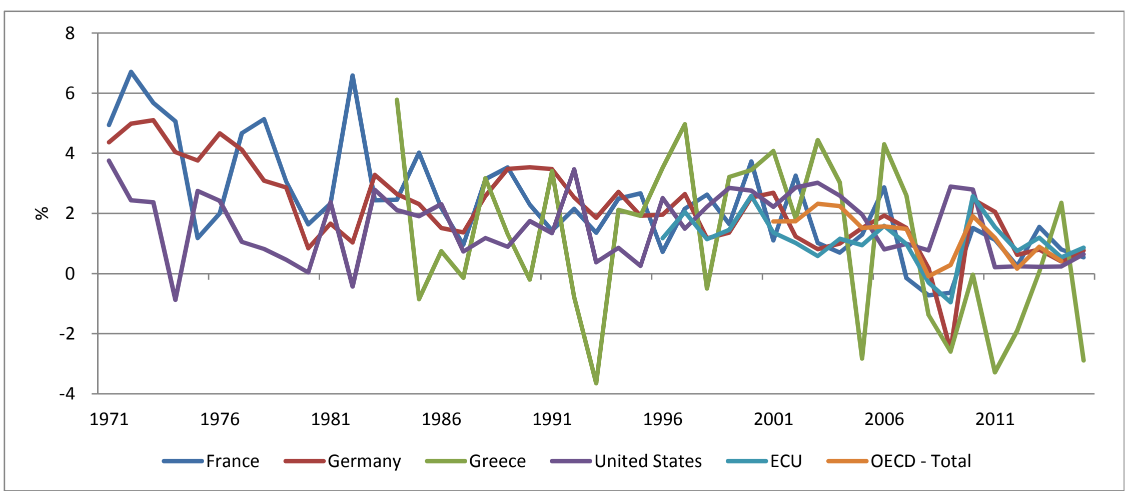
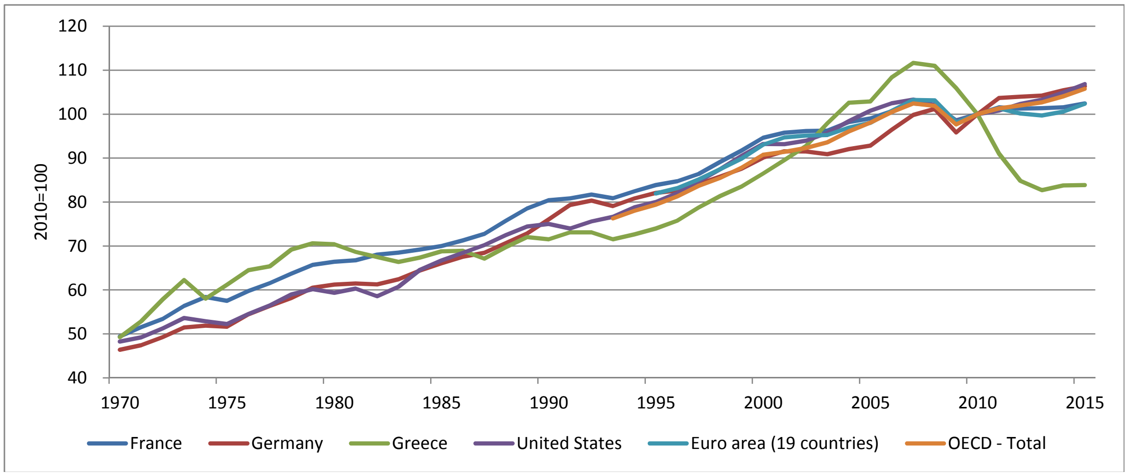


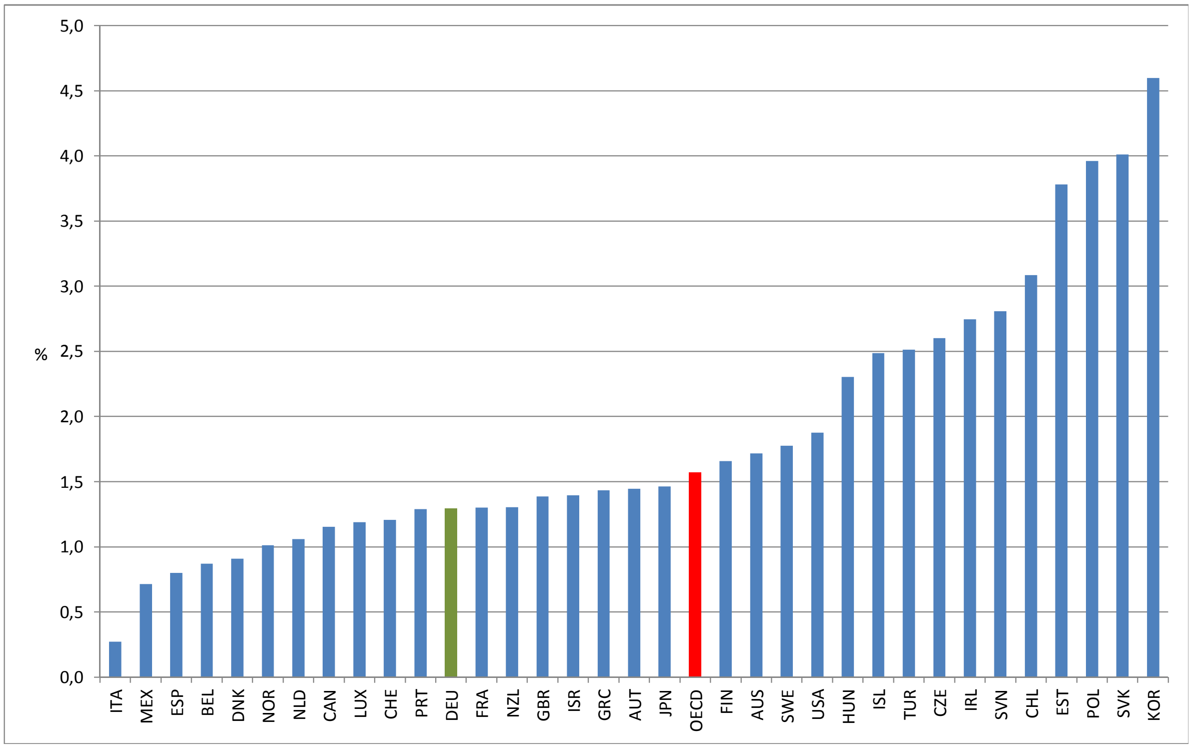
Figure 5: Labour Productivity, (GDP per hour worked, total economy, 2010=100) 1970-2015. Source: OECD Database (2014); own illustration.



In addition to the year-by-year scenario, the OECD also provides data in a large compendium of productivity indicators (i.e. OECD (2015a)). Labour productivity trends for a great variety of countries are separated into three intervals examining the impact of the global financial crisis of 2007-2009: a default scenario, which captures the entire time interval from 1995 to 2013, a pre-crisis interval, which captures the development from 2001 to 2007 and a post-crisis scenario, capturing 2007 up to 2013.

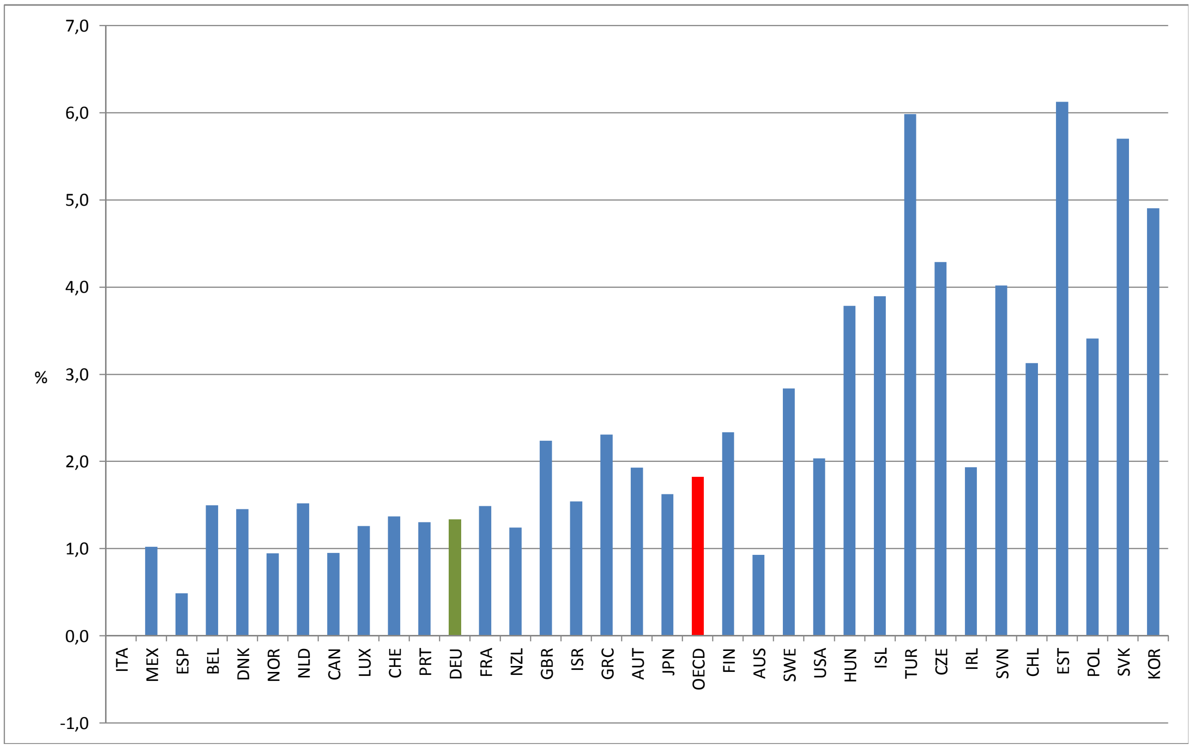
The default-scenario of labour productivity trends in the OECD, as illustrated in figure 6, shows the average annual growth rates for the OCED and its member states from 1995 up to 2013. Labour productivity in the OECD has grown by 1.57% annually, while Germany shows a growth rate of 1.29% only. Noteworthy is Korea with 4.6%, whereas Italy at the bottom end only grew by 0.27%. Such a large time-interval has to be treated with caution, as several business cycle effects - and therefore volatilities - do not show up (however often they are not significant for long run, if they only display short-run phenomena, reversing themselves and therefore disconnected from long-run trends). The 'default-scenario' is the reference scenario, the short-time intervals are then depicted in relation.

Figure 6: Labour Productivity, (GDP per hour worked, total economy, percentage change at annual rate) 1995-2013. Source: OECD (2015a); own illustration.



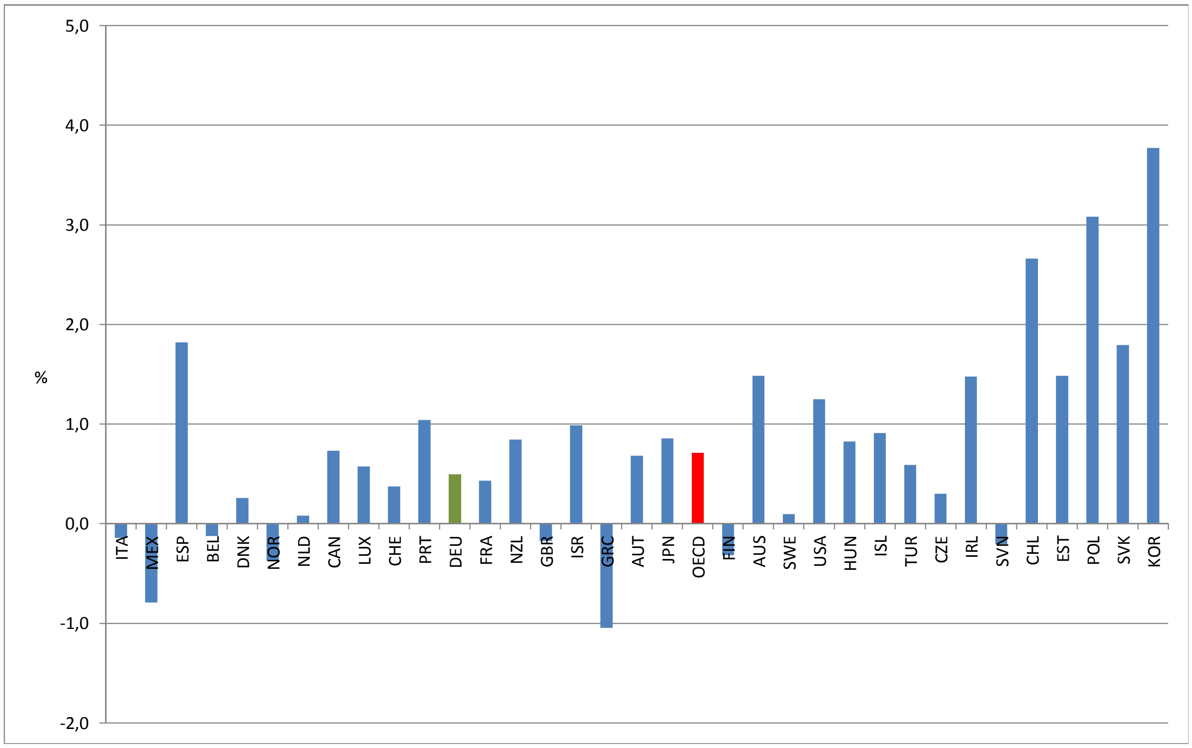
In the pre-crisis-era of 2001-2007, as illustrated in figure 7, the OECD in total grew by 1.82% annually, Germany by 1.34%, Korea by 4.9%, and Italy offered a slightly negative trend of -0.01%. Compared to the default scenario, even in the 2001-2007-interval many countries have already suffered from a decline in productivity (i.e. Spain, Italy or Australia). A result, that could indicate a rejection of a business-cycle based explanation for the decline in productivity growth.

Figure 7: Labour Productivity in the Pre-Crisis Era, (GDP per hour worked, total economy, percentage change at annual rate) 2001-2007. Source: OECD (2015a); own illustration.



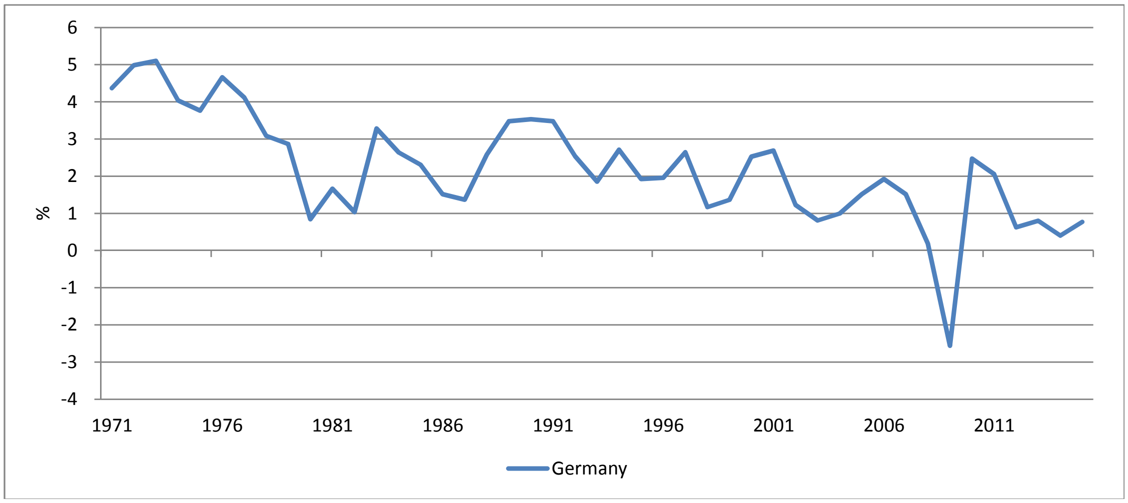
To account for the negative impact of the global financial crisis and the resulting European crisis on economic data, illustration 8 shows the average annual growth rates in labour productivity from 2007-2013 (post-crisis interval). Whereas several countries have experienced negative growth rates in this period (i.e. Greece, Italy or even Great Britain), the OECD in total still grew by 0.71 %, Germany by 0.5% and the United States by 1.25%. In general, labour productivity numbers have fallen significantly compared to the 'pre-crisis'-interval. Growth rates have declined even more (with the exception of Korea), compared to the 'default scenario' (1995-2013), which is not a surprising result.

Figure 8: Labour Productivity in the Post-Crisis Era, (GDP per hour worked, total economy, percentage change at annual rate) 2007-2013. Source: OECD (2015a); own illustration.



It can easily be seen, that growth rates over time have declined globally. As even in the pre-crisis interval growth rates are lower compared to the default scenario, one can see, that the major parts of productivity gains were located in the 1990s. Exemplarily taken and illustrated in figure 9, Germany shows a steady decline, starting with remarkably high growth rates (expressed as GDP per hour worked) of about 3% to 4% in the 1990s (and even 5% in the 1970s, i.e. 5.1% (1973)) down to rates of about 0% to 1% in the late past (i.e. 0.4% (2014) or -2.6% (2009), the latter one as a result of the global financial crisis).

Figure 9: Labour Productivity Growth in Germany (GDP per hour worked, total economy, percentage change at annual rate) 2007-2014. Source: OECD Statistics (2016); own illustration.

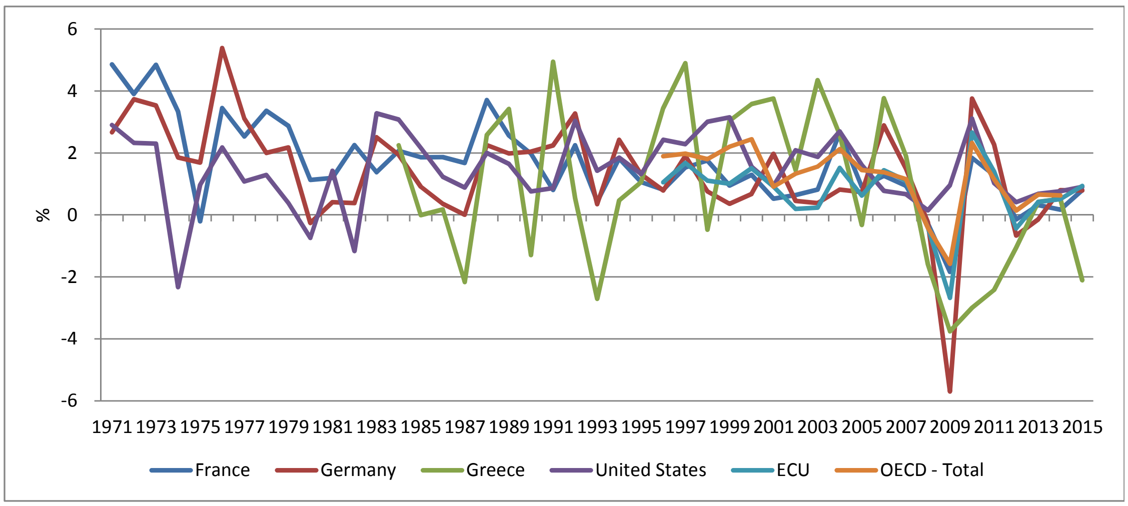


Per Person Employed

As already discussed, labour productivity per capita provides conclusions on the level of welfare, as well as output produced per person of the economy. A more precise way for productivity analyses is the per hour worked approach, as it allows a more detailed breakdown and corrects for differences across countries, as well as for differences over time regarding the standard working week. Output is produced by the working population but labour productivity per capita "distributes" output over the entire population, regardless of being part of the production process or not. Productivity analyses across countries or over time then can also diverge due to different fractions of people available for work. Demographic change also influences the labour market supply side and has to be taken into account. Even though the overall trends of the different measuring approaches should converge, a comprehensive empirical analysis requires the labour force to be taken into account. For further discussions and a decomposition of labour market variables, please see chapter 8.6.

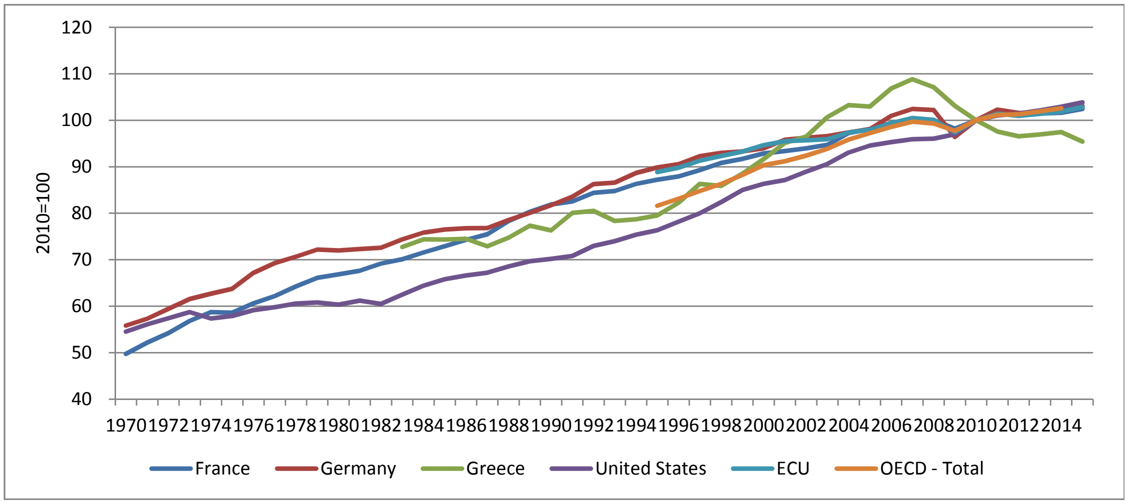
The results from the per person employed approach look similar to the hours worked method regarding direction and trend. Growth rates in the 2000s move along the zero bound, only marginally positive, as figure 10 shows. The dips, however, are even more extreme. Has the decrease of labour productivity growth per hour worked in Germany in 2009 reached a value of -2.6%, so does it reach -5.7% according to the persons employed approached (more examples can easily be spotted). According to the per person employed approach, the global financial crisis in 2007-2009 has hit Germany hard, even harder than Greece (2009: -3.8%) and the OECD in total (2009: -1.6%).

Figure 10: Labour Productivity, (GDP per person employed, total economy, percentage change at annual rate) 1970-2015. Source: OECD Database (2014); own illustration.



Currently, labour productivity per person employed circulates around the 1%-mark (i.e. 2015: 0.8%). So does the performance of the other countries considered. In 2015, France shows 0.8%, too, whereas the United States and the European Currency union (ECU) show 0.9% and the OECD in total 0.6% (2014). Figure 11 shares the statement. Since 2010, labour productivity per person employed, expressed as an index, has slowed down in Germany, too. In 2011 the index (base year 2010) was at 102.3, in 2015 at 103.1.

Figure 11: Labour Productivity, (GDP per hour worked, total economy, 2010=100) 1970-2015. Source: OECD Database (2014); own illustration.



Calculating labour productivity as GDP per person employed is an alternative measure. Even though often used to quantify labour input, it can be considered as inferior to the hours-based approach. This is due to the fact, that the average amount of hours worked varies from country to country and is also dependent on business cycle trends. Even countries in a relatively homogeneous economic area differ among average hours worked per person and day. In 1995, in the European Union, 38 hours per week have been worked, currently 36 (2017)[40], including full-time and part-time occupations regardless of age and sex. Average working week in Italy and France shrunk from 40 to 37 hours, in Germany even from 40 to around 35. A separate calculation, based on data of the IAB, also shows a decreasing trend over time but 32 hours on average for Germany (see section 8.6; differences occur due to different datasets and methodology). Moreover, resulting from cultural and social differences, from regulatory issues or structural factors, country-by-country comparisons might be subject to distortion.

Entrepreneurial behaviour is another crucial aspect, which has to be considered. Capacity utilization of firms changes in a pro-cyclical way - when being exposed to a recession, an entrepreneur often forgoes firing workers in order to keep transaction costs low (those costs include 'barriers', like

[40]In order to avoid structural breaks as best as possible, European Union here consists of the first 15 countries, who joined in between 1995 and 2004.

contract-rigidities, regulatory issues or simply the time necessary to train a worker for the production process). If labour productivity is measured by GDP per person employed, the denominator (labour, input) is kept constant, as working hours do not play a role, whereas the enumerator declines due to the recession. Individual productivity, more precisely the efficiency and ability of the remaining workers, has remained constant - a result not indicated by the declining labour productivity term (already stated in section 8.2, see Okun (1962)).

Additionally, labour market policy sometimes allows or even promotes for separating full-time jobs into part-time contracts. Reducing unemployment (as measured by persons), especially in pre-election times, is quite common and famous for policy-makers to secure their re-election, or to boost their standing. If then, for example, an 8-hour workload, which has been executed by one person in the past and is now executed by two part-time workers, employment, as measured by persons, has doubled - but has labour productivity now being cut into half? Obviously not. Even though a per-person calculation is tempting to 'directly' imply for per capita efficiency, the per hours concept has to be preferred, in order to avoid manipulation but correctly display the 'volume' of labour put into production in an economy.

8.3 MFP/TFP

Total factor productivity (TFP) or multi-factor productivity (MFP) is the other main variable of interest when it comes to productivity analyses. Part II has discussed the nature of total factor productivity and its relevance for technological changes. Taking it as an equivalent, or as a proxy if considered as only loosely related to technology. In any case, it is the gold standard in use for overall productivity comparisons and analyses.

An economy's development path is deeply interconnected with the development of MFP. The more technologically advanced an economy is, the higher its level of development and economic welfare becomes.

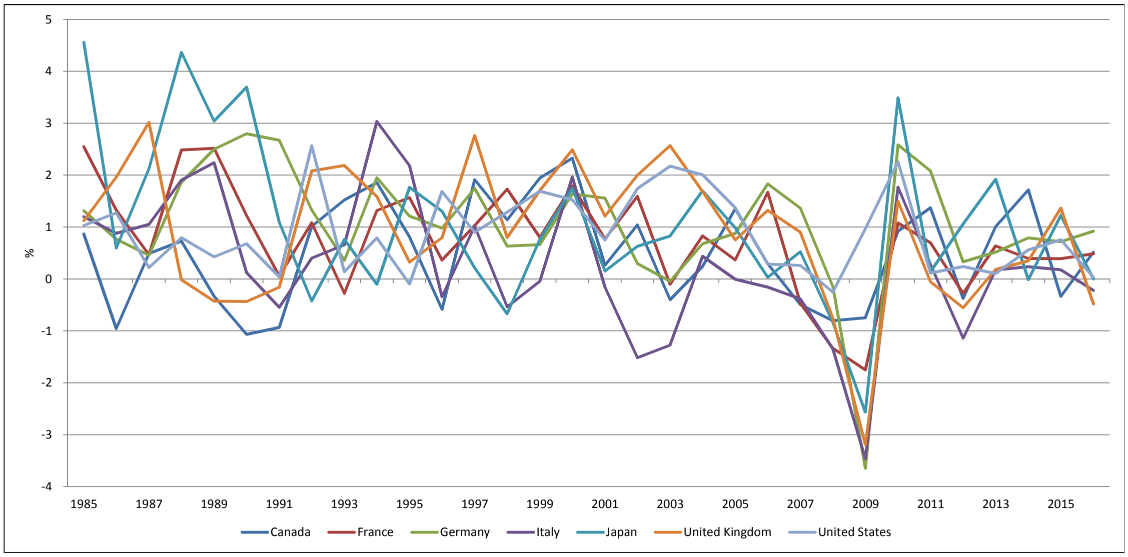
Even though labour productivity is taken as the central variable for discussing the productivity puzzle in the present study, the TFP-view shall not be neglected. It contains a broader view, as all factors in production are evaluated regarding efficiency. Especially when it comes to the discussion about declining rates of gross capital formation (see chapter 8.5), TFP provides a valuable perspective for productivity analyses. The connection between labour productivity and TFP has been unfolded theoretically in chapter 8.1.

Figure 12 shows TFP growth rates for the G7-states. Besides the two major economies of interest for the present study, Germany and the United States, the G7-countries are taken into consideration. They exhibit similar structures and general economic endowments like Germany and the US do.

Experiencing TFP growth rates of almost 3% in the late 1980s, France - the Grand Nation - now ranks among many nations with growth rates of below the 1%-mark (disregarding some positive and negative outliers attributable to short-term cycles). In 2016 the French MFP growth rate was at 0.5%.

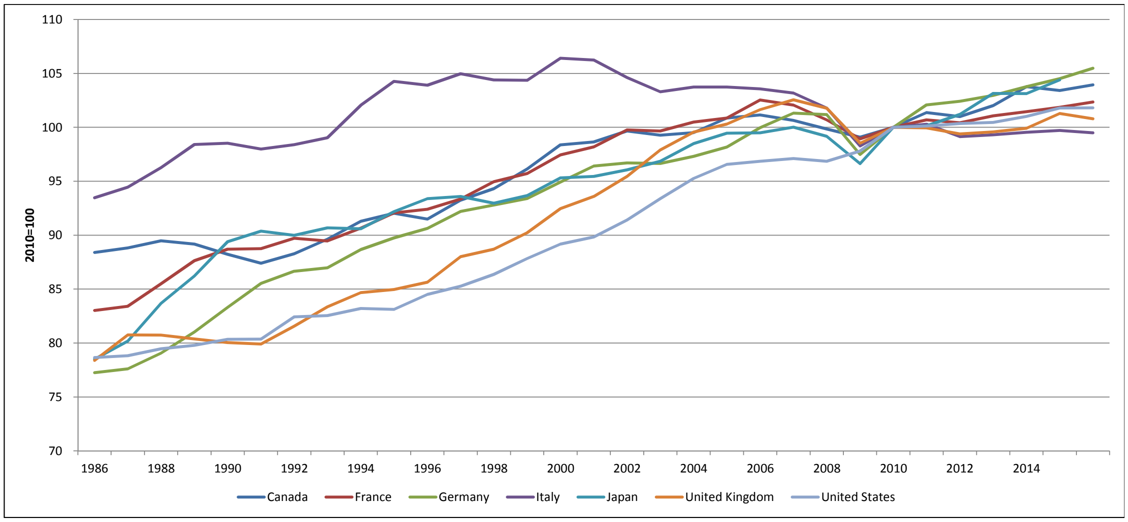
Germany's peak, in the time interval considered, can be found around its age of Reunification (1989: 2.5% and 1990: 2.8% and 1991: 2.7%). In the 21st century, however, it outperforms France just by little (Germany in 2016: 0.9%). Canada's strongest values are located in the 1990s, peaking in 2000 (2.3%) and currently circulating around 0.5% (2016). Italian's growth magnitude is a little bit larger, hereby showing rates from -3.5% (2009) up to 3% (1994) and currently -0.2% (2016). Japan has started strongly with 4.6% in 1985 and 1988 (4.4%), before slowing down to values at around 1%. In the 2000s it has managed to rebound to 3.5% (2010). Great Britain had its strong years of MFP-growth in the end of the previous century (1997: 2.8%) but went on to an era of (many) years of negative growth rates, currently showing -0.5% (2016). For the US it is interesting to note, that almost every year considered shows less growth in TFP compared to Germany and France. Peaking in 1992 (2.6%), the US nowadays finds itself at a stagnation value of 0.0% (2016).

Figure 12: (TFP/MFP, total economy, percentage change at annual rate) 1985-2016. Source: OECD Database (2014); own illustration.



The results become even clearer when depicted by using the index-method, as figure 13 does. Prior to the Global Financial Crisis in 2007-2009, all countries offer similar slopes, representing continuous development. After the dip, their development process has slowed down dramatically, represented by a flatter slope of the curves. For the illustration, 2010 is taken as base year. Six years later (2016) the values for the US (101.8), Germany (105.5) and France (102.3) show the decreasing speed in development (maybe except Germany, which has performed slightly better). Italy even shows a slight decrease in its multifactor productivity level (2016: 99.5). The same scenario applies for the United Kingdom (2016: 100.8), whereas Canada (2016: 103.9) and Japan (2015: 104.4) rank among better-performing countries.

Figure 13: TFP/MFP (total economy, 2010=100) 1985-2015. Source: OECD Database (2014); own illustration.



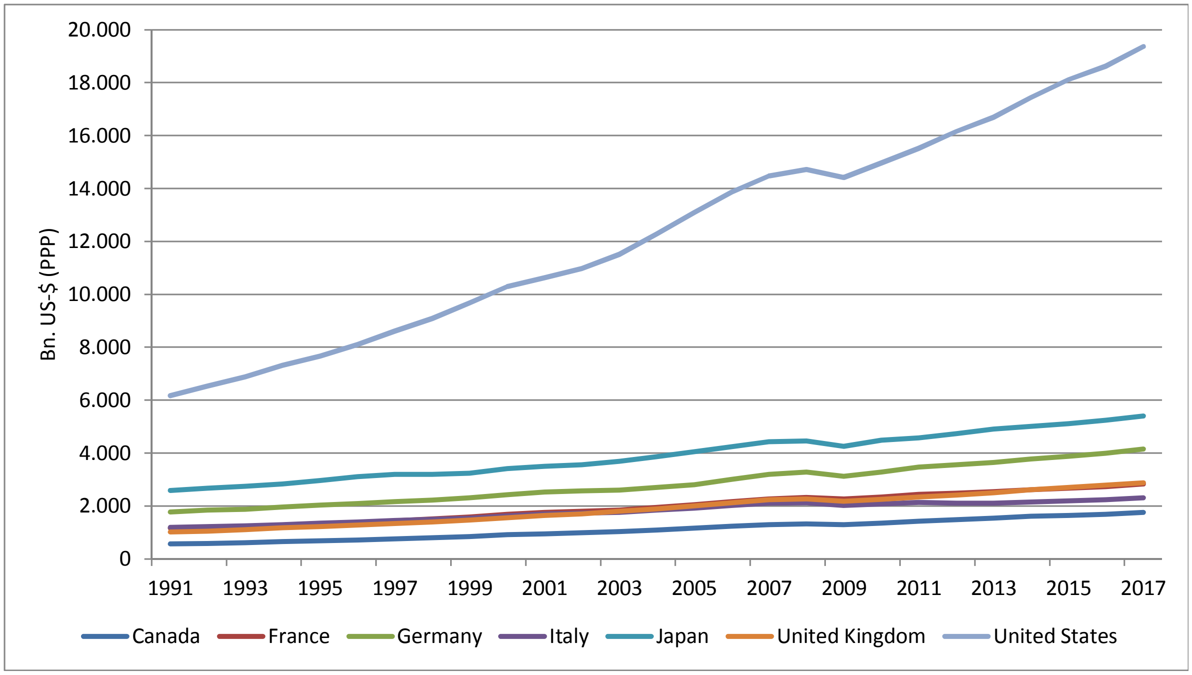
8.4 GDP

As labour productivity contains a numerator of output and a denominator of input, it also seems appropriate to analyse the components separately. A declining numerator can result in less labour productivity growth, so does an increase in the denominator.

Figure 14 shows the GDP-development of the G7-economies (in current prices, converted into international US-dollar via Purchasing Power Parity)[41]. Besides the 2009-dip in the course of the financial crisis, the United States shows the sharpest slope. When compared to the United Kingdom, Italy shows a "falling behind" in the 21st century. In fact, 2003 was the first year of Great Britain to overtake Italy ($1.794 trn. (GB) vs. $1.762 trn. (Italy)). An opening gap between the United States and Germany is quite obvious; Germany has outperformed GB over the last decade. Has the gap between the two countries remained constant (in this context it means a gap of $0.752 trn. in 1991 to $0.796 trn. in 2005 and only temporarily overstepping the $0.8 trn.-mark), it has widened over the last decade. Currently (2016) the German GDP exceeds GB by $1.269 trn..

[41] Note that 2017 is provided as forecast due to data availability (January 2018).

Figure 14: GDP International, current prices, PPP-conversion 1991-2017. Source: International Monetary Fund (2017); own illustration.



As a comparison based on current prices only might lead to insufficient information and conclusions, the respective growth rates in constant prices shall be taken into account as well. By using constant prices, the price effect can be erased, forming a more reliable view on output performance of a country.

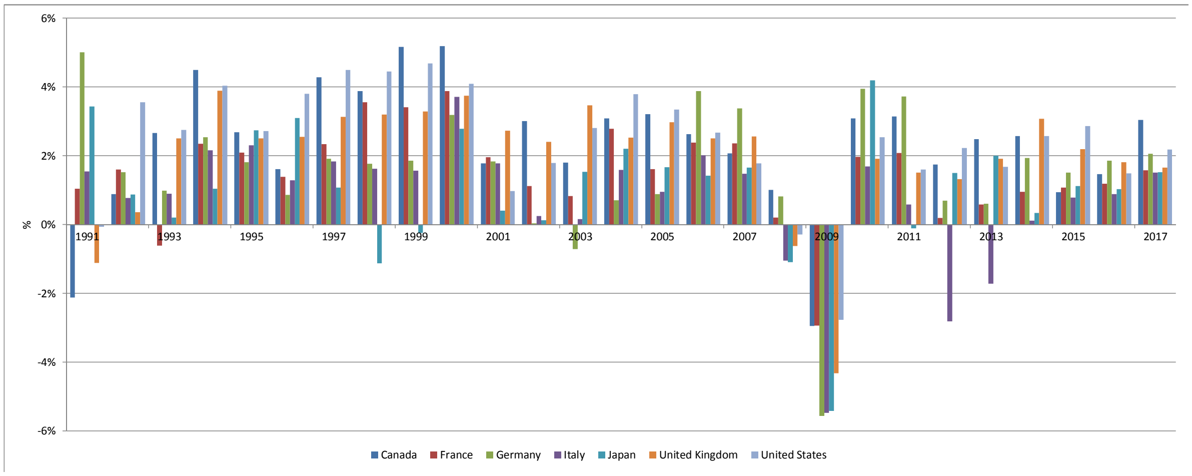
Figure 15 provides the (real) growth rates and hereby shows a separation into two parts. The first one, ranging from the mid-1990s until the year 2000, exhibits strong rates of economic development. Especially Canada, Great Britain and the United States have performed well above the 2%-mark for many years. Canada only temporarily understepping the 4%-boundary. German growth in the time interval can be considered as conservatively constant at around 2%.

The second interval, representing the starting years of the 21st century, is characterised by growth rates on a rather moderate level. Most of the countries provide rates of around or below 2%, except for some outliers.

Noteworthy are the two years of recovery in Germany after the economic turmoils in 2007-2009.

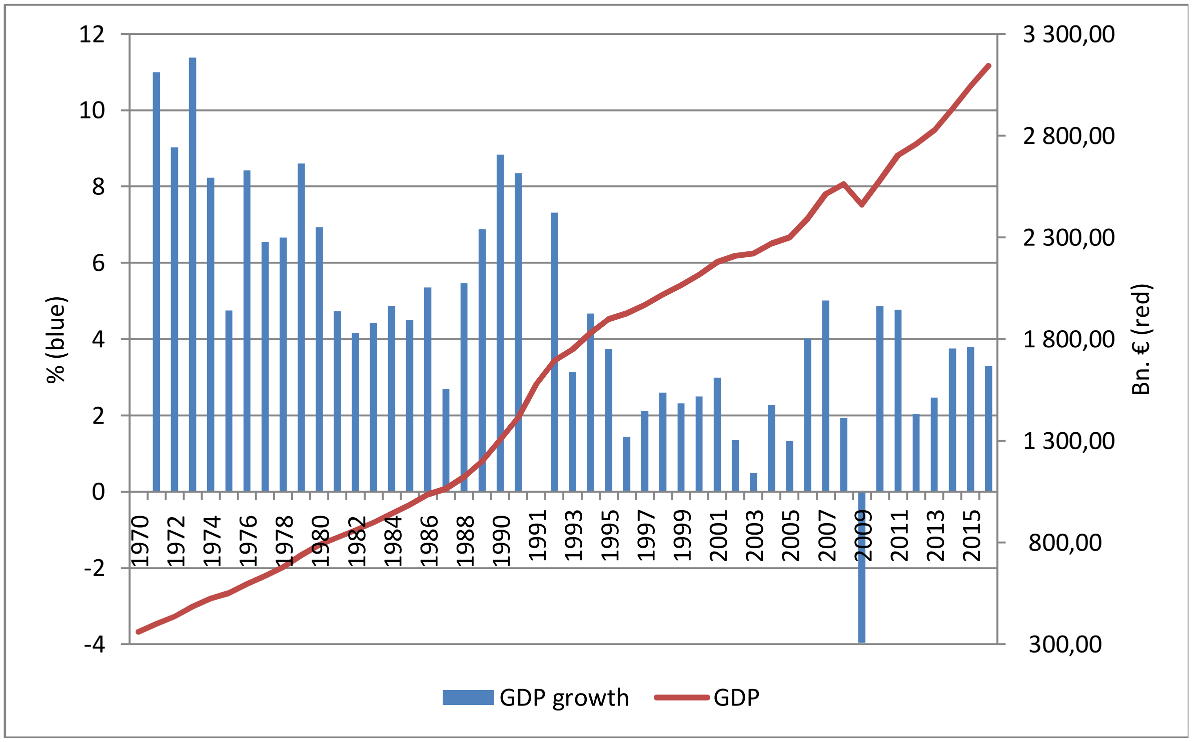
Compared to other G7-countries German economic growth has re-accelerated quickly to 3.954% (2010) and 3.718% (2011). Only Canada was able to catch up but did not experience a sharp decline in 2009 like Germany did (-5.563% Germany vs. -2.950% for Canada).

Figure 15: GDP Growth, constant prices, percentage change 1991-2017. Source: International Monetary Fund (2017); own illustration.



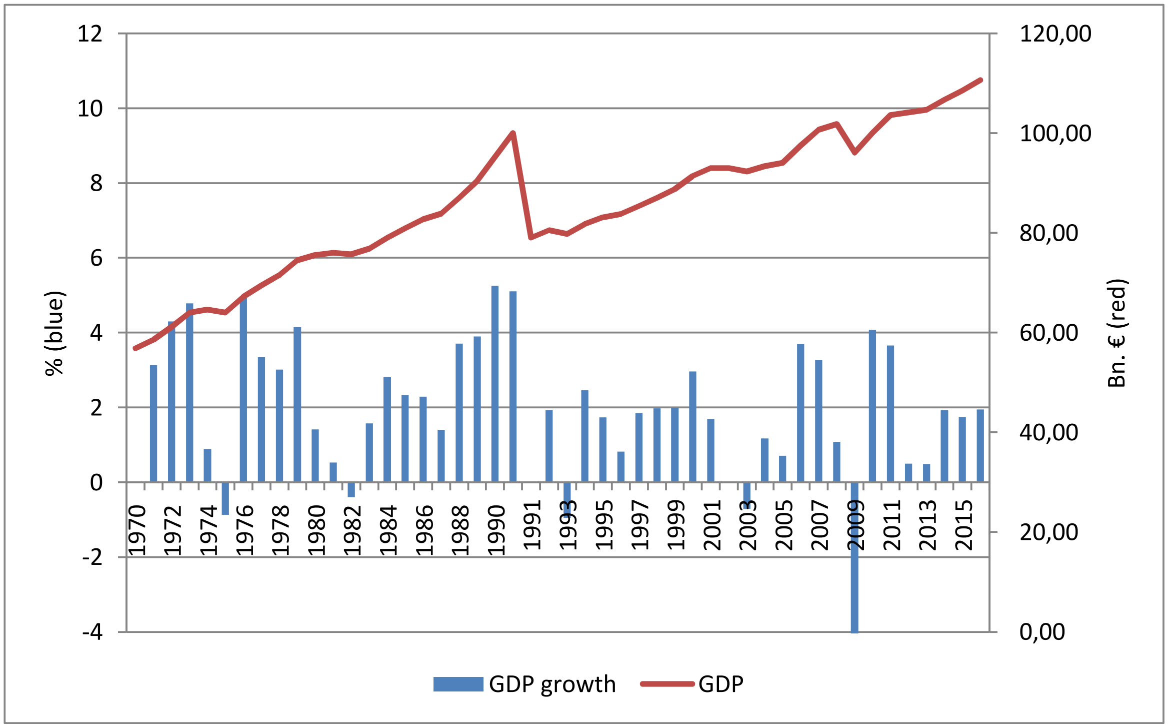
In order to shift the focus to Germany, Figure 16 shows (nominal) gross domestic product (GDP) and the respective growth rates from 1970 to 2016. Neglecting the business cycle dip in 2009, its trend is (linear) positive. Growth rates, however, offer a different point of view. Strong economic growth at the beginning of the 1970s (i.e. 1971: 11% and 1973: 11.4%), were cut by the oil-price shocks (resulted in growth rates of around 5%) and revived at the beginning of the 1990s and in course of the German Reunification (i.e. 1990: 8.8%). Since then, their values have only temporarily overstepped the 3%-mark (hereby neglecting the -4%-outlier in 2009). In general, a trend towards less economic growth is visible, when compared to decades ago. Also, when compared to other European countries, which were hit by the global financial crises as well (see figures 14 and 15 and Weber (2017) for example).

Figure 16: GDP, total economy, percentage change and levels 1970-2016. Source: Statistisches Bundesamt (2015c); own illustration.



More meaningful is figure 17 and the real values for the German performance. Whereas the index (red line) provides a positive but less strong growth, compared to the nominal values in figure 16, real growth rates (blue bars) show real economic growth of less than 2% p.a.. Compared to the nominal values, more years of shrinking growth rates (i.e. 1993: -1%, 2003: -0.7%, 2009: -5.6%) can be identified.

Figure 17: GDP real, total economy, percentage change and levels 1970-2016. Source: Statistisches Bundesamt (2015c); own illustration.



8.5 Capital Formation, Investment Dynamics and Infrastructure

8.5.1 General

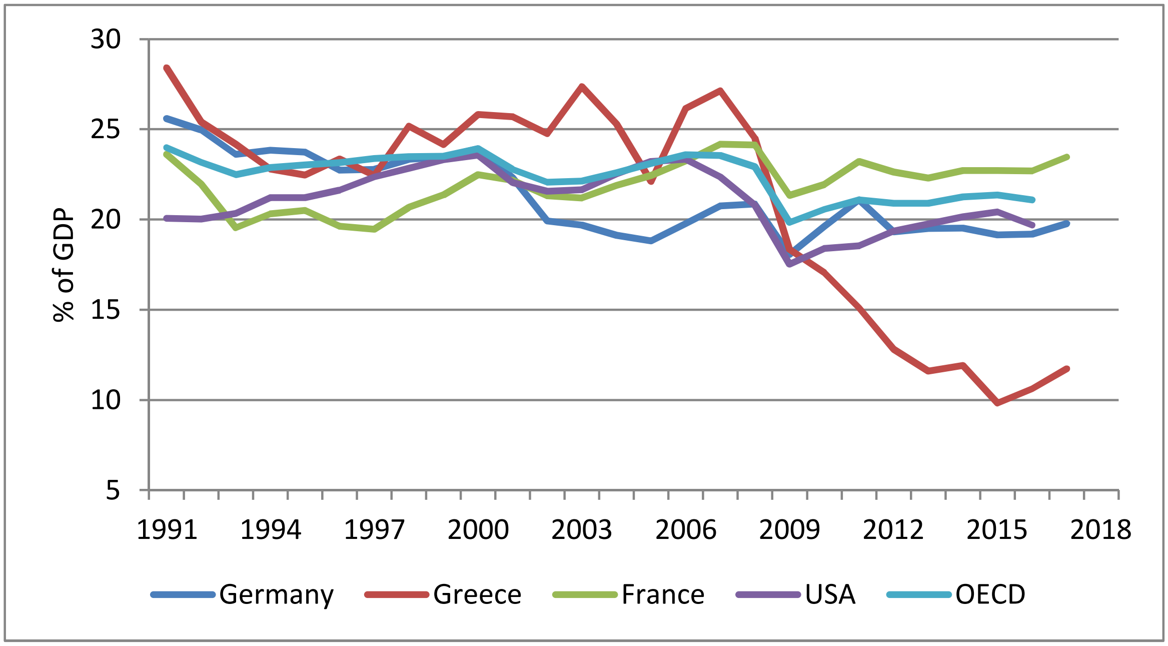
Chapter 8 provides the base for the discussion in the remaining chapters, dealing with potential explanations for productivity puzzles. Capital formation also plays its role, as labour productivity, TFP and capital deepening are linked to each other.

Many studies on capital formation in the recent past have set their primary analyses on the public sector, addressing the issue to the public capital stock. However, besides public investment, also private investment has experienced a sharp decrease over the last decades in the world's major economies. For the present study, many variables of the investment category contain informative value. It is tried to select the most important ones for the purpose of shedding light into the darkness of productivity puzzles. For a detailed and more comprehensive analysis of investment dynamics in Germany over the last (almost) three decades, please see Hagemann et al. (2016, especially chapter 3).

For an international categorisation, figure 18 provides trends of (developed) countries with regard to their total gross capital formation[42]. It shows gross capital formation as the fraction of the economy's GDP. Almost all countries are exposed to a declining trend, varying by the extent, however. In a first superficial view, the German rate of investment appears to be on a rather sufficient level; unfortunately offering only slightly better numbers in relation to the starting values. In the 1990s, Germany has shown significantly high values of 25.5% (1991) - over and above OECD-average (23.9% in 1991) - but has dropped below OECD-average and shows only 19.2% in 2014. Over the last years, it has slightly recovered to almost 20% (19.8% in 2017). The US-value has peaked in 2000 (23.5%) and is currently (19.7% in 2016) ranked in the same regions as Germany. Like in most countries considered, the French ratio (France chosen due to similarity with the German economy and importance for the European Union) has dropped in course of the financial crisis (2007-2009) but has recovered then in 2017 (23.5%) - an even higher value compared to the ones shown in the 1990s (i.e. 19.5% in 1997). Greece, in contrast, has not yet recovered from the ramifications of the global crisis and ranks among low-level productivity countries, currently providing gross capital formation of around 11.7% (2017). Its drop seems to be remarkable, as for most of the years considered, Greece has circulated around the 25%-mark - and it has outperformed Germany and others.

[42]Total gross capital formation includes the two parts of sectoral demarcation of an economy's capital stock - the public one and the private one.

Figure 18: Gross Capital Formation (in per cent of GDP) 1991-2017. Source: World Bank (2019); own illustration.



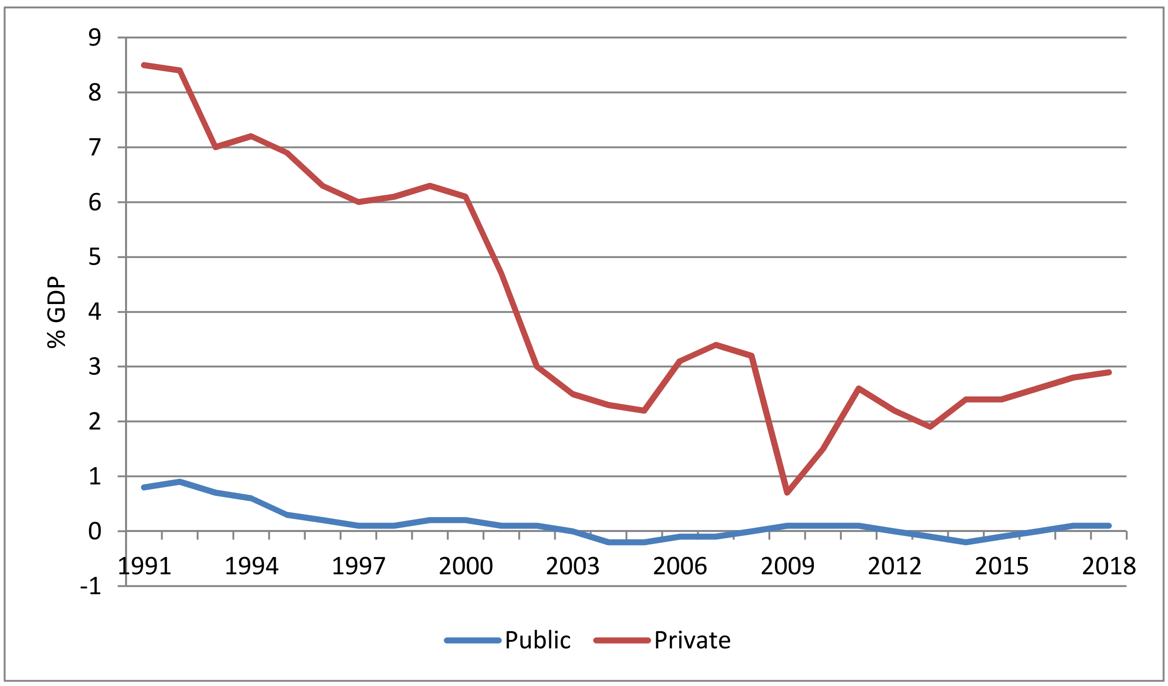
Depreciation of capital goods plays an important role in the evaluation of an economy's capital stock, so that gross values can only tell one part of the story. Net capital formation[43] is another, maybe even more accurate way to show the (rather poor) development of the German case. Figure 19 provides net capital formation, as well as a separation between investment in the public and private sector. Especially the public sector's rates are subject to concern. Negative net values imply a "consumption" of the public capital stock (i.e. infrastructure, military or ecological aspects) (i.e. see Expertenkommission „Stärkung von Investitionen in Deutschland" (2015), Grömling et al. (2019)). Generally speaking, the supply of public goods not only plays a direct role for aggregate welfare of an economy in the short run, but it also positively shapes and stimulates the environment for private investment (see chapter 9.2.3 and the discussion of the so-called "Aschauer-hypothesis").

Back in the 1990s, net public investment has circulated around the 1%-mark but has now dropped below the zero bound (2014: -0.2% and in 2018 just slightly positive: 0.1%). For the private sector,

[43] Net and gross values are linked by the effect of depreciation.

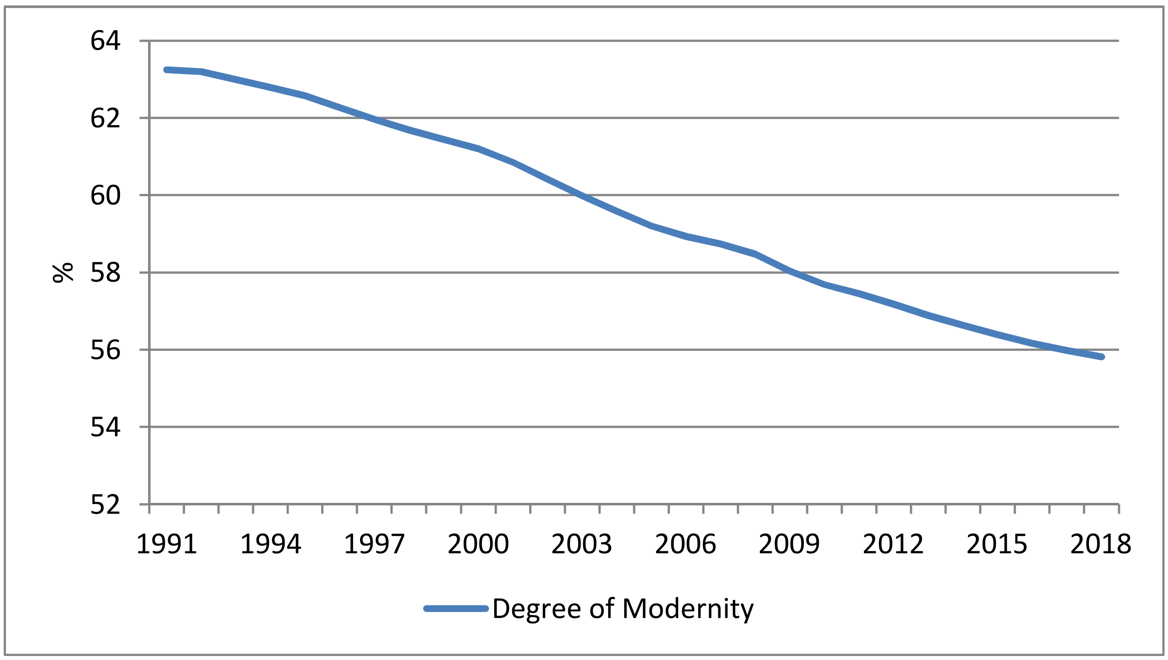
the dip is even stronger, however, numbers are still positive. Starting with almost two-digit values (1991: 8.5%), the private sector's net investment fell back to 2.4% (2015) - hereby neglecting the lowest value in 2009 (0.7%) as part of cyclical fluctuations. Whereas the private sector hardly manages to maintain the (quantity) of its capital stock, the public sector has failed completely. However, one could carefully interpret the last three years (2016-2018) as a sign of moderate recovery. Currently, net capital formation for the private sector has rebounded to the 3%-mark (2.9% in 2018).

Figure 19: Net Capital Formation (in per cent of GDP) 1991-2018. Source: Statistisches Bundesamt (2018b); own illustration.



In addition to net capital formation (and in order to highlight the effect of depreciation), the degree of modernity of total capital equipment can be used to provide information about the modernity of a nation's capital stock. It is defined as the ratio of net to gross fixed assets and provides a stock-based view (contrary to the flow-perspective of investment). Figure 20 shows the declining trend of the German capital stock's degree of modernity (Statistisches Bundesamt (2017c), Code: 81000-0118). Over the years, the degree of modernity has dropped from 63% (1991) to 59% (2018). Future, positive net capital formation is necessary to oppose the decrease and modernise the capital stock. A modern capital stock is crucial, as a requirement for any kind of technological progress, high rates and levels of productivity and more generally economic development.

Figure 20: Degree of Modernity (total economy) 1991-2018. Source: Statistisches Bundesamt (2017c); own calculation and illustration.



As a short side note on the discussion about capital stocks and gross capital formation - this only describes the quantitative evaluation. Quality and efficiency aspects are not captured so that one might come to contrary messages on the state of Germany's capital stock. Moreover, decreasing trends do not reflect a calculation of setpoints or optimal values; they just suspect insufficient equipment of business infrastructure. Detailed information and data on the (quantitative) need is required, in order to derive explicit policy implications (Hagemann et al. (2016, pp. 196 ff.)).

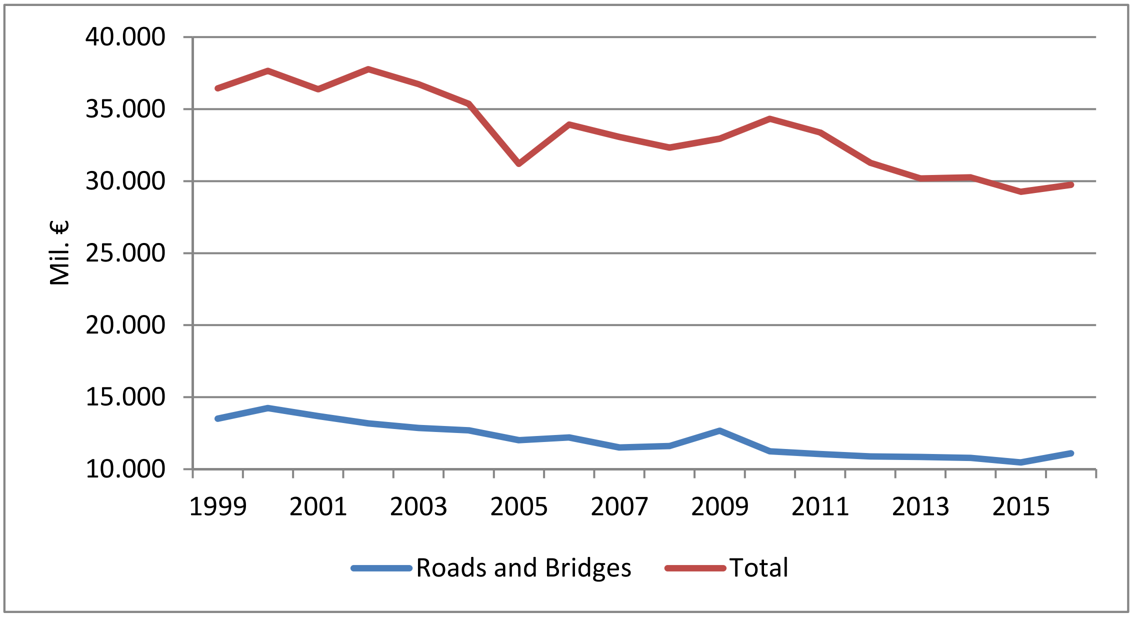
8.5.2 Infrastructure

A part of capital formation is the investment in infrastructure. Chapter 9.2.3 will discuss, infrastructure contains several aspects, shaping the environment (business as well as private) for an economy. One of the most important sub-categories of infrastructure is related to traffic and transport[44]. In order to provide a comprehensive view of traffic infrastructure, data on (gross) capital formation, as well as on fixed assets and the degree of modernity are displayed. In general, gross and net values are connected by the effect of depreciation. It also implies that positive net capital formation is in need to (at least) maintain the current capital stock. The following figures, with data taken from Bundesministerium für Verkehr und Digitale Infrastruktur (2018b), are set up for the time interval of 1999 to 2016 and are calculated and presented in 2010-€ so that price effects do not play a role. For an analysis of traffic and infrastructure, many components are likely to be chosen. For the purpose of the present study, the overall traffic category, as well as the sub-category roads and bridges, are shown, as the latter one plays the most significant role for the business environment with regard to transport conditions. Numbers for 2016, marked with asterisks, contain provisional values but should not distort overall conclusions on the trend.

Figure 21 shows gross capital formation. In line with the general investment behaviour in Germany over the last decades, gross capital formation in traffic infrastructure, as well as for the sub-category roads and bridges, exhibits a declining trend. Peaking at the beginning of the 2000s (total traffic: €37.774 mil. in 2002), the lowest value has been marked in 2015 (total traffic: €29.264 mil.).

[44] Another important sub-category is related to human capital and the educational system. Chapters 8.6 and 9.2.5 deal with it explicitly, so that the present chapter focusses on traffic only.

Figure 21: Gross Capital Formation (traffic, in 2010 prices) 1999-2016. Source: Bundesministerium für Verkehr und Digitale Infrastruktur (2018b); own illustration.



Simply taking capital formation for an evaluation is not sufficient. Fixed assets represent the capital stock of an economy - and in this case the traffic infrastructure for Germany. Figure 22 shows the gross values, figure 23 the net values. Whereas the gross capital stock shows a constant or even slightly increasing trend, the net capital stock interestingly provides a declining trend. For an evaluation of the infrastructure capital stock, net values are more meaningful, as depreciation seems to play a significant role. Net fixed assets have peaked in 2011 (total traffic: €698.127 mil.), and declined since then (€690.413 mil. in 2016).

Figure 22: Fixed Assets Traffic (gross) (in Mil. Euro, in 2010 prices) 1999-2016. Source: Bundesministerium für Verkehr und Digitale Infrastruktur (2018b); own illustration.

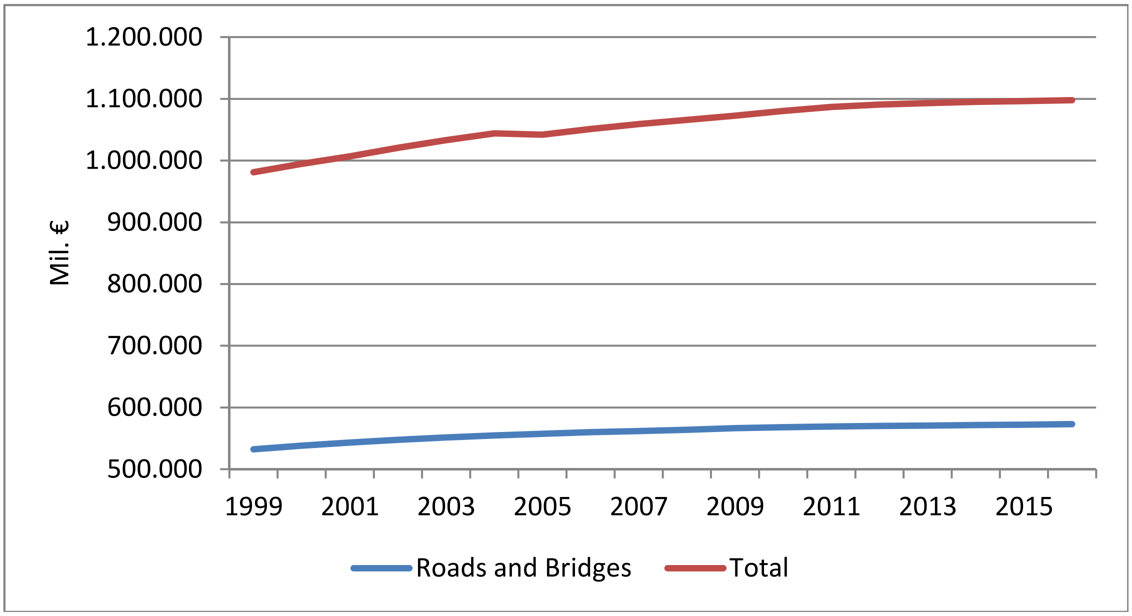
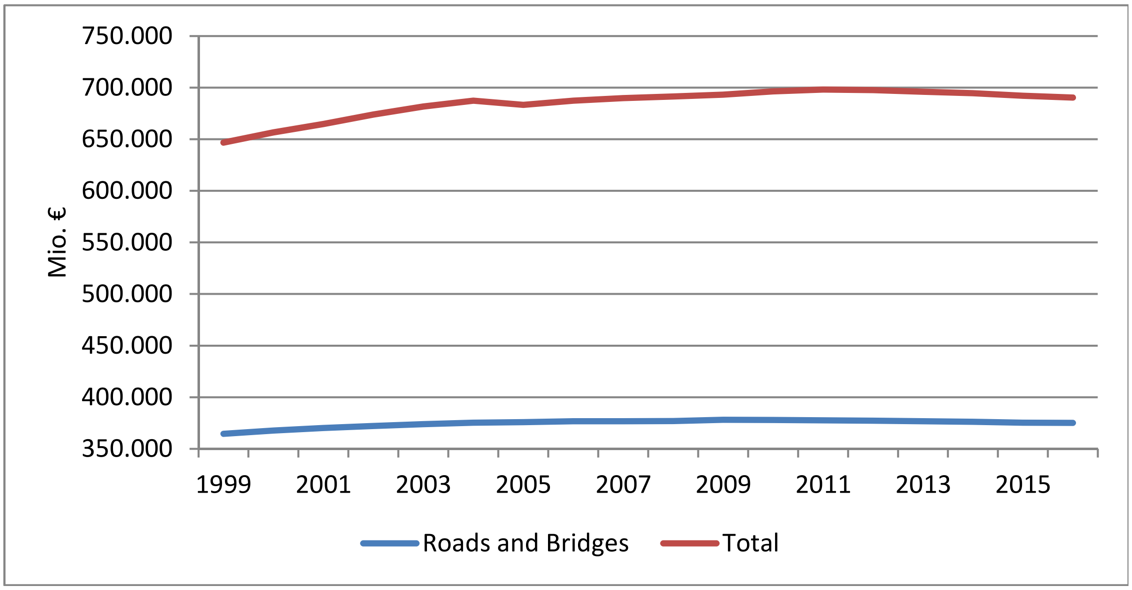
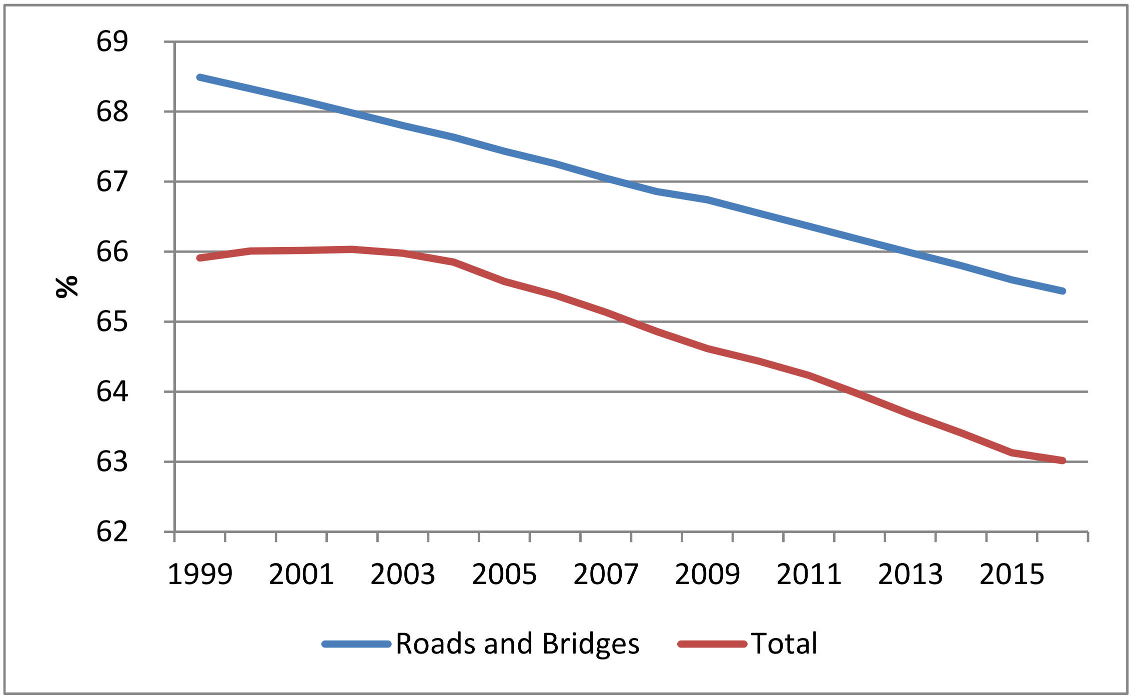


Figure 23: Fixed Assets Traffic (net) (Mil. Euro, in 2010 prices) 1999-2016. Source: Bundesministerium für Verkehr und Digitale Infrastruktur (2018b); own illustration.



More obvious is the degree of modernity of fixed assets with regard to traffic. Figure 24 shows the degree of modernity for traffic infrastructure in total and for roads and bridges. Over time, there has been a drop in the degree of modernity for both categories. Total infrastructure after 2005 dropped from 66 to 63, roads and bridges from 68 (1999) to 65 (2016). The implications are obvious - there has been insufficient investment; insufficient insofar as it was not even able to fulfil the needs of depreciation.

Figure 24: Degree of Modernity 1999-2016. Source: Bundesministerium für Verkehr und Digitale Infrastruktur (2018b); own illustration.



Special Case: Digital Infrastructure

In order to be prepared for technological developments and challenges of the 21st century, in addition, there is the need to provide a sufficient level of digital infrastructure. Digital infrastructure includes many aspects. Probably the most important one is related to data transfer. Best illustrated as broadband coverage and the speed of internet accessible to households and companies. Broadband technologies, in fact, is a notion, which includes wired and wireless technologies, other than smallband technologies (the ones used at the early stage of digitalization back in the end of the 20th century). Internet technologies, which can be summed up under the broadband notion are Digital Subscriber Line

(DSL), Fiber, mobile communications[45], (TV-) cable solutions and satellite technologies[46]. Unfortunately, no common international standard exists for the exact definition of broadband with regard to speed benchmarks (in comparison to smallband technologies). According to the International Telecommunication Union (ITU), technologies belong to the broadband category if they exceed data transfer speed of 256 kilobits per second. It is the definition, the Statistisches Bundesamt makes use of, too (see Statistisches Bundesamt (2019d)).

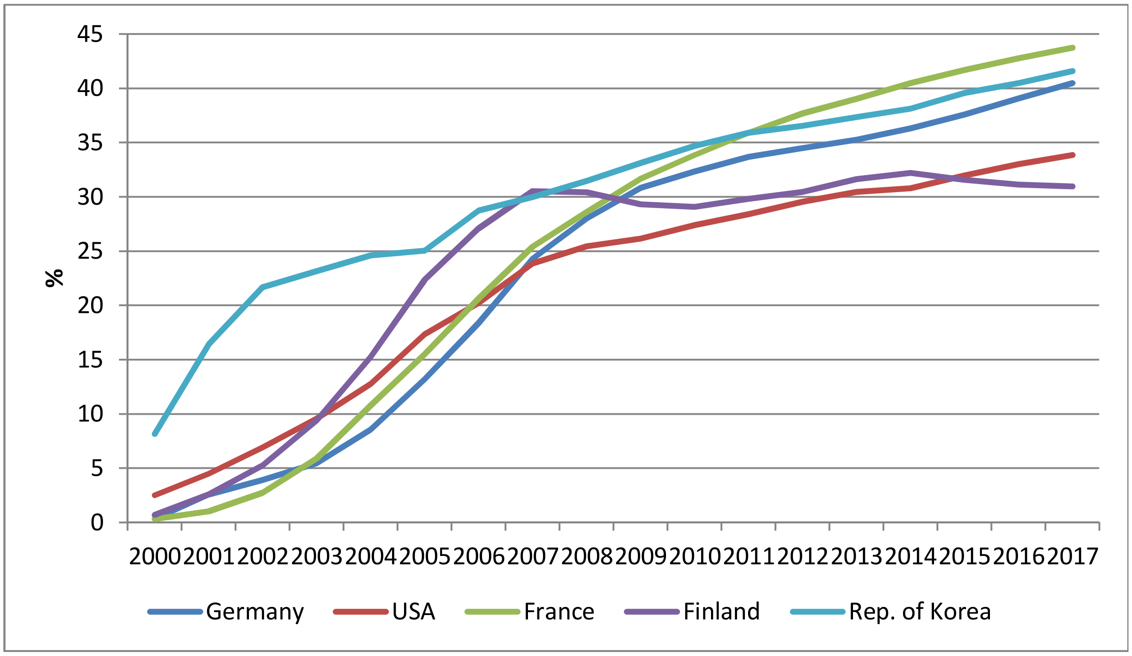
In Germany, most households are equipped with broadband access. Around ten years ago, just every second household (50% in 2008) had access to broadband technology, nowadays (2018) it is 86% of all households in Germany (Source: Statistisches Bundesamt (2019a)).

Another potential variable is "Fixed broadband subscriptions per 100 inhabitants" from the ITU (Source: International Telecommunication Union (ITU) Database (2019)). It can be used as another proxy for the evaluation of broadband coverage in Germany. Figure 25 shows the trends for several countries with regard to fixed broadband subscriptions per 100 inhabitants.

[45]Mobile communications in international standards is measured and labelled with notions from 1G to 5G and represents a generation of mobile communication technologies. Whereas 1G was associated with the very beginnings and included analogue technologies, going back to the end 1950s, 5G is the latest version and should be available by 2020. It is expected to provide speed of up to 20 gigabits per second (in comparison to 10-15 kilobit per second of the 2G-technology) (Source: <<https://www.techbook.de/mobile/smartphones/lte-4g-unterschied-mobil-smartphone>>).

[46]For a definition of broadband and its sub-categories please see Bundesministerium für Verkehr und Digitale Infrastruktur (2018a) or <<https://www.fcc.gov/general/types-broadband-connections>>.

Figure 25: Fixed broadband Subscriptions per 100 Inhabitants, 2000-2017. Source: International Telecommunication Union (ITU) Database (2019); own illustration.



Except for the Republic of Korea (8.17%), almost all countries chosen started with zero in 2000 (Germany: 0.33%). Germany showed a steady increase of up to 40.47% in 2017, whereas the US fell behind to 33.85% (2017). Remarkable is the case of Finland for the previous years. Nordic countries usually show leadership roles when it comes to technology and innovation. Finland started strongly and was the first of the five countries overshooting the 30%-mark (2007) but then merely stagnated since then (2017: 30.95%).

For more data and further elaboration on the requirements and implications in the course of the new wave of technological progress, please see chapter 9.2.3.

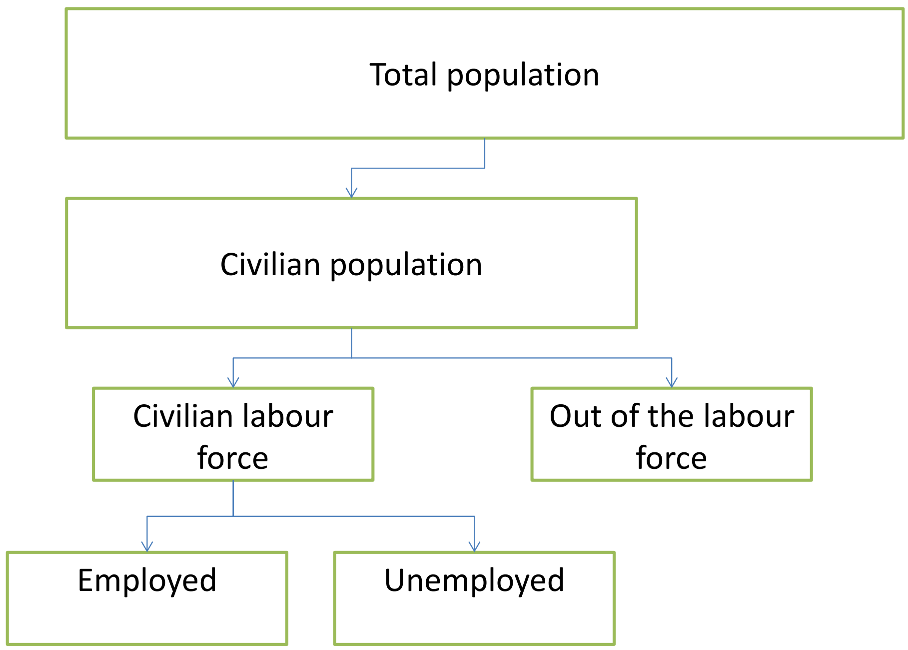
8.6 Labour Market Statistics and Demographics

Labour market developments influence economic welfare, too. Average working hours per employee or a change in the employment volume (and structure) affect the outcome of the production process. As the present study tackles the question, where to find the reason for less economic development (income and productivity), empirics for the labour market shall be provided, too.

According to the identity, displayed in equation (10), average working time per employee, the labour force participation rate (LFPR) or demographic issues (i.e. quantitative and structural changes in the employment potential) influence productivity and income. Before discussing their individual contributions, this chapter provides a compendium of labour market indicators for the German economy.

The following scheme is set up after the South Dakota Department of Labor and Regulation (see South Dakota Department of Labor and Regulation (nd)) and structures the labour market into its individual parts. For Germany, the separation is similar; some definitions slightly vary. In order to have a more common base, the concept of the International Labour Organization (ILO) is adopted (which offers minor differences to the one of the German Federal Employment Agency).

Figure 26: Overview Labour Market. Source: South Dakota Department of Labor and Regulation (nd); own illustration



- The civilian (non-institutional) population consists of the fraction of the total population of a country (which is older than 15 years, not living in institutions and not member of the armed forces (for the US); source: South Dakota Department of Labor and Regulation [47], as well Sauermann (2005) referring to the ILO-concept).
- It is formed by the civilian labour force plus the sum of persons out of the labour force.
- Out of the labour force defines persons, who are required to attend school or who are not available for employment (i.e. due to health issues).

[47] <<http://dlr.sd.gov/lmic/labor_force_technical_notes.aspx>>.

- Persons employed include any employees or self-employed, working in the private or public sector. Voluntary work is excluded.
- Unemployed summarizes all persons, actively searching for paid work (within the past four weeks) and working less than one hour. According to German law, registration at the Federal Employment Agency is not necessary[48].

As a typical indicator for structural changes in the labour market, the so-called labour-force-participation-rate (LFPR) is calculated as:

$$LFPR = \frac{civilian - labour - force}{non - institutional - civilian - population} x100 \tag{11}$$

and describes the potential employment of an economy.

8.6.1 Average Working Time/Week $\frac{h_t}{E_t}$

Figure 27 shows the trend for the employment volume (measured as total hours worked, blue line), the number of persons employed (including self-employed, orange line) and the development of the average working week measured in hours per worker (black line)[49] .

In Germany, the working volume [h] has remained constant over time (1991-2016). Including employed and self-employed workers, a total volume of around 60.000 million hours has been measured (this is 60 bn. hours). Total employment, measured by persons involved in labour market operations, increased from around 39 million (1991) to around 44 million at the moment (2016).

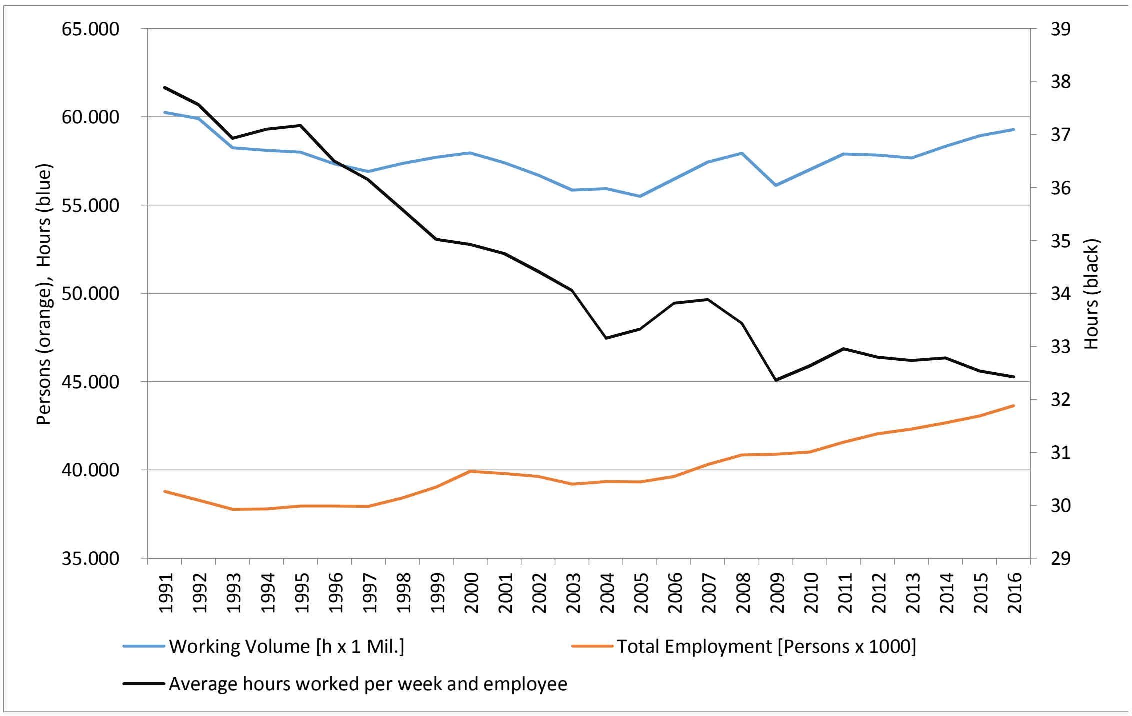
By dividing the working volume [h] by persons [E] in the respective year t, adjusting for effective working days (i.e. subtracting public holidays) and multiplying by five (by assuming a five-day-working-week) one receives the average working week per-person employed. Over the last two decades,

[48] Please note that there are differences between the German definition according to the Federal Employment Agency (Bundesagentur für Arbeit, BA) and the International Labour Organization (ILO). The scheme, provided in this chapter, is based on the ILO. As for the German system, a registration as unemployed is necessary to be labelled as unemployed. Otherwise, the person, not working, is defined as "erwerbslos"; this fraction of people is not following a regular work but is looking for it without the help of the German Bureau of Labour Market (BA). Additionally, being "unemployed" in the German sense includes persons, registered and working up to 14 hours per week.

[49] Using data from IAB <<https://www.iab.de/de/daten.aspx>>, the numbers are calculated as follows: Working Volume [hours] divided by persons employed (plus self-employed) divided by effective working days (i.e. subtracting public holidays) times five (assuming a five-day-working-week).

the number has fallen from around 38 hours per week and worker in 1991 to around 32 hours per week and worker in 2016. Put together, total working volume has remained constant, employment has risen, so that average employment per worker has necessarily gone down.

Figure 27: Working Volume, Employment and Average Weekly Workload, 1991-2016. Source: Institut für Arbeitsmarkt- und Berufsforschung (2017b); own calculations and illustration.



8.6.2 Employment Ratio $\frac{E_t}{EP_t}$

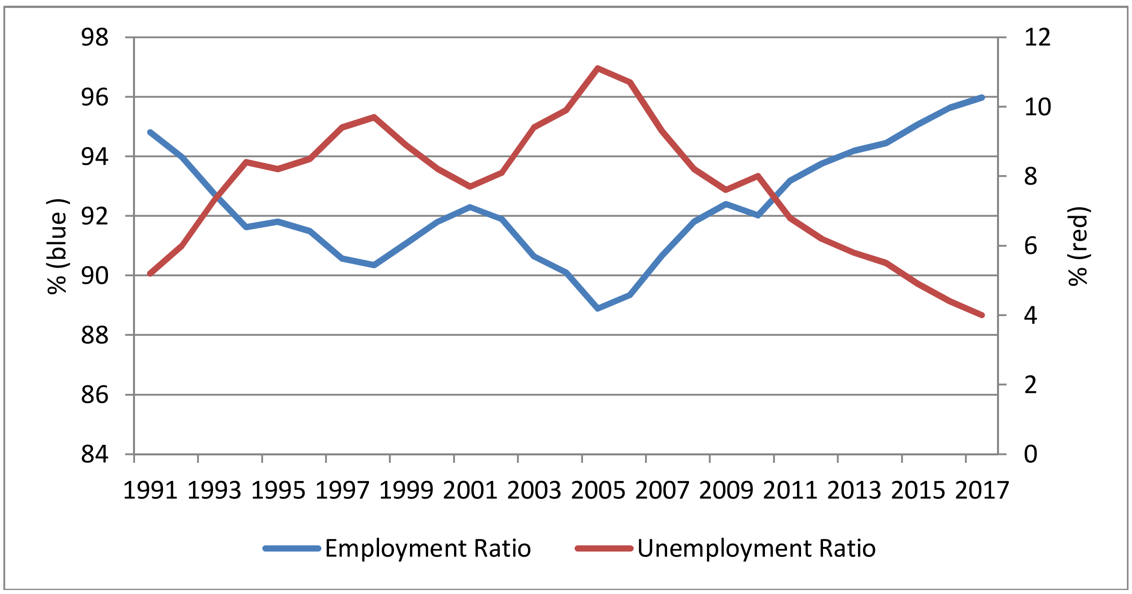
In order to calculate the employment ratio, data for the number of people employed [E] (it includes self-employed) as well as for the entire civilian labour force is required [EP]. Figure 28 depicts the trend for the employment ratio (blue line) in Germany[50]. Following the ILO-concept, no separation between registered and unregistered persons is required but everything summarized as unemployed.

[50]The interval of 2007-2017 contains original data, whereas 1991 to 2006 is calculated via "Berliner Verfahren Version 4.1" (BV 4.1) - a specific time-series analysis method. It makes use of seasonal adjustments and component dissection, developed by the TU Berlin (Technische Universität Berlin) and DIW (Deutsches Institut für Wirtschaftsforschung) back in the 1960s. See Statistisches Bundesamt (2004) for further details.

Unemployment implies all persons actively searching for paid work (within the past four weeks) and working for less than one hour. In relation to the civilian labour force, one obtains the employment ratio. Figure 28 also provides the unemployment ratio (red line), by re-arranging the equation:

$$CivilianLabourForce = Unemployment + Employment \Leftrightarrow Unemployment = CivilianLabourForce - Unemployment \tag{12}$$

Figure 28: Employment Ratio, 1991-2016. Source: Statistisches Bundesamt (2017c) Code: 13231-0001; own calculations and illustration.



Starting in 1991, the civilian labour force in Germany has consisted of 39.31 million people (not displayed) and an amount of 37.27 million people employed. This results in an employment ratio of 94.8% (unemployment of 2.04 million people; equivalently 5.2%). Over time, employment dropped to a minimum of 88.88% in 2005 and respectively 4.51 million people without work (11.1% unemployment rate). Severe and rapidly installed labour market revisions (“Hartz reforms”) in course of the “Agenda 2010” of the Administration Gerhard Schröder have led to a positive stimulus for employment, leading to a maximum of 96.00% in 2017 for total employment (1.73 million people unemployed).

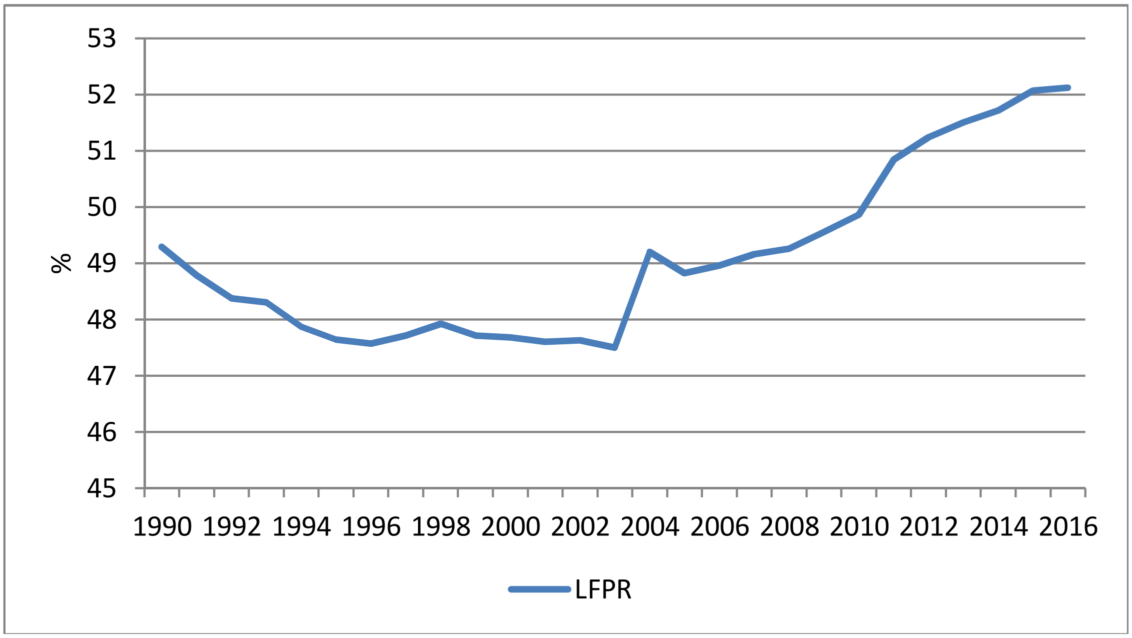
So, over time the numbers of the civilian labour force, as well as the numbers of persons employed, have risen - from 39.31 million (1991) to 43.01 million (2017) persons for the labour force and from 37.27 million (1991) to 41.28 million (2017) for the employment. Most empirical studies suggest evidence in the same direction (i.e. see Krebs and Scheffel (2013); Krause and Uhlig (2011)). Implications on productivity resulting from relatively higher rates of employment growth (in relation to GDP-growth) and the effects on productivity are discussed in more detail in chapter 9.2.5.

8.6.3 LFPR $\frac{EP_t}{Pop_t}$

The labour force participation rate (LFPR) is calculated as civilian labour force divided by total population. It necessarily has to be divided by total population, in order not to violate the identity. Data is taken from Statistisches Bundesamt (2017c) (Code: 13231-0001) for the civilian labour force and (Code: 12411-0001) for the overall population[51]. Figure 29 shows the trend of the LFPR for Germany from 1991 to 2016.

[51] Please note that data for the civilian labour force is provided with every January, whereas overall population data is reported at the end of a year. A higher degree of precision can be achieved when the ratio is calculated as follows: $\frac{EP_t}{Pop_{t-1}}$.

Figure 29: Labour Force Participation Rate, 1991-2016. Source: Statistisches Bundesamt (2017c) Codes: 13231-0001 and 12411-0001; own calculations and illustration.



In 1991 around 49.3% of the total population was available for work and therefore part of the LFPR. For many years and at the beginning of the 21st century, the ratio declined to values of in between 47% and 48%, before experiencing a sharp increase, especially after 2007. Nowadays around 52.1% are part of the LFPR. With regard to equation (10), this can be marked as a positive sign for the future trend on the labour market, as a higher potential for people available for work (including those already equipped with a job) increases economic welfare in terms of $\frac{GDP_t}{Pop_t}$. Higher LFPR suggest that more people are available for work. And this might be true on average. However, it does not guarantee a sufficient quality level of the labour force. Moreover, and with regard to the quality aspect, a mismatch between skills and knowledge on the one side and requirements by the companies on the other side, is another story. In line with the necessity to provide labour market supply, an adequate educational system is crucial to achieve a high level of human capital in the economy.

8.7 Intermediate Conclusions on the Empirical Section

In order to tackle the productivity puzzle, a sufficient empirical base is required. According to chapter 8.1 and equations (8) and (10), several of their "ingredients" play a central role, as they show that there is mutual dependency between labour productivity, total factor productivity and the effect of capital deepening. Furthermore, labour productivity per capita, per hour worked and other variables of the labour market play a role; demographic effects likewise. Even before going into discussion, these linkages raise the supposition that not just one single reason for declining trends in productivity is responsible.

$$\hat{LP} = \hat{k} + T\hat{F}P \qquad (8)$$

$$\frac{GDP_t}{Pop_t} = \frac{GDP_t}{h_t} x \frac{h_t}{E_t} x \frac{E_t}{EP_t} x \frac{EP_t}{Pop_t} \qquad (10)$$

In the previous chapters, the empirical trends of the components have been analysed with a special focus on Germany. Three potential views on labour productivity are offered - measured per capita, per hour worked or per person employed. Even though the trends of all three contain the same conclusions, the magnitudes differ. Growth in labour productivity per capita has slowed down since the 1970s in Germany to stagnating values of around 0% nowadays, for the US to around 1%. Expressed as per hour worked, the trend was less volatile. Interestingly, most developed countries offer slowdowns in comparison to the 20th century (especially when compared to the 1990s) - varying by the extent, however. The most extreme dips are noted when measured and expressed as per person employed. It seems to be a little more accurate with regard to productivity, as the different components of labour markets and demographic changes influence countries (unevenly).

Globally, total factor productivity development likewise has peaked in the 1990s. For Germany, the strong years of growth are noted around its Reunification (i.e. 1989 with 2.8% TFP-growth). Germany generally outperforms the US (and many other countries) with regard to TFP/MFP numbers. This should not tempt to express satisfaction, though, as the trend for Germany seems to be strictly decreasing. Nowadays TFP-growth in Germany circulates around the 1%-mark (i.e. 0.9% in 2016).

Shrinking labour productivity can mathematically result from a decreasing numerator or a rising denominator. Even though nominal GDP has increased up to around €3.4 trn. in 2018, real values have dropped and growth rates have constantly fallen below the 2%-mark. It allows for the possibility that labour productivity has decreased due to insufficient production in Germany.

As already proposed by equation (8), a decline in the capital-labour ratio can depress labour productivity, too. This would be the result of insufficient amounts of capital formation. In Germany, there is an ongoing debate on the likelihood of an investment gap. For both sectors - the public and the private one - declining trends have been identified. In addition to declining rates of investment, the amount of fixed assets has shrunk over time, especially when compared to the 1990s. It implies a loss of the degree of modernity for the capital stock and provides insufficient conditions for business development in Germany - forming “headwinds” for (future) economic growth.

Especially negative net capital formation for the public sphere seems to be a significant problem, as it is responsible for the supply of infrastructure. Infrastructure in this context has been defined mainly by traffic and the special case of digital infrastructure. Whereas the former relates to the transport of goods (and services), the latter is responsible for the requirements in course of the new wave of technological change. Especially access to broadband technologies is a potential bottleneck for economic progress. Broadband coverage and speed falter economic growth if supplied on an insufficient level. Even though the trend for broadband coverage is positive, having led to more than 80% of households equipped with modern technology, coverage in rural areas and speed limits provide obstacles for companies (i.e. a target of 50 Mbit/s by the Bundesregierung (2017) is considered as insufficient according to entrepreneurs’ opinions).

Equation (10) has decomposed labour productivity with regard to labour market related variables (denominator). On the one hand, a reduction of the average working week since the 1980s has been stated, depressing labour productivity. On the other hand employment volume has increased from around 36 mil. in 1991 to around 41 mil. in 2017. In addition to the positive aspect of a higher employment volume, the potential of inhabitants available for work (LFPR) has increased, too.

The empirical section has not only provided several variables, which seem to be important for the discussion about productivity puzzles. It also has already strived potential problems, associated with quality aspects (i.e. GDP) or the necessity to provide targets (i.e. for capital formation). Moreover, collecting data on an aggregate, economy-wide use and the fact that a variety of aspects are included in the discussion about productivity trends also make measurement problems more likely. In the next chapters, the issue of decreasing productivity is tackled. Two major strands of explanations are provided. On the one hand and ultimately following the empirical section, there will be a discussion about "real" economic causes, implying declining trends in productivity. On the other hand, it will be tested, if there is the possibility of an insufficient measurement framework - so-called mismeasurement, which is not able to reveal the correct data.

9 The Productivity Puzzle

9.1 Preliminaries and the 1970s

As indicated, I accept Gordon's view on the separation between less technological innovations - and their impact respectively - (his major argument) and headwinds, creating a negative environment for growth processes (his minor arguments). In fact, Gordon relates his analysis to the phenomenon of secular stagnation with regard to economic growth - the idea, however, goes into the same direction as for the productivity puzzle: what reasons can be identified for the weak economic performance of developed economies in the 21st century - and in addition to Gordon, is the entire lack of productivity growth just illusory? Therefore and for reasons of simplicity I separate between

- Problems associated with the measurement process (**Mismeasurement**) and
- **Real reasons** (as the separation between Gordon's major and minor arguments is of less concern for this study, one can summarize all real reasons under the definition of "headwinds").

Before going on, and shifting the focus to the 21st century, the study shortly turns back to the 1970s, when a similar scenario was laid out. In fact, many arguments Gordon (2012) states have been revived and recycled from debates in the past.

So, a worldwide productivity slowdown is not a new phenomenon. Declines in productivity numbers have hit the United States in the 1970s, as well as other economies - by some exceptions and of course to the extent (i.e. Griliches (1988, p. 9)). After periods of strong economic growth and productivity accelerations, in 1973 this era came to an end. Besides the second oil-price shock in 1979 and its economic consequences, the year 1973 represents one of the most important turning points in economic history of the 20th century. In course of the Yom-Kippur (the holiest day in Judaism on 6th October 1973) war and the subsequent conflict between Arabian countries, especially Western economies suffered from sharp economic problems (Syria and Egypt were involved in the war directly and supported by other (Arabian) countries - most of them part of the Organization of Petroleum Exporting Countries (OPEC)). In order to maintain (political) pressure on the (Western) countries backing Israel, oil production and export was cut by 5%, which led to a significant increase in barrel prices. As production in most Western economies was highly dependent on the supply of fossil fuels, production dropped, unemployment rose and the financial burden for the public budget grew significantly, resulting from the OPEC-embargo (for more information on the oil-crises of the 1970s see i.e. Painter (2014)).

The post-1973 era was then characterized by high levels of unemployment and a decrease in production; and characterized bythe switch of the German Bundesbank from fixed to flexible exchange rates, after having left the Bretton-Woods-system. Many studies have explored the ramifications of the OPEC-embargo afterwards (i.e. Cullison (1989); Denison (1985); Griliches (1988) and Nordhaus (2004)).

Cullison (1989), with his analysis, refers to the exhaustive study by Denison (1985) for the US on the productivity slowdown of this era. The four reasons (they can also be characterised as "headwinds" in a broader general sense) for the slowdown, Denison (1985) sums up to, are the following:

- a declining capital-per-worker ratio (resulting from a decrease in capital formation per working unit),
- regulatory issues (i.e. higher environmental protection and worker protection regulations),
- effects of significantly rising energy prices,
- the end of (a wave of) structural change (more precisely, the shift from low-productivity jobs in the non-farm sector to higher-productivity jobs; as i.e. discussed in Frey and Osborne (2017), Graetz and Michaels (2015) or Brynjolfsson and McAfee (2014)), as well as
- general economic problems of business-cycle character, arising from the two (global) recessions in the 1970s, implying a global downturn.

The last three reasons, Denison considers as having a larger impact on the slowdown, compared to the former two. Even though the oil-price shocks (1973 and 1979) and the resulting energy-crises are included only indirectly in Denison's (quantitative) study, their contribution and impact are undoubted. Especially long-term effects, so-called hystereses- and persistence-phenomena play a significant role.

Hysteresis and persistence are derived from physics and describe the hang-over from any kind of disturbances (i.e. a supply-side shock). The entire system just slowly converges back to its initial state in the case of persistence; forces do not bring back the system to its initial state in the case of hysteresis. Hystereses-phenomena appear in many shapes, often found in labour markets when business-cycle unemployment is converted into a rise of the natural rate of unemployment (i.e. Blanchard and Summers (1986), who discuss hystereses-phenomena for the Western European labour market).

The study of Denison (1985) claims to explain around 40% of the post 1970s-slowdown by the four contributors named above – structural change (15%) and the recessions (16%) hereby playing the major role. Taken together, Denison's two major reasons are able to explain around one-third of the entire slowdown (which is one-third (= 0.5%) of the total decrease in productivity of 1.5% for 1973 to 1982).

The remaining 1% of the decline in productivity growth (from 1973 to 1982) shall then be explained by several other reasons (they explain around 60% of the entire effect). The remaining reasons, as named and elaborated afterwards by Cullison, are (Cullison (1989, p. 11)):

- Measurement errors/mismeasurement
- Declining labour quality
- Rising energy prices
- Environmental protection regulations (as a form of regulatory issues)
- Depletion of mineral resources/natural resources
- Depletion of investment opportunities

Especially the appearance of the measurement error hypothesis is often cited when it comes to finding explanations for declining trends, as it offers a large potential for modern economies (modern economies are associated with a high fraction of services contributing to national product. Services nowadays make around 69% (2015) of German GDP and are subject to measurement problems due to their immaterial character (Statistisches Bundesamt (2015b)). If the arrival of modern technology

- or more broadly speaking- technological change - like modern communication technology, pharmaceutical improvements, electrical technology or even electricity in the late 18th century[52]- has been identified incorrectly in National Accounts, also labour productivity (and TFP) might be subject to underestimation. As chapter 9.3 will show, measurement of service-sector related goods and products still hinder correct measurement and form the main research area for the mismeasurement hypothesis.

Nordhaus (2004) analyses the 1970s-slowdown by making use of data since WWII, precisely industrial data from 1948 onwards. Doing so, the author argues that the 1970s-slowdown is a rather unusual event, however, not unique in history since the post civil war period in the US. He describes the slowdown in the 1970s as a "major outlier for the period since WWII" (Nordhaus (2004, p. 7)), finding its (natural) rebound in the mid of the 1990s.

Decreasing numbers are found in any sector of industrial production. Nordhaus introduces an artificially constructed output-measure variable (so-called "well-measured output"; WMO), which tries to account for inadequateness in measurement for services and finance sectors (Nordhaus (2004, p. 29)). The WMO only contains those sectors with goods that are rather simple to measure due to the nature of their outputs (i.e. manufacturing, transportation, forestry). One of his findings is that the alternative productivity variable WMO exhibits stronger productivity growth, compared to 'classical' variables (i.e. total factor productivity), a result that could account in favour of potential mismeasurement and in contrast to real economic reasons. Excluding some (and undoubtedly important) production sectors is a shortcoming in his analysis, so that the results have to be used with a certain amount of care.

The magnitudes of the rates (WMO and traditional/classical), however, are quite similar. Additionally, but not surprisingly, energy-intensive sectors were hit hardest by the slowdown (sharp increase on the supply side due to oil embargo by the OPEC). The problems were solved and productivity growth after the 1970s-slowdown went back to normal due to shifting from "the oil age to the electronic age" Nordhaus (2004, p. 30), implying a new wave of structural change and a reallocation of sector's production contributions.

Griliches (1988) also points on the energy-price related shock effects. Investigating the connection

[52]In 1775 Alessandro Volta invented the very first possibility to store up electricity - the invention of the battery. In fact, however, many other starting points for "electricity" are likely, too. For information on Volta please see <<https://www.britannica.com/biography/Alessandro-Volta>>.

between (poor) R&D-development in the United States in the 1950s and 1960s, he claims "the rise in energy prices and its macro consequences" (Griliches (1988, p. 19)) as responsible. This has not only changed the production of companies (production structure, scrapped capacity, bad expectations) but has also affected several other variables in the economy (i.e. negative consequences on aggregate demand, trade balance effects at the expense of general economic problems for the US economy and a period of prolonged underutilization).

Jorgenson (1986) explores the link between the rise in energy prices and decreasing rates of productivity. The author points on the reallocation effects as a result of the oil-price spikes. In these days, workers have been reallocated from energy-intensive sectors towards less energy-intensive ones. If one moves highly-productive workers (i.e. in the steel industry) to jobs, where they are less productive, such a reallocation negatively affects aggregate productivity (Jorgenson (1986, p. 64 f.)).

Griliches (1988) makes an interesting statement by summarizing the issue; something, which is (probably) valid for the productivity puzzle in the 21st century, too: there is no single variable or reason, exhibiting sufficient explanatory power for the entire magnitude of the slowdown. Instead:

> "Of course there may not be a single cause - one murderer. Perhaps it is more like the Murder on the Orient Express - they all did it!" (Griliches (1988, p. 19))

This statement offers pretty much wisdom even for today's productivity puzzle, as the subsequent chapters will show. It will be shown that many contributors can be named and identified, all of them providing potential for an explanation.

9.2 Less Innovations, Headwinds or a 'simple' Measurement Error?

Potential reasons and hypotheses for the current[53] slowdown are diverse. Chapter 9.1 has provided several reasons for an ex-post explanation of the productivity slowdown in many Western economies in the 1970s. Chapter 9.2 then is related to current developments, hereby expanding the view and leading a more general discussion on the reasons of (general) weak productivity growth.

[53] 'Current' in this sense is related to developments in the 21st century. Depending on the country and definition of a slowdown, one finds arguments for different inflexion points (i.e. the bust of the New Economy, the global financial crisis in 2007 or especially for Germany the developments in the 1990s in the aftermath of the German Reunification). For this section of the study, exact dates play less important roles, so that the term 'current' can be interpreted for many other points in time.

As the mismeasurement hypothesis is of central concern for this part of the study, it shall be discussed seperately in sub-chapter 9.3. Before discussing the validity of the mismeasurement hypothesis, I discuss (in short) other potential reasons for less productivity growth (and lower productivity levels) in order to have a broader and more complete view about the issue.

Several approaches and studies analyse productivity slowdowns all over the world. Their reasons and linkages are diverse and often depend on the country considered and sometimes on the respective time intervals (as well as the chosen inflextion points). The following discussion does not claim completeness and tries to present a brief talk on potential channels for productivity slowdowns.

Generally, a slowdown can either be attributed to a statistical lack expression (mismeasurement) or to 'real' economic causes. It either only appears in the balance sheets of national accounts as a result of miscalculations or it is really present, derived from 'real' economic problems.

Whereas the mismeasurement hypothesis claims that there is no 'real' slowdown but the one identified in the statistics, other possible reasons ('real' reasons) state that an economy suffers from unfortunate economic developments or conditions (in this context 'economic' is not strictly limiting but also attributable to any political, institutional, sociological and other maldevelopments, having a direct or indirect effect on human well-being).

One might argue that the mismeasurement-hypothesis is of less concern, as economic activity is 'just' underestimated and falsely published. To a certain point, one can agree, that 'real' economic problems are worse in terms of the (future) economic welfare of a country but false measurements have to be corrected too, as they infer serious problems (Mokyr (2014, p. 88)).

Companies, consumers, policy-makers and any other agent in an economy derive and execute (policy) actions based on various data. If this data is under- or overestimated, insecure, incomplete or biased, the inferred decisions cannot be optimal in a sense of maximizing welfare of an individual, company or economic level. Therefore, also policy implications vary, as the respective explanations do. Additionally, the problem of time-lags has to be considered. If economic policy lacks reliable and complete data, provided in time, executive actions can lead to (pro-cyclical) maldevelopments, implying further instabilities and wrong developments in an economy.

For example, in a recession or after a shock (i.e. the global financial crisis 2007-2009), economic policy has to find reasonable and appropriate steps in order to overcome negative developments. These steps target - in a short-run Keynesian sense - the stimulation of aggregate demand and can consist of (e.g.) fiscal actions, like an increase in government spending, lowering the tax burden on consumers or providing more/higher social welfare transfers.

Also, monetary and foreign trade actions provide possible solutions - interest rate adjustments as examples for the former, tolls or subsidies as examples for the latter. Economic policy, therefore, cannot exist without a reliable data-underlying (and of course a well-suited theoretical framework).

Not only does data provide a framework for an ex-post analysis, it also builds the base for forward-looking decision-making processes. Pro-cyclical developments can occur, when policy actions are executed to the wrong extent and/or at the wrong time and lead to even stronger maldevelopments (i.e. over- or undershooting of GDP-growth, which is correlated with poor inflation or deflation processes).

Every 'real'-reason hypothesis ('headwind') offers a vast research area for itself. It seems impossible to fulfil the aim of completeness. For the purpose of this study, these reasons shall only be strived in order to provide a suitable and more complete framework for productivity analysis, however, laying the focus on measurement errors. For convenience, possible headwind-orientated explanations for slowdowns are summed up prior to their discussion. In addition to chapter 9.1. They include:

- (Less) technological progress or less innovations and poor knowledge diffusion (i.e. lack of innovations, less R&D-expenditures)
- Weak demand (= the demand-side secular stagnation argument)
- Weak capital spending (i.e. decrease in gross capital formation)
- Demographic issues (i.e. maturing population, declining working population)
- Declining labour quality and the educational system
- Excess public debt
- Inequality
- Environmental protection regulations (as a form of regulatory issues) or negative effects from globalisation
- Slowdown as a natural (business cyclical) phenomenon (i.e. assuming that developments generally occur in cycles)
- Other 'shock-related' arguments (i.e. rising energy prices)

Secular stagnation captures the negative long-term developments of an economy. It is usually associated with an economy being characterised with a high level of per capita income, but negligibly small rates of growth. Secular stagnation is expressed as a period of unsustainable financial expenditures (Summers (2017)). Further, the employment situation suffers from rather low rates of economic growth, too.

The reasons for the phenomenon of secular stagnation can be separated - as usually - into a demand and supply side explanatory strand. Supply side effects are split up and will be discussed separately (headwinds #2-8). Supply side secular stagnation focuses on the environment and conditions for a (balanced) growth path of an economy. Many reasons do in fact overlap so that any try to categorize might be discussable.

Even though this elaboration tries to classify arguments, as a key to understanding secular stagnation and a general decline in economic development, one has to keep in mind, that:

> "In the end, secular stagnation is not about just demand or supply but also about the interaction between demand and supply" (Gordon (2015, p. 58)), as well as
>
> "Lack of demand creates lack of supply potential" (Summers (2015a, p. 63))

For the analysis, I follow Gordon's structure for the analysis of (supply side) secular stagnation (see Gordon (2012) and Gordon (2015)). For the explanation of the stagnation process and connected productivity puzzle, he separates between a major reason (less technological innovations) and minor reasons, so-called "headwinds", which themselves influence the poor productivity developments. These "headwinds" provide a poor (business) environment for economic activity. However, depending on the country considered (Gordon's field of research are the US), these headwinds vary. Generally, they include obstacles, a development process faces. Most of these obstacles have a rather structural character (like demographic aspects or the educational system) but also include business-cycle phenomena like taxes or capital formation. The question, the present study tries to solve is, whether there are 'real' reasons (no matter whether related to the major or minor arguments) or whether the slowdown is just illusory and a result of a mismeasurement problem.

9.2.1 Technological Progress and Knowledge Diffusion (headwind #0)

Supply side secular stagnation captures the development of potential (real) GDP growth over time. Potential GDP growth describes the natural boundary of an economy's development and its ability to grow. Decreasing trends in potential real GDP growth not only have a direct effect on the standards of living but also an indirect effect on net investment, which itself leads to less growth in productivity (Gordon (2015, p. 54)). Even though Gordon only labels his minor arguments as potential headwinds, for the present study, his major arguments (technological progress and knowledge diffusion) can be interpreted as potential obstacles. So, the notion "headwind #0" seems appropriate.

As technological progress is undoubtedly (one of) the main reason(s) for (potential) economic growth, especially in the long run, its role for productivity slowdowns is more than noteworthy. There are, however, many ways, in which technology can work as a source of explanation for the missing portion of output (the 'drop' in productivity over time) - hereby representing a rather short run perspective.

First, there is the hypothesis of (simply) less technological progress in the sense of less innovations or less significant innovations in general over the last years. Lower productivity rates then must be considered as quite logical. It is, at first glance hard to believe in this hypothesis, as several innovations have taken place within the last two or three decades and significantly re-shaped the worldwide economy and the working environment likewise (i.e. for the discussion about robots, potential automation and computerization see for example Graetz and Michaels (2015) and Brynjolfsson and McAfee (2014)).

On the onset (or even in the middle) of a new wave of technological progress, this explanation seems highly doubtful (David (1990, p. 355)). This wave was created by the appearance of a new set of GPT (general purpose technology), including innovations in healthcare but mostly due to innovations in the sector of information and communication technology (ICT). Gordon (2012) calls it the third industrial revolution (IR#3). His classification of 'industrial revolutions' might confuse and shall be explained in more detail in the remainder of this chapter.

Especially modern ICT has developed strongly within the 21st century. One just has to compare the working environment of an office in the 1990s equipped with typewriters, fax machines and physical file cabinets. Nowadays, it is more accurate to describe everyday life at work with notions like cloudcomputing, crowdworking and any kind of digital equipment. Digitalisation is pushing forward at an enormous pace. It is hard to believe that there might be less innovation these days. The question of whether data fits reality is not a new one. Griliches (1988, p. 10) for example raises suspicion for the developments in the US of the 1950s and 1960s. Mining and construction have seen decreasing rates of productivity in the data, financial and other service sectors at least stagnation. Developments in the post-WWII period associated with strong economic growth correctly doubt on the numbers in the data sheets.

However, and as discussed below, Gordon (2012) assumes, that the impact of innovations in the latest past (in course of IR#3) is smaller, compared to those of IR#2. Less technological progress, therefore, works as his major argument for the productivity puzzle.

Secondly, another approach to technology in this context is related to the issue of knowledge diffusion or diffusion of technology across an economy - or in a more global sense, across the entire world (see Holwegler (2003, p. 9 f.) for the way how new technologies enter the economy).

One can separate firms into a first category, operating at the technological frontier and into another one of those companies lagging behind. Global technology diffusion, however, cannot be taken for granted (OECD (2015b, p. 3)). Even more, the OECD in one of their recent productivity reports explicitly states, that "[f]uture growth will largely depend on our ability to revive the diffusion machine" (OECD (2015b, p. 3) - a clear statement on the necessity of percolation in order to gain the benefits from technological change.

Impact and benefits of innovations and modern technology in an economy become stronger if more firms are able to adopt so-called 'frontier technology' (i.e. Acemoglu (2002), Pissarides and Vallanti (2007), OECD (2015b)). Frontier technology represents the latest technology set available, directly emerging from R&D activities. It usually changes dramatically when a new wave of technological progress is on the onset.

The more firms are able to implement the latest technology, the more productive on aggregate the economy will become (Griliches (1987, p. 1)). A possible explanation for the productivity slowdown, therefore, lies in poor (or slow) technology diffusion of an economy. Potential reasons for poor diffusion are diverse (i.e. high fix costs, transaction costs or bureaucratic obstacles).

Firms, which "can drive one technological wave" (OECD (2015b, p. 46)), produce around five times higher in terms of MFP and around ten times in terms of labour productivity (OECD (2015b, p. 45)). Even more, and according to Andrews et al. (2015), the gap between frontier-firms and non-frontier-firms has even increased in the 21st century, also implying less spillovers and therefore less technology diffusion[54] OECD (2015b, p. 46).

Less spillovers, slower technology diffusion and less growth in technological equipment development at the firm level could, therefore, work as another possible explanation for decreasing productivity. Knowledge and technology diffusion not only stimulate economic growth but economic (in-)equality

[54]The study takes an international approach. It defines the technology frontier by the 100 most productive firms in each 2-digit sector in ORBIS, whereas all other firms are considered as non-frontier. ORBIS is a database, provided by the OECD, which contains data for more than 44 million firms on the micro-level all over the world (see https://orbis.bvdinfo.com for further details).

(headwind #6) likewise. The less firms diverge according to their technological underlying, the smaller the inequality, measured in terms of related incomes, becomes.

The linkage between technological progress, knowledge diffusion and productivity development can be described by evaluating the amount of expenditures in research and development (R&D). As already stated, poor R&D-spendings might have caused negative ramifications for economic growth in the past - and they still do. Griliches (1988) for example, confronts the productivity puzzle by investigating the connection to R&D. He asks, whether poor R&D-spendings can account for the poor economic development in the US in the 1970s and finds, that R&D-spendings cannot be blamed as possible explanation but yet warns about possible mismeasurement errors, when it comes to R&D. Nevertheless, knowledge diffusion and the distribution of modern technology (as a driver of productivity growth) is ultimately connected to the investment behaviour and weak capital spending (discussed as headwind #2 in this study).

In addition to the less technological innovations argument, Gordon (2012) states, that present innovations can be considered as of inferior importance or less impact, compared to more meaningful ones in the past. He doubts on the assumption of economic growth as continuously developing for all time. Instead, Gordon (2012) understands growth as a sequence of discrete events and raises the suspicion, that the period of substantial growth in the twentieth century has to be considered as rather unusual, instead of taken as granted or 'natural'.

His analysis is not entirely focussed on the US economy. Despite the present evaluation of the productivity puzzle for the US, he elaborates on a rather global view and understanding with regard to frontier economies. Whereas Great Britain has been the frontier economy until the beginning of the twentieth century, this position has been taken over by the US then.

Gordon (2012) elaborates the sequence of discrete periods of growth, by splitting into three industrial revolutions Gordon (2012, p. 1):

- IR#1 (1750-1830). Main inventions: steam engines, cotton spinnings and railroads.
- IR#2 (1870-1900). Main inventions: electricity, machine power/the internal combustion engine, and running water with indoor plumbing.

- IR#3 (1960-today). Main inventions: found in the ICT-sector.

The innovative process has to be understood as a sequence of discrete events, followed by marginal improvements. Follow-up inventions appear after substantial improvements in the course of an industrial revolution. According to Gordon (2012), the second industrial revolution (IR#2) has caused the biggest impact and has required around 100 years (for IR#1 even more, at least 150 years were necessary) to completely diffuse through the economy (Gordon (2012, p. 3).) In the 1970s slower rates of economic and productivity growth have formed the end of the wave of IR#2. Since then, those (high) rates of growth were out of reach, even in course of IR#3.

The effects of IR#2 lasted for 81 years (1891-1972), whereas those of IR#3 (2004-2012[55]) only lasted for 8 years - more precisely the impact on measured growth in productivity. IR#3 itself began in 1960 with the commercial use of computers and peaked in the 1990s.

To highlight the importance of the IR#2 and non-continuous economic growth, the doubling in productivity and the standard of living is taken as proxy for the speed of diffusion. There was almost no growth at all at the beginning of the scenario considered back in 1300. It then took 500 years (1300-1800) to double living standards and 100 additional years afterwards (1800-1900) for the next double-up. The shortest periods, describing the most significant changes in the standards of living in course of IR#2, were 1929-1957 (28 years) and 1957-1988 (31 years). Confirming the hypothesis of scepticism and slow productivity growth afterwards, a doubling in the standards of living then will (probably) take around 93 years (2007-2100) according to a (loose) approximation. It results from expecting less (significant) impact from IR#3 and anything related to the "New Economy"-era (Gordon (2012)).

Besides, Gordon (2012, pp. 12-14) calculates levels of productivity for a (hypothetic) scenario, which describes a continuation of the productivity trend of 1948-1972 (strongest period of growth in course of IR#2), compared to the actual values. His findings confirm the supposition, that there has been a large gap between the actual level in 2012 of output per hour in 2005 US-dollars ($53.90) and the (hypothetic) scenario, which assumes a continuation of the strong economic performance in course

[55] The impact of the global financial crisis is neglected insofar, as calculations last until 2007 and the consecutive years are extrapolated under the assumption of not having the financial crisis.

of IR#2 ($83.20). A gap of almost 69% of “missing” productivity.

Illustrating the argument, that economic growth not necessarily develops continuously but rather in a discrete way - one of Gordon’s main proposals - can be executed by using the examples of urbanization, speed of travel and (improvements with regard to) temperature of interior space. These one-time-only events have all unravelled their effects and impacts without further improvements with regard to productivity (Gordon (2012, p. 2)). Speed of travel is a well-suited example for this phenomenon provided by the author.

Was travel by horse omnibus possible at a pace, that could have been easily achieved by walking back in 1860, it has increased dramatically by railroads and subway systems in the following decades. Their level of speed is a multiple of a horse-drawn carriage (3 miles per hour (1860), compared to 40 miles (1906) and little later at 80 per hour (1960)). Speed of travel, however, has then reached its peak without further acceleration. Modern flight traffic runs at even slower paces, compared to decades ago, in order to conserve fuel (Gordon (2012, p. 10)). Rather small steps (or none at all) followed the giant leap - or even developed backwards.

A special feature of IR#2- and IR#3-inventions is that their effects are singular and non-repeatable. Their inventions also narrow the possibility of further essential leaps in economic development (Gordon (2012, p. 15)).

With regard to the mismeasurement hypothesis in this study, it shall be noted, that there is another period of surprisingly less economic and productivity growth back in 1906-1928. One could have expected IR#2 to fully unfold its impacts. As an explanation for this, David (1990) provides a “diffusion lag”-hypothesis, leading to a delay in the exploitation of modern technology (David (1990, p. 357 f.)). The author compares the computer-invention in course of the ICT-wave to the invention of electrical technology almost one century before and claims - with regard to the famous quote of Robert Solow (1987) - that “[i]n 1900, contemporary observers well might have remarked that the electric dynamos were to be seen ’everywhere but in the productivity statistics!’” (David (1990, p. 356)).

In 1899 in the US, just a small fraction of households (below 10%) and other establishments (such as factories) were equipped with electrical technology. In order to fully exploit the benefits from innovations, a decent amount of time was necessary to gain the benefits in the productivity statistics. Regulatory changes in favour of the introduction of electrical technology to production (and households) helped to unfold the effects of the innovation of electrical technology (David (1990, p. 356)) then, however, not immediately after the date of the (technical) availability.

In line with Gordon's major argument for lower productivity growth rates, some studies favour a rather natural development as explanation. Griliches (1988) hereby points on the necessity to separate between a "cyclical fluctuation [and] ... a serious break in the underlying historical trend" (Griliches (1988, p. 11)). Fluctuations associated with the business-cycle appear as rather natural, serious breaks in the historical trend provide challenges for future economic growth.

According to the theory that weak R&D spendings[56] have caused the 1970s-slowdown, Griliches argues by making use of the "time-lag"-hypothesis. It requires time for technologies of IR#2 to completely diffuse through the economy in order to make visible the gains of innovation. Instead, he claims the oil-price shocks and ramifications (price increase) of being responsible for the drop in productivity (Griliches (1988, p. 9)) as well as general measurement problems " in various incarnations" (Griliches (1988, p. 11)). Whereas the exact mechanism of how rising prices for the supply of oil can be linked to the productivity slowdown is unclear (the slowdown has appeared in many other countries and industries), arguments against R&D-contribution have been outlined and shall be discussed in the headwind #2 category (chapter 9.2.3).

Jones (1997) argues in the same direction and addresses the slowdown to the discussion on whether the US economy is/was on a steady state balanced growth path. His study rejects the (main) view, that the US has been on a steady state balanced growth path. In opposite, being off this path, changes in the level of globalisation and R&D-developments provide (or have provided) additional stimuli for the US economy. The author in 1997 correctly anticipated the consecutive economic development (the 21st century) to reverse to the negative, when those stimuli weaken or even disappear. It is a matter of definition then, whether it is a real cause or the natural ramification of the omission of real economic developments, which have caused the slowdown.

[56] Griliches' study is set up for the US. He states, however, that "[t]his drop in productivity growth was actually larger, in absolute terms, in some other countries (such as Canada, Japan, and Sweden) than in the United States, making explanations for these events which rely heavily on specifically U.S.-based causes or arguments somewhat less plausible" (Griliches (1988, 9)) - therefore a quest for a more general explanation began.

Syverson (2013), reviewing Byrne et al. (2013), describes the considered labour productivity trends. Rejecting a “Jevonstype sunspot theory of labour productivity growth” (Syverson (2013, p. 39)), Syverson shows the (cyclical) movement of productivity after every new wave following the introduction of a GPT (general purpose technology). As we are currently riding the ICT-wave, Syverson illustrates and compares it to the previous wave, the invention of electricity (1890-1915). Even though not explicitly mentioning the circular character, Syverson states that “[h]istory shows that productivity growth driven by general purpose technologies can arrive in multiple waves; it need not simply arrive, give what it has, and fade away forever thereafter.” (Syverson (2013, p. 39)).

Despite the sceptical analysis of future growth and productivity development, Gordon (2012) assumes productivity development to continue - albeit less strongly. His minor arguments on the poor productivity performance concern the negative environment in an economy - his so-called “headwinds”. He elaborates six fields of interest, which harm the development process: in original, they include demographic issues, the educational system, globalisation, ecological environment, income inequality and public and private debt.

The headwinds vary among the countries analysed. In the following chapters, it is tried to provide a discussion on important factors shaping the economic environment and providing potential problems for development processes. The discussion diverges from Gordon’s headwind-approach insofar, as the importance of the respective headwinds for the US and Germany vary and the focus is shifted to the latter. Also, the demand-side (headwind #1) finds entry into the “headwind”-categorization as stated in the introduction of this chapter (9).

9.2.2 Weak Demand (headwind #1)

The demand-side explanation for secular stagnation phenomena was initially proposed by Alvin Hansen (Hansen (1939)) back then and has been revived in the latest past by statements of Larry Summers (i.e. see Summers (2014a; 2014b; 2015b; 2015a)). Summer’s demand side theory is related to the weak capital spending argument (as discussed in chapter 9.2.3). At the core of his analysis lies the deviation of (aggregate) savings from investment, leading to a decline of the natural interest rate, the one which causes full-employment (full-employment real interest rate (FERIR)). A situation of stagnating growth in output and per capita income and higher ratios of unemployment can then be associated with a decreasing FERIR - which has led to less investment in modern economies.

Summers also emphasizes the possible hystereses-effects of missing capital spending and the ramifications for the supply side of an economy; he therefore also accuses policies of decreasing capital formation (Summers (2015a, p. 63)). Summers names and discusses several reasons for the decline of the FERIR, which then work as an explanation for the (demand side) secular stagnation theory (see Hagemann et al. (2016, pp. 219-221) for a short summary).

Reverse population growth and declining innovations (or slower rates of technological growth) generally name two very popular reasons in growth theory and have been met in many growth models before (just to mention the Solow-Swan-growth model Solow (1956); Swan (1956) and the expansion by Solow (1957)). Besides the two, Summers points out the possibility of capital-saving technological progress in the course of the increasing importance of the ICT-sector. This has led to the relative decline in capital costs and to the relative increase in wages respectively (which could then work as an explanation for a poor employment situation).

Additionally, rising inequality of national income distribution, and wealth distribution likewise (see chapter 9.2.7), could have led to distortions in the "natural" balance of investment and savings - in favour of those cohorts, characterised by a higher propensity to save.

Furthermore and as the global financial crisis (2007-2009) has shown, many economies still suffer from problems regarding their public budget (for a detailed analysis see chapter 9.2.6). Higher deficit-to-GDP ratios and more generally an increase in public debt has led to a diversion of interest rates in the banking sector - more precisely, it has led to an ongoing separation between low rates of profits for savings, compared to higher lending rates, provided by the banking systems (the latter ones as crucial for any kind of private investment). Therefore "secular stagnation" can also be interpreted as "a prolonged period in which satisfactory growth can only be achieved by unsustainable financial conditions" (Summers (2017)).

Other studies come to similar results and follow Summers. Rao and Li (2013), for example, investigate slow productivity growth in Canada based on a Verdoorn-model-approach (the productivity-output-approach, developed by the Dutch economist Petrus Johannes Verdoorn (1949 in original, Verdoorn (1980)), which was once made famous by Kaldor (1966)). Rao and Li (2013) find that for the post-2000 era weak demand has contributed significantly to the productivity slowdown in Canada.

Weak internal and external demand not only decrease economies of scale and scope but also directly affect R&D-investment. If this result can be taken for granted, the ramifications for Germany are almost the same - German R&D-spending is, as chapter 9.2.3 will provide - compared to the OECD-average, on a rather low level (in relation to general economic activity and development). Rao and Li (2013) state that for Canada, 93% of the slowdown in the covered period (1981-2000 vs. 2001-2012) can be attributed to the result of weak demand (Rao and Li (2013, p. 14)).

Not only R&D-investment but general gross fixed capital formation and less ICT-investment favour these negative results. Besides economies of scale, economies of scope and increasing returns (modelled and displayed for example in the Verdoorn-approach), Rao and Li (2013) find human capital, general capital accumulation, technology diffusion and optimal sectoral allocation as key drivers for (Canadian) productivity growth.

All these key drivers - in a sense of reverse causality - suffer from prolonged periods of weak output growth, leading to less growth in measured labour productivity and less income per capita likewise. Weak demand is not an internal problem only. Export-led driven economies are (additionally) opposed to global shocks. Spiro (2013) points out the importance of the export sector for the Canadian productivity puzzle. If we accept the importance of export sectors, this is valid for Germany even more, as Germany is ranked among the top-exporting nations. In 2017 Germany was ranked in #3 among the top exporting nations just close behind the US. In 2017, German exports had a value of almost $1.5 trn. (Statista (2018)).

If external shocks harm the export sector, not only weak demand and less output growth is the result - but also the labour force and labour market, in general, is affected. Losing their jobs make people lowering their requirements for a new position. If on average, less people work in a position, where they can fully extract their skills and knowledge - the result is a mismatch-scenario. Mismatch-scenarios are generally linked to less productivity, as more persons work apart from their qualification level. External shocks and weak demand therefore not only affects the numerator but also the denominator (the input factor for productivity). Mismatch-scenarios between job position requirement and qualification of the employee are therefore linked to the declining labour quality argument (see chapter 9.2.5).

Weak (aggregate) demand is often also assumed to show a high correlation with the issue of private debt. If households are exposed to higher financial burdens, it will reduce the propensity to consume and hereby depress aggregate demand (i.e. Jauch and Watzka (2012), who argue in favour of the private debt-to-demand link by evaluating the case of Spain).

9.2.3 Weak Capital Spending and Infrastructure (headwind #2)

Another central argument is related to the capital equipment of the economy. As chapter 8 has shown, labour productivity and TFP are connected via the capital-per-worker ratio k. Labour productivity decreases either through less TFP-growth or declining rates of capital per working unit. Decreasing rates of capital formation lead to a lower k and less productivity, therefore.

An increase (decrease) in labour productivity, therefore, can result from less technological progress or less capital formation over time. Not only does positive (net) capital formation provide capacity and income, it additionally transfers technological innovations (the "diffusion machine"). Its economic relevance is multilayered.

In addition to discussions about declining rates of economic growth and productivity, there is an ongoing debate on whether Germany was or still is experiencing a lack of investment over the last decades (a so-called "investment gap"). As the time of the German Reunification has led to structural changes in the German economy, 1991 is often used as a starting point for the empirical analysis. Extensive research has tackled the investment issue over the last years (i.e. Hagemann et al. (2016), Expertenkommission „Stärkung von Investitionen in Deutschland“ (2015), Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung (2014) or Daehre (2012)), testifying decreasing rates of capital formation for many countries - including Germany and the United States and hereby implying a shrinking of the (public) capital stock. Whereas most studies agree on a general decline in investment, the question about an optimal amount of investment is another one (i.e. in contrast to most other studies, SVR argues on minor needs to invest for the public sector and states that private investment is not experiencing significant decreases. See Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung (2014, pp. 12 ff.) in contrast to i.e. Expertenkommission

„Stärkung von Investitionen in Deutschland“ (2015) or Hagemann et al. (2016)). In general, the quantification of the appropriate level of public capital spending is a sensitive topic and will always be subject to discussion. In example Grömling et al. (2019), with regard to Expertenkommission „Stärkung von Investitionen in Deutschland“ (2015), state that net capital investment of the public sector seems to be an inadequate indicator for the evaluation of the public capital stock. Hereby, the study also argues against the proposed financial rule for the public budget, which forces the government to at least invest the amount of depreciation. Grömling et al. (2019) do not share the view of a decreasing public capital stock but argue in favour of a stagnation. Moreover, the study states that structural changes have shifted the scope to intellectual property and investment in research and development. For (public) infrastructure and the respective capital stock, the authors, however, agree on the need to re-evaluate the amount spent in the public sector, especially in the municipal area.

If there is weak capital spending over time, an economy's capital stock deteriorates, leading to declining rates of growth in output and productivity likewise. Some studies also emphasize economic shocks, triggering the decrease in productivity (i.e. OECD (2015b, p. 28)). So this kind of (short run) shocks can create 'base effects' and imply tremendous ramifications for economic performance; structural long-term development is of even more concern, as it shows a trend instead of rather cyclical swing-phenomena. Short-term shocks must not be neglected, as they might 'convert' themselves into long-term effects (so-called “hystereses”- or “persistence”-phenomena[57]). Recent studies on German investment development have shown, that weak capital spending is not a new phenomenon but lasts (at least) back into the 1990s (Hagemann et al. (2016), Ragnitz et al. (2013) or Baldi et al. (2014), the latter one addressing the issue to Europe in general).

Infrastructure[58]

Business environment in an economy is dependent on several aspects with regard to infrastructure - and infrastructure itself is multilayered. It not only contains the field of traffic such as motorways, railroads, shipping or air traffic but also the educational system, the tax system or other factors of

[57] A system not rebounding to its initial state after being shocked is exposed to a hysteresis-phenomenon. When reaching its initial state but requiring a certain amount of time - this is a persistence-phenomenon.

[58] 'Traditional Infrastructure' in this context relates to any category of infrastructure except the digital components, which are discussed separately in the next section.

regulatory intervention. As the current wave of technological progress, the innovations in course of "economy 4.0" and the respective structural changes, require a special case of infrastructure, namely digital equipment, digital infrastructure (i.e. broadband coverage) plays an important role. The educational system and respective implications on human capital stock are discussed separately (see chapter 9.2.5), data on infrastructure in this chapter focus on traffic infrastructure.

Infrastructure in the traditional sense (traditional in a sense of excluding digital equipment) and its trend over time provide information on whether the business environment is suitable for economic development or whether it works as a potential bottleneck for economic progress. International competitiveness of an economy is also highly dependent on the possibility to produce with high quality and at low costs - the latter directly linked to infrastructure. If companies face obstacles in a sense of higher transaction costs (i.e. due to higher costs of transportation), then a loss of competitiveness and less output and employment growth result. Hagemann et al. (2016, p. 192) state that the current level of German infrastructure seems to be on a sufficient level, at least when put in international benchmarks. They base their conclusion on central studies on the state of infrastructure[59] but admit that deficits might exist. Again, the question about an optimal level of investment is different (and way more complicated) to a description of trend behaviour over the last years.

Even though the private sector exhibits the same trend, public investment plays a special role in an economy's development process. An economy's public capital stock has to be treated with concern. Commonly speaking, it represents all the public goods of an economy. Infrastructure hereby plays the most significant role and includes roads and rail traffic, highways, bridges, as well as technical endowments and more - a matter of how to define infrastructure. In the course of a new wave of technological progress. it also includes anything related to the requirements of modern information and communication technology - digital infrastructure.

An economy, highly dependent on export-led growth like Germany requires a healthy business environment for the challenges of international trade. Decreasing values of public infrastructure capital do not fit this requirement. There are plenty of examples in Germany (i.e. the dilapidated Rhine-bridge, close to Leverkusen, which has been closed temporarily due to cracks in the surface) in the

[59]Considered as central studies for the issue of infrastructure in Germany: World Economic Forum (2015), Dobbs et al. (2013) and Woetzel et al. (2016).

near past, when companies had to face obstacles with regard to transporting the produced services within Germany or to a destination abroad. These obstacles mark additional (transaction) costs for companies and in general a loss of international competitiveness for the German economy in total due to rising prices in course of higher costs of transaction.

As provided originally by Aschauer (1988b), the theory of "crowding-in" (instead of a "crowding-out") of public investment states that gross capital spending for public purposes stimulates the economy even more and provides a healthy environment for private investment (for a deeper understanding of Aschauer's "crowding-in"-hypothesis, see Hagemann et al. (2016, pp. 133-147) and in original Aschauer (1988b)).

Public investments (i.e. in infrastructure, ecological environment or national defence) provide a vital sphere for economic growth. Aschauer's studies are in line with famous precursors like Adam Smith (1776). They all stress on public capital and discuss the impact and relevance for economic growth. More precisely, Aschauer values public capital as complementary (rather than substitutional) to private investment, implying positive marginal gains in the private sector (see Hagemann et al. (2016, pp. 133-138) and Aschauer ((1988b; 1988a; 1989c; 1989b; 1989a)). There is no crowding-out but crowding-in effect of public investment instead. A present example of a "crowding-in" effect is found in the establishment of subsidization of capital formation of ecological innovations (further discussed in chapter 9.2.8) by the European Union. Under the headline "Horizon 2020", the European Union guarantees almost €80 bn., hereby also targeting incentives for complementary private investment (Bundesminsterium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (2017, p. 55)).

Gross capital formation in any sense is crucial for an economy's growth and development process. It hereby contributes in three ways. Firstly, a vital investment environment creates a substantial and required level of aggregate demand. In the sense of a Keynesian point of view, aggregate demand (at least in the short run) is responsible for the economy's evolution process and its level of welfare, therefore. Secondly, and in a rather long-term perspective, gross capital formation renews and increases aggregate capacity. Capacity in this context can either be understood as physical capital (i.e. machines) or non-physical capital (i.e. human capital); it marks the boundaries for every economy and sets its potential to grow. Thirdly, investment is the prerequisite for the diffusion of technological progress and its innovations. Conversely to what former modelling approaches have assumed (i.e. the Solow (1956)-Swan (1956) growth model and the 'manna from heaven'-story), technological progress is not exogenously but is in need of certain requirements - most important of all this is investment.

Capital spending, however, is a rather imprecise variable, as it contains several sub-components or separation possibilities (i.e. private vs. public sector, R&D, infrastructure, inhomogeneous goods varying by quality).

For the post-WWII in the 1970s, a drop in R&D-investment was often assumed to be responsible for the decline in productivity. Griliches (1988, pp. 13-16) for example has provided arguments against the explanatory power. The timing of the slowdown was "right" in a sense, that the time-lag, associated with the speed of diffusion of R&D, had the right amount. It had appeared, however, in other Western economies likewise, without providing a significant correlation (between the extent of R&D-slowdown and drop in productivity). In addition, R&D-investment has merely decelerated in governmentally supported sectors, which appear to have a rather light influence on aggregate productivity (due to their small contribution; i.e. see Lichtenberg (1984) for further details on the "too-small"-argument).

Digital Infrastructure

An insufficient environment or infrastructure falters economic growth and productivity development. In the course of the new wave of technological progress and the innovations in the ICT, the current re-shape of the economy ("economy 4.0") digitalizes almost every aspect and part. It is a matter of providing the appropriate conditions, in order to fully exploit the benefits of this wave of innovation. Digital infrastructure hereby plays a major role. Several components are included, subsumed under the headline of digital infrastructure - (one of) the most important variables already provided in the empirical section, which is broadband internet access. Besides broadband coverage and speed, several risks and opportunities are associated with the requirements of the "4.0"-era.

In 2017, the German government has presented a report for 2014-2017, which contains landmarks in course of the process of digital transformation (Bundesregierung (2017)). Hereby, three main fields of interest were outlined: growth & employment, access & participation and trust & security. The aim is a formation of government, research and civilian population to push further the process of digital transformation and strengthen (or maintain) Germany's role as a powerful and innovative economy in the future. Hereby, the agenda presents several fields of action, digital infrastructure as one of them.

Depending on the understanding and definition of infrastructure, the notion, however, could be expressed differently (i.e. Bundesregierung (2017) presents "Security, Protection and Trust" as an extra chapter - but clearly, this section could be summed up under infrastructure, too). Broadband coverage and speed support participation of all economic agents and inhabitants. According to the Bundesregierung (2017), a download speed of 50 Mbit/s is targeted; appropriate fundings have already been provided and successfully lead to changes. In 2016 around 75% of households were equipped with broadband internet access, and in 2018 it was 86%, as the present study has shown (see chapter 8.5). Unfortunately, no target for upload speed is presented by the Bundesregierung, neglecting the necessity to implement a fully workable structure for modern working technologies. As an example, most forms of cloud-computing - the general definition for IT-services via cloud-solutions - require 50 Mbit/s of download but also upload speed to work properly (see Erber (2014)). If provided less upload-speed, this will falter business development in the new working age and have negative implications for productivity growth.

Aggregate numbers on broadband coverage and speed are just one part of the story. Certain areas still lack sufficient coverage and fall behind in terms of business development. Moreover, this supports heterogeneity and inequality. For a more detailed analysis of the supply of broadband access in Germany, one can separate the analysis for households, the production side or on a state level. As a useful source of information, the Bundesministerium für Verkehr und Digitale Infrastruktur (2018a) (in collaboration with the TÜV Rhineland) regularly provides a study on the issue of broadband for Germany.

According to the Bundesministerium für Verkehr und Digitale Infrastruktur (2018a, pp. 5-6), around 83%[60] of households were equipped with broadband coverage of a speed of 50 Mbit/s or faster but only 66% with a speed of more than 100 Mbit/s. As technological innovations in the future will likely make use of higher speeds than the current target (which is 50 Mbit/s, Bundesregierung (2017)),

[60]The study separates for wired and wireless connections, whereas the numbers from the ITU contain wired access only. It seems that wired connections play a more significant role as the Bundesministerium für Verkehr und Digitale Infrastruktur (2018a) states that "technologies over and above 6 Mbit/s are dominated by wired technologies" (Bundesministerium für Verkehr und Digitale Infrastruktur (2018a, p.6, own translation)).

there is still room for improvement and further expansions.

For the private use, 50 Mbit/s seem sufficient - for business purposes not. According to a survey of the IHK Berlin (IHK Berlin (2019)), most companies expect a demand of 100 Mibit/s in the near future; 50 Mbit/s seem appropriate just for around 10%. Such a divergence between the needs of the production side and the goals of the digital agenda (Bundesregierung (2017, p. 11)) will definitely lead to problems and show up in the productivity statistics.

As provided, broadband coverage seems to cover most parts of Germany; a positive trend over the last one and a half decades has been outlined, too. However, not all parts of Germany enjoy access to high data speed. What about the remaining areas, disconnected from modern technologies? Negative implications for households and companies are self-evident. An area, lacking of access to broadband technology, is less attractive not only to households but also to companies. The latter will then move their production to another area. Job losses and structural problems are inevitable results. In addition to lower job availability, households will tend to move, implying further problems. Usually, rural areas suffer from insufficient coverage and speed. As provided by Bundesministerium für Verkehr und Digitale Infrastruktur (2018a, p. 8), just around 50% of households in rural[61] areas have access to rates of 50 Mbit/s or more (in comparison, urban areas exhibit a coverage of around 94%). It is an instruction for the German government to set the appropriate actions, in order to fill the gap. Unattractive rural areas, in a sense of broadband availability, not only falter economic growth in general. They support the evolution of structural problems and imply further problems (i.e. the trend for households to move to urban areas leads to additional pressure on residential lease prices).

In Germany, around 82% of companies have access to broadband technology. The larger the company, the more likely it is equipped with broadband technology. Logically, smaller companies face excess financial burden for implementing the required digital infrastructure. As a potential solution for smaller companies, there is private (broadband) access used for company purposes. Here, small companies face the same conditions as households and almost the same numbers apply (Bundesministerium für Verkehr und Digitale Infrastruktur (2018a, pp. 8+26)). The need for company-solutions on a private base might work as a potential substitute but also lacks complete[62] coverage.

[61] In the study, "rural" is defined by population density of less than 100 inhabitants per square kilometre.
[62] "Complete" not necessarily meant as 100% but meant as not having faltering effects on the allocation of companies.

Several other aspects shape the digital infrastructure. One of the requirements in the course of the digital transformation is the availability of huge amounts of data - the necessity and potential to make use of a large amount of numbers. Big Data is the key for a new age, as the technology available nowadays allows to work with huge amounts of data, traditional software and technology did not (Chen et al. (2014, p. 173)). It allows to make useful applications work (i.e. Google Maps with on-time availability of traffic data to find the best route) and creates patterns (i.e.) in consumption, companies can make use of. Whereas broadband technology supplies the traffic infrastructure for data premises, technological innovations have closed the gap towards any kind of smart-systems (i.e. smart-homes or smart-factories). Without digging deeper, any change in the transformation of the economy is related to opportunities and risks likewise. Moreover, there are plenty of other aspects (compared to those discussed in the present study), with justification to be included into what we understand of "digital infrastructure". Besides the broadband aspect, another aspect shall be discussed in short - security. More precisely, any aspect of security related to Big Data, digital infrastructure and the developments in course of the current wave of digital transformation.

Increasing amounts of data require a legal framework to maintain personality rights and let "4.0" work under acceptable conditions to preserve privacy rights. In 2018, the European Union has set an important landmark by introducing the General Data Protection Regulation (GDPR)[63]. It is a regulation for the work with personal data (more precisely, the automatic recording of personal data) and aims to maintain personality rights. It is set up, in order to have an even generally agreed framework for the EU. Besides, and only indirectly linked to "digital" are the implications on general infrastructure - such as the social security system or labour laws in Germany. The social security system in example, as part of the general infrastructure, has to be adjusted for (potential) structural unemployment (i.e. providing additional funds for unemployment benefits or retraining) (i.e. Tiemann (2016, p. 3), Bundesministerium für Arbeit und Soziales (2017, p. 179)).

In addition, labour laws have to be brought in line with the change. As an example, all-time availability for employees via modern ICT or the increasing fraction of people making us of home-office, provide risks for the health, asking for more strict regulations (i.e. not to exceed a maximum

[63]See <<https://gdpr-info.eu/>>.

daily working load or the right for work-absence in holidays) (i.e. Bundesministerium für Arbeit und Soziales (2017, p. 122, 136, 138), Schweppe et al. (2016)).

9.2.4 Demographics (headwind #3)

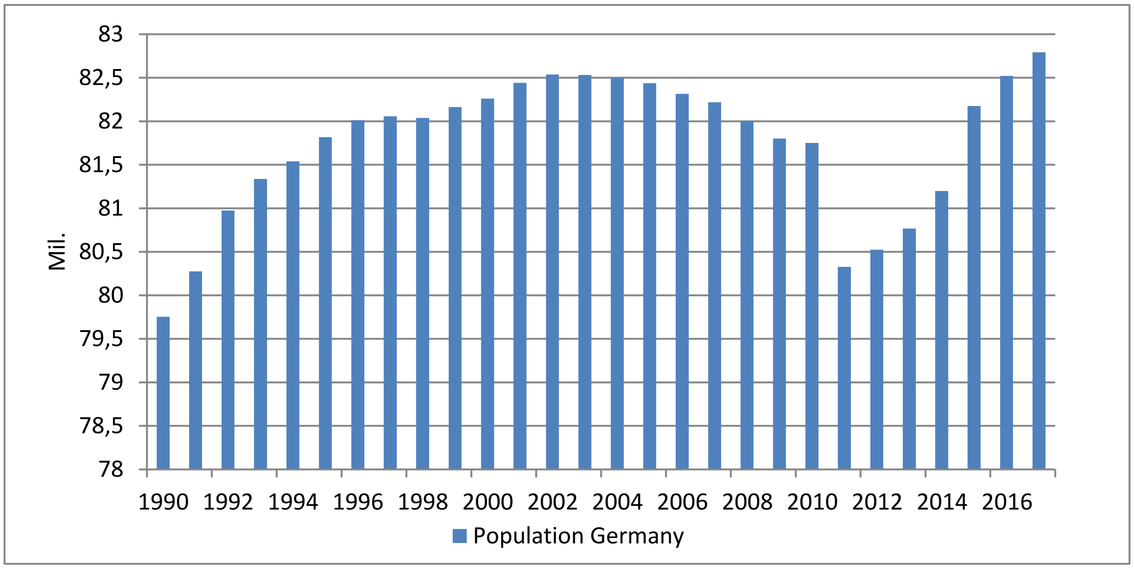
As provided in the empirical section, output per person can be decomposed into:

$$\frac{GDP_t}{Pop_t} = \frac{GDP_t}{h_t} x \frac{h_t}{E_t} x \frac{E_t}{EP_t} x \frac{EP_t}{Pop_t} \qquad (10)$$

Many studies propose a significant correlation between productivity and demography (i.e. see Gordon (2015); Feyrer (2007); Westelius and Liu (2016)).

According to Gordon (2015, p. 54), labour productivity ($\frac{GDP_t}{h_t}$) in the US has decreased due to slow growth in the working volume per person employed ("average working time", $\frac{h_t}{E_t}$), which itself results from a declining labour force participation rate (LFPR, $\frac{EP_t}{Pop_t}$). Likewise, a decreasing population (Pop_t) in total is stated - something even more applicable to Germany. Figure 30 shows the trend of the overall population (Pop_t) in Germany. After reunification, German population has consisted of around 80 mil. citizens. Its value has peaked in the early 2000s at around 82.5 mil. before dropping to 80.3 mil. (2011). The last years are characterised by an increase back to 82.8 mil. (2017) - a trend associated with significant flows of migration (the fraction of non-German residents has increased to 11.2% in 2016 according to Statistisches Bundesamt (2018a)).

Figure 30: Population Germany, (Population Germany in Mil.) 1990-2017. Source: Statistisches Bundesamt (2019b); own illustration.



A declining LFPR reflects an economy's labour market structure, more precisely, the structure of the labour market supply side. It describes the fraction of the civilian labour force in relation to the entire (non-institutional) population. Therefore it is the potential for an economy to make use of the production factor labour (some kind of upper boundary or potential bottleneck in production). The higher the ratio is, the more people are capable of taking part in the working life (no matter whether employed or actively searching for employment, at least available for work).

For Germany, it is argued persuasively, that the demographic conditions are even worse. Among the G7-countries, Germany ranks in #2 regarding the extent of the demographic impact just behind Japan (Westelius and Liu (2016)). Compared to the US, German population will not only suffer from an ageing process of the (working) population but - as seen in figure 30 - it will furthermore shrink in total numbers, whereas the US is 'only' confronted to ageing problems (Deutsche Bundesbank (2017a), Herzog-Stein et al. (2017, p. 10) quoting Colby and Ortman (2015)).

Despite (positive net) migration, refugee embodiment, slightly rising birthrates, increasing female labour market participation and increasing participation of the elderly, the German working volume

(h) is about to decrease further in the near to middle future perspective (Fuchs et al. (2017)). Working volume in Germany has already rebounded to values similar after Reunification, as chapter 8.6 has provided.

In 1991 around 60 billion hours of work (Germany) have been noted on aggregate, dropping to a low (for the time 1991-2016-interval considered) of around 55 billion in 2003 and back to 59 billion in 2016. As employment, measured in persons, has increased, the average working volume per person employed has (necessarily) gone down, as chapter 8.6.1 has already reported.

If one shares the pessimistic view of Gordon (2012), the reduction in the average working volume per person offers a huge problem from the demographic perspective, providing headwind for economic progress. Simply said, the less hours people work on average, the less they contribute to national product and this, in turn, decreases productivity. If decreasing employment is forecasted for the future under the assumption of stagnant per-person-working time, it necessarily has to lead to a decrease in productivity growth. Arguing from a quantitative perspective, negative developments due to a decreasing amount of suitable employees will then reduce the possibility for Germany to gain satisfying rates of productivity growth. Connected to the aspect of the quality of labour, a mismatch situation of applicant's skills diverging from company's requirements is then more likely to occur, if highly-skilled employees become rare (at least sufficiently-skilled for the requirement of the changing requirements in course of "Work 4.0"). Implications for the labour market supply side can be inferred from the current transition to this new working environment. Effects of automation and robotics will have further implications for the labour market, the demographic structure and in the end for economic development. As the effect of automation and the connected probability of substituting capital (i.e. robotics) for labour is mainly of interest for specific labour market discussions, it shall be neglected in this study. Central arguments, examinations as well as forecasts can be found in many studies; especially recommended are Graetz and Michaels (2015) with an analysis for 17 countries including Germany and Frey and Osborne (2017), Brynjolfsson and McAfee (2014) as well as Arntz et al. (2017) for the US labour market.

Deutsche Bundesbank (2017a) calculates employment projections for up to 2025 in terms of the development of the working volume. Ageing (working) population goes in hand with a higher probability of part-time working contracts. The working volume then is assumed to develop according to an inverted U-shaped curve, decreasing after 2020 due to the effect of an ageing population. By 2025, the study expects a deficit of around -0.75% compared to 2017, the start of the projection (Deutsche Bundesbank (2017a, p. 42)). Knetsch et al. (2013) share this view by estimating the development process of full-time equivalents and project a deficit of -1% in 2020, compared to 2012. This drop is characterised by an ageing population, still (and even longer, compared to decades ago) taking part in the working life but more often in non-full-time jobs.

Additionally, Fuchs et al. (2017, p. 6) provide data for the different cohorts of the working population in a forecast scenario adjusting for migration, working behaviour (i.e. part-time preferences) and demographic effects (i.e. change in female labour market participation or simply the ageing factor). Under the most realistic forecast assumptions, Fuchs et al. (2017) confirm the possible shrinking of the labour force. The youngest cohort (<30y.) in Germany in 2015 was composed of 9.5 million and since then is expected to develop downwards steadily to around 8 million (2030) and 7.5 million (2060)[64]. The middle-cohort (30-49y.) is about to develop similarily: from 20.2 million in 2015 it is expected to be reduced to 19.6 million (2030) and more significant to 17.4 million in 2060. Until 2035 most of the "baby-boomers" will still take part in the working life so that the demographic problems are covered up a little bit (Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung (2015, p. 316) assume effects resulting from the "exit", that will be starting in 2020 and fully launched thereafter). The oldest cohort (50-64y.) will grow steadily from 14.7 million (2015) to 16.2 million (2021) before decreasing to about 12.1 million (2060), also due to the exit of the "baby-boomers". Even under the assumptions of having similar migration flows like those in the past, labour market potential will drop below the 40 million-mark in 2060 (Fuchs et al. (2017, p. 7)). High migration rates do counteract against negative demographic trends (i.e. ageing) but cannot fully compensate for.

Even though, one expands the view and 'corrects' for a later retirement age (i.e. the Deutsche Bundesbank (2017a) study calculates the working population from 15-74, in order to correct for the fact, that many people - around one-seventh to be precise - still take part in the working life after having reached the official age of retirement) the results show the same trends (a decrease of more

[64] The study makes use of three different forecast scenarios, hereby taking the most realistic one for the projection. In this most realistic scenario a net migration of 200.000 people is assumed on average per annum.

than 2 million people in the working age until 2025).

Likewise, ageing population and workforce have another notable effect, when it comes to innovations in course of structural change (Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung (2015, pp. 316-318)). Whereas the former developments just describe a quantitative argumentation for the bottleneck on the labour market, ageing population provides another challenge. Modern technology and innovations are usually associated with the necessity to adapt to a modern working environment, as well as the skills to make use of them. Different cohorts of age are associated with different kind of skills. The younger the worker, the more likely developed are skills related to innovation (so-called "fluid-cognitive skills"). Contrary, the older cohort contains a larger endowment of experience, language skills and the ability to focus on the basic essentials (so-called "crystalline skills") (Herzog-Stein et al. (2017, p. 10), Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung (2015, pp. 317-318)). Especially the fast innovation pace in the ICT-sector and the requirements in the working life yield the crucial necessity to regularly keep up and continue one's very own education. Ageing population, therefore, can be associated with a decline of the average innovation capability (Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung (2015, 317)).

Older workers are more likely to lack the skills, which are required to perform on an adequate level in course of technological change. As innovation capability matters, individual productivity, therefore, highly depends on age and working age - the longer ago a period of education has taken place, the higher its depreciation effect on the (individual) human capital stock is.

It is argued, however, for some good reason, that working-age itself might be correlated positively to productivity (see Feyrer (2009) for example) due to learning effects and growing experience; an effect, which is outperformed by the obstacles, technological change provides for the older working cohort. In contrast to the ageing-population-problem, Feyrer (2009) analyses demographic issues, leading to a change in the quality of (business) managers. More precisely, this study asks whether the entry of the baby-boomers into workforce has an effect on productivity. When entering labour market the average quality of the manager necessarily decreases (it is assumed, that quality is positively dependent on years of working experience) and increases after gaining years of experience. Using a Lucas-model (Lucas (1978)), the author finds explanatory power of roughly 20% for the 1970s-slowdown and foregoing developments in productivity, which emphasizes the relevance of demographics for productivity analyses.

Further, labour market reforms affect general labour supply. The "Hartz reforms" at the beginning of the 21st century have introduced many employees of lower quality into the labour market in Germany, in order to increase employment volume and decrease unemployment (i.e. see Krause and Uhlig (2011); Krebs and Scheffel (2013); Elstner et al. (2018)). Whereas the quantitative effect is remarkably fine (if arguing from a simple perspective of having re-introduced more unemployed into the labour market), effects on productivity due to less quality from the labour market supply side is noteworthy. Productivity is not only dependent on the quantitative amount of work available but also from the worker's human capital. If more workers with low productivity are introduced to the labour market, the average productivity necessarily drops. Labour market reforms were also meant to provide a higher degree of flexibility, in order to better adapt the market to structural changes in course of technological developments. Modern and more flexible working models (some of them subsidized by the government or labour market institutions respectively) can contribute hereby. More important for the adoption of the labour supply side of an economy is the duly adjustment to structural change by economic policy. More precisely, an educational system is crucial, which not only offers education for "first-timers" but also provides an extensive offer for "re-trainers" (Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung (2015, p. 318)). As the educational system is of central importance, this shall be discussed in chapter 9.2.5.

Especially from 2015 onwards, Germany has experienced larger flows of refugees, entering the labour market. As a positive aspect, migration and refugee integration counteract shrinking working population. It, however, requires some time to break down language and cultural barriers, to close educational gaps and - a difficult undertaking - to abolish prejudices on the employer's side, especially when it comes to smaller and less internationally connected companies (Deutsche Bundesbank (2017a, p. 42)).

Despite having most of the G7-economies being faced with ageing problems for the near to middle future (i.e. as stated by United Nations (2015)), Westelius and Liu (2016) provide a study for

Japan, which is ranked in #1 (Germany #2) among the G7 regarding macroeconomic problems due to shrinking and ageing population. One of their findings is that prefectures with a larger service sector show less productivity growth over time (measured as TFP-growth; Westelius and Liu (2016, p. 11)), strengthening the ageing-population argument. Ageing population in course of demographic change exhibits another - rather indirect - effect on productivity. The larger the fraction of older people (or generally speaking, the older the entire society is), the higher the demand for services becomes. This is valid especially for the health care service sector. Increasing demand for services implies nothing else than structural change and a re-shift of the economy's focus in production and output. In the course of the increasing importance of services, the labour market follows. Health care and the entire service sector in total is characterised by a higher degree of labour intensity and less productivity likewise. If the fraction of services in national products rises, productivity on aggregate necessarily declines (Westelius and Liu (2016, p. 5)). Besides the indirect effect of increasing demand for services due to the ageing of a population, there is the question which side of the direct effect dominates. On the one hand, older employees have accumulated a significant amount of lifetime experience in the working process, on the other hand, younger employees show a higher level of adaptability, the skill to satisfy the requirements in the course of a changing labour environment.

Aksoy et al. (2015) even offer three channels, through which demographics affect an economy's productivity development. Besides ageing of the workforce and the different innovation capability of the cohorts, lifetime consumption decisions, as well as human capital considerations, play a role (Aksoy et al. (2015, p. 43)).

Innovation capability, as their first channel, is measured by using patent application as proxy. The study finds a strong positive effect for the middle-age cohort (40-49yo.) on patent application, whereas older cohorts show the opposite (Aksoy et al. (2015, p. 9 f.)). According to the results, an ageing population and a decrease of the most important cohort for the innovation process, therefore, lead to less innovational activity and shrinking rates of productivity over time.

Secondly, investment in human capital is an important linkage. Depending on the fertility rate and/or ageing process of the population, different savings decisions can influence the rate of growth. If, for example, ceteris paribus, fertility decreases (symbolic for an ageing population), workers have to increase their savings for retirement, implying less (current) investment. As the share of youngsters (dependants) decrease likewise, capital spending per capita can be assumed to increase, leading to more investment in human capital and implying higher growth rates (Aksoy et al. (2015, p. 39 f.)).

The third channel, the authors offer, is related to the life-cycle adjustment of consumption in course of higher longevity of the population. If people expect to live longer, they have to adjust their savings accordingly. Higher savings and higher asset accumulation in the course of the working life then, in turn, reduces consumption. The additional savings made by the workers are then used for capital and innovation investment, implying higher rates of growth. In contrast to the positive effect of higher savings, the necessary decrease in consumption and corresponding negative effect on aggregate demand can outperform or even falter the positive effect (Aksoy et al. (2015, p. 38 f.)).

Projections of the Aksoy et al. (2015)-study expect German long-term GDP-growth to drop by about -0.91% from 1.66% p.a. (on average between 2000-2009) to 0.76% p.a. (2010-2019 and 2016 to 2019 as projections Aksoy et al. (2015, p. 21)). More generally, they state that "our results provide further indication that OECD economies are more likely to experience episodes where aggregate demand externalities may lead to stagnation in the following decades." (Aksoy et al. (2015, p. 12)). Similar results are shown by Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung (2015, p. 318), which provides a drop of -0.6% GDP-growth per person and year.

Lindh and Malmberg (1999) also find evidence for the influence of the demographic structure on labour productivity. According to their human capital augmented Solow modelling approach with regard to OECD countries, the 50-64yo. cohort has a positive influence on productivity, young cohorts provide ambiguous effects whereas retirees (>65yo.) exhibit negative implications for productivity trends (Lindh and Malmberg (1999, p. 431)). Experience is the linkage, they base their study on; shortcomings of the approach are admitted. In contrast to Aksoy et al. (2015), Lindh and Malmberg (1999) do not include other channels in their empirical studies. Saving behaviour and effects on aggregate demand are excluded so that they experience-argument in their study as explanation for the productivity channel has to be used with a certain amount of care (Lindh and Malmberg (1999, p. 445)).

Like Gordon (2012) has proposed for the United States, the demographic headwind blows against

Germany, too. Through various channels, productivity is and will be depressed. As Germany is not only confronted with an ageing population but a shrinking one likewise, the headwind has increased significance. When in the previous century the baby-boomer generation, as well as increasing rates of female labour market participation, entered the economy, this has created a positive stimulus for economic growth. It not only has come to an end but will be in "reverse motion" (Gordon (2012, p. 16)) - faltering economic growth. When the generation of baby-boomers will retire, total hours worked per capita necessarily has to decrease, implying lower rates of productivity.

As demographic effects are connected deeply with the educational system of an economy and the corresponding degree of labour market flexibility. The subsequent chapter deals with this linkage.

9.2.5 Human Capital and the Educational System (headwind #4)

Declining labour quality is another potential source of explanation. It is a component ultimately linked to an economy's (factor) endowment and hereby stimulates economic growth and productivity. Its importance - more precisely the importance to establish a suitable system for the development of human capital - is also linked to its rigidity in the short run. Ramifications of inappropriate educational attainment become visible usually over longer time horizons only; the time required for changes likewise. Such time-lags between (policy) actions and their respective outcomes encumber the supply side of an economy in the short run. As a potential source of explanation for productivity puzzles, an examination of the educational system of Germany has its entitlement.

Gordon (2014) examines the US educational system and its relevance for hampering productivity and growth. This section of the study first follows Gordon (2014) by adressing secondary education and higher education as the two relevant components of educational attainment. Two points are added, however: numbers on non-academic education, as well as numbers on retraining, which deal with separate career entry points (mobility).

Especially Germany with a traditionally strong middle class relies on a specific fraction of its economic performance in the non-academic job market. The need to incorporate the non-academic sector is crucial as in many countries and for many levels of profession a college degree is mandatory - however, in Germany often it is not. Training and qualification on a high non-academic level work as a suitable substitute in the educational system and for the German labour market.

Secondary Education

Secondary education prepares for higher education. It forms the basement for the specialization in skills, acquired in college or in any other tertiary education system. For most countries, it is compulsory, at least until the age of 16 (in the US depending on the state). Secondary education is sometimes split into sub-categories of schools, which makes a comparison often even more problematic. As a suitable indicator for the quality of pupils, enrolled in secondary education, the OECD regularly (in a three-year-cycle) ranks countries regarding crucial skills. Poor positions in the rankings provide information on the relative (dis-)advantage of domestic pupils from a qualitative perspective and a possible lack in the qualification for post-secondary education.

The program for international student assessment (PISA) regularly ranks OECD countries (and some others) among the fields of mathematics, natural sciences and reading ability. It also provides information on the effect of gender, social background and migration on education[65]. Test results then estimate the quality of a country's (future) labour endowment and allow implications on the structure of the educational system.

All data of the PISA tests provided for the relevant OECD countries can be found in annex V. The data for the 35 member states of the OECD are taken from OECD (2018). For mathematics no data was available for 2000 and for (overall) science there were no data for the years 2000 and 2003.

When in 2001 the results of the first PISA test were made public and Germany was ranked in the very bottom half among the OECD peer group (i.e. #21 in category "overall reading"; PISA study 2000), politics as well as general public discussed the consequences and implications for the future of the educational system. Since then, in the reading category, Germany has moved up the scale to position #9 in the latest test (2015). In the second field of testing - overall science - Germany was able to maintain its position in the upper area (currently ranked #10; the same position as in 2006), whereas in the category of mathematics it has improved from #17 (2003) to #11 (2015).

Top positions in all categories are shared traditionally by Japan, Finland and Canada, whereas the

[65] Data is collected in a three-year interval since 2000.

United States are merely ranked in the bottom half of the table. Compared to the US and Robert Gordon's (2012) examinations, for Germany, we can first assess a better relative position, as well as improvements over the last (almost) two decades. The United States, in contrast, have lost positions (#14 in 2000 to #20 in 2015 in the category of overall reading and from #26 in 2003 to #32 in 2015 in the category of mathematics) and just slightly improved from #24 to #19 in the field of overall science.

Secondary education and the related skills, measured by the PISA testing, do not necessarily provide a bottleneck for educational attainment in Germany. Furthermore, the positive development among the categories shows that, in contrast to the US, Germany is prepared better for the future. Nevertheless, there is still room for improvement. As politics have set the goal to close the gap to leading nations in technology and overall development, a top position must be the purpose (i.e. see Wanka (2015)).

If PISA represents implications on the quality of a nation's endowment of secondary education, a quantitative analysis is complementary. In this context, it is interesting to analyse the amount of pupils having completed secondary education (or by measuring the opposite - the so-called "drop-out rate"). Studies provide fair grades for Germany's secondary educational attainment (i.e. Herzog-Stein et al. (2017, p. 11) who state stability of drop-out rates over the last 25 years in Germany and increasing percentages of graduates with general university entrance qualification).

Over the last years, the amount of pupils leaving secondary school without graduation (drop-out rate) has decreased in Germany. In 2008 (64 918) the value was almost the same compared to 1992 (63 560). In relation to total students in secondary schools, Germany has, in fact, reduced its drop-out rate from 8.19% (1992) and 6.98% (2008) to nowadays 5.75% (2016). In contrast, the percentage of students with the general university entrance qualification[66] has increased from 24.73% (1992) and 30.20% (2008) to 34.82% (2016) (Statistisches Bundesamt (2017b, p. 561 f.)).

One, however, has to treat these numbers with care. Increasing numbers and fractions of people equipped with the general university entrance qualification and lower drop-out rates from secondary education do not necessarily lead to the implications of improvements in the educational attainment.

[66] No separation between "Fachhochschulreife" and "Allgemeine Hochschulreife" is made in this case.

It can also be inferred by simply lowering the standards and requirements. This argument, however, is met and weakened by the better performances in the recent PISA-tests, discussed above. Another point noteworthy is the possible mismatch between qualification and skills on the one side and requirements by companies on the other. As in Germany, currently around 1.25 mil. vacancies (Institut für Arbeitsmarkt- und Berufsforschung (2018)) exist (without having a full-employment situation on the labour market supply side), a mismatch is likely, indicating defects in the educational system.

Higher Education / Tertiary Education

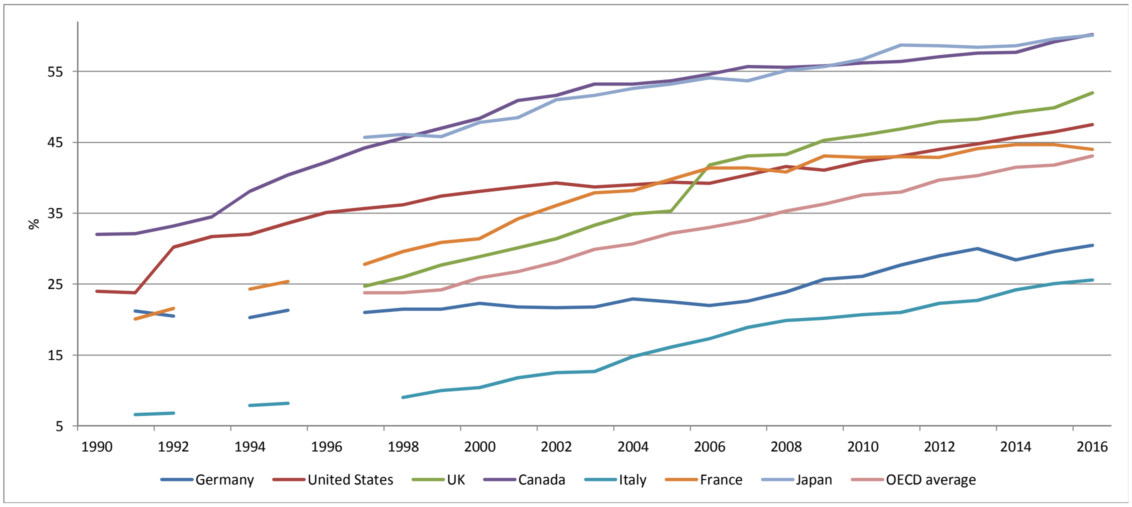
Higher education is defined as "all post-secondary education, including both public and private universities, colleges, technical training institutes, and vocational schools."[67]. It "includes both theoretical programmes leading to advanced research or high skill professions such as medicine and more vocational programmes leading to the labour market." (OECD Statistics (2018b)).

Figure 31 shows the development of the 25-34 year-olds, equipped with tertiary education, in G7-countries, as well as numbers for the OECD-average. Even though implications for the educational attainment can be derived from other age-groups as well, the 25-34 year-olds are the primary target group for tertiary education (note that to be included in the statistics, one must have successfully completed tertiary education, not just started). Usually, people aiming for tertiary education get enrolled right after having finished secondary education, which is at the age of around 20[68].

[67] See <<http://www.worldbank.org/en/topic/tertiaryeducation#what_why>> for further details.

[68] For a better and more broad analysis, data for 20-24 year-olds should be taken into account. Unfortunately, data for this age-group is not provided by the OECD.

Figure 31: Fraction of Tertiary Education, (in per cent) 1990-2016. Source: OECD Statistics (2018b); own illustration.



Currently, around 30% of the 25-34 year-olds in Germany are equipped with tertiary education (2016: 30.5%). It represents an all-time high, despite low rates of increase within the past years (2012: 29%). Figure 31 shows the flat curve feature, starting at around 20% in the 1990s and only moderately growing afterwards (1991: 21.2%, 2000: 22.3%). Remarkably to note is Germany's poor position among the G7-countries and its relative position to the OECD-average (OECD currently provides a value of 43.1% (2016) of tertiary education among the 25-34 year-olds).

The United States showed a level similar to Germany back in 1991 (23.8%) but managed to increase to a value of almost 50% (2016: 47.5%). Italy caught up over the years and has closed the gap to Germany. Starting at a rather poor level of 6.6% in 1991, it nowadays offers similar levels to Germany (25.6% in 2016 for Italy).

Generally, the highest values are offered by Canada and Japan. Despite a long-lasting tradition of a high percentage of tertiary education (Canada started 32.1% in 1991, Japan at 45.7% in 1997[69]), both countries have hit the 60%-mark in 2016.

Other cohorts (not displayed graphically and of less importance for implications on tertiary educa-

[69]Unfortunately, for some years and countries data lacks completeness; therefore 1997 has to be taken as starting point for Japan.

tion) show similar trends. Canada and Japan again performed outstandingly by almost doubling their values over the years in the respective time interval. Pretty remarkable is the increase in the 45-54 and 55-64 year-old-cohorts. Here, the fraction of people equipped with tertiary education has almost tripled (i.e. Canada 55-64 year-olds: 16.7% in 1991 to 46.2% in 2016; Japan 55-64 year-olds: 13.7% to 39.7%). Whereas the United States shows a similar trend (from 17.1% (1991) to 41.9% (2016), 55-64 year-olds), Germany increased its fraction from 16.5% (1991) to 26.3% (2016).

It is interesting to note, that the leading countries show similar trends over all age groups nowadays (2016: i.e. Canada: 60.2% (25-34 y.-o.), 62.8% (35-44 y.-o.), 55.7% (45-54 y.-o.) and 46.2% (55-64 y.-o.)). Italy as counterpart provides a negative correlation between age and fraction of people equipped with tertiary education (25.6%, 20.5%, 14.0% and 12.4% for the respective age groups).

Only by implying statements from quantitative analyses on the tertiary educational system might lead to distorted points. If the supply, provided by universities, colleges and other institutions of the tertiary level, does not meet the demand of labour, structural problems are inevitable. Such a mismatch situation can be displayed by the amount of graduates ending up in unemployment. This point, already stated for secondary education, becomes valid for tertiary education, too.

According to Institut für Arbeitsmarkt- und Berufsforschung (2017a), the unemployment rate of graduates with tertiary education is on an all-time low (since 1980). Currently (2016) only 2.3% are unemployed; the rate has slightly decreased from 2015 (2.4%). The opposite is true for unemployed without any kind of educational form (2016: 19.1%). When separated into Western and Eastern Germany, the numbers also imply structural problems. In Eastern Germany, more precisely states of the former GDR, show significantly higher unemployment rates: 29.2% in Eastern Germany and 17.7% in Western Germany (2016). Even though the heterogeneous labour market situation in Germany is a problem of unevenly benefitted regions, the trend over the last (almost) three decades goes into the right direction. Eastern Germany was able to reduce its unemployment rate for non-graduates from an all-time high of 55% (1997) to 29.2% (2016) and for overall population likewise (from 19.9% in 2004 to 8.1% in 2016).

However, as the overall unemployment rate in Germany has decreased within the last years, it allows for the statement of an overall improvement of the German labour market. For 2016, 6.2% have been unemployed (overall German unemployment), showing a three-in-a-row reduction since 2013. Double-digit unemployment rates at the beginning of the 21st century continuously shrink - which in fact benefits all groups of people regarding their qualification level. It seems, the very best option to evade unemployment still represents education.

Another point worth to note with regard to tertiary education is the financial aspect. Traditionally, tuition fees in the United States have accumulated a serious amount of student debt. American students owe around $1 trn. in total college debt Gordon (2014, p. 10 f.). Even though a college degree generally offers a higher probability of finding a decent job and higher income likewise, Gordon (2014) states, that around one quarter of college graduates fail to find a well-paid job right after graduation, Many graduates then end up being worse off: firstly, the benefits from higher education are out of reach and secondly, they are burdened with a serious amount of debt[70].

Besides a service fee for each semester (currently, 2018, at approximately €100-200), there are no tuition fees for public universities in Germany[71]. In addition, the qualificatory gap between public and private schools seems to be smaller in Germany, compared to the US. Attending public schools in Germany is quite more common and with the effect of similar education (compared to private schools), it is more than an adequate substitute. Numbers on tuition fees and graduates, however, only provide one side of the coin. Increasing numbers of students at university often go hand in hand with structural problems when faced insufficient equipment and infrastructures.

Crowded lecture halls, the simple lack of desks for individual learning in libraries, an increasing student-to-tutor ratio and generally speaking a worsening college infrastructure (due to insufficient investment over the past years) will have a significant impact on human capital in Germany if no adequate measures are executed soon.

In the United States, it is more expensive to attend college - as relevant tertiary education. Average yearly tuition fees range from $3.500 to $24.000, depending on the duration of study and university chosen (College Board (2018), tuition fees increase significantly for students from other districts or

[70] Furthermore, they have invested living time for - which seems- nothing and have to depreciate individual human capital with every day working apart from their qualification level.

[71] For some years and states in Germany tuition fees were set up. All (former) countries of Western Germany charged €500 per semester except Bremen, Rhineland-Palatinate and Schleswig-Holstein. So from around 2006 to 2014, there was a minor fee for students to pay - ridiculously low compared to tuition fees of US-colleges.

even states). Private colleges on average even ask for around $32.000 per semester, which burdens private budgets for schooling expenses. In this comparison, any other costs besides from tuition are neglected as they appear for any student (and vary depending on the place of study and personal preferences; i.e. accommodation or food).

In Germany - and probably in many other countries, too - the main reason for increasing private debt is (still) unemployment (Creditreform Wirtschaftsforschung (2017, pp. 70 ff.)). According to Creditreform Wirtschaftsforschung (2017), there are five main reasons for private debt in Germany: parting and divorce, (addictive) illness or accident, uneconomic household management, failed self-employment and unemployment. In sum, the "big five" name the reasons for around two-thirds of the debtors, unemployment the major reason.

In 2010 for 28.2% of the debtors unemployment was the main issue, in 2017 this number has decreased to 20.2%. The overall debt-ratio of households in Germany has slightly increased. In 2004 3.10 mil. households were considered as indebted, in 2010 3.19 mil. and currently, this number has increased to 3.41 mil. (2017). The good news in this context is that the average sum of debt per household has decreased. On average an indebted household in 2006 was burdened by €36.000, nowadays €30.200 € (2017). This is valid for the overall sum of debt, which has declined over the years (from €265 bn. in 2006 to €209 bn. in 2017). Less debt in total but an increasing number of debtors may have a contrary effect on the likelihood of taking on tertiary education.

If one considers debt as an obstacle for proper education in Germany, the implications of the rising debt in German are rather negative. Debt not only prevents people from taking on further education (as many are forced to earn money instead of investing in their own human capital stock), debt also depresses effective demand for goods and services - the issue already discussed in chapter 9.2.2.

Non-academic Educational System

Another component of the educational attainment is the non-academic sector. For some professions - usually lower quality jobs - no academic education is required. Even more - for some jobs a more practice orientated training, so-called vocational training, can be considered superior. The quality of college education varies among countries, so does the quality of the non-educational component. Many countries are endowed with a well-functioning non-academic sector. For those, non-academic training can be considered as an alternative on a high level (Herzog-Stein et al. (2017, p. 11)). Whereas Germany owns a well-functioning non-academic educational system, the US does not. Moreover, for Germany, for any profession, there are central rules and regulations, set by the federal government. In the US, no such regulations exist - the US constitution does not include aspects of education, which allows states to individually establish non-academic standards - a potential bottleneck for mobility and allocative efficiency.

Dual schooling in Germany connects theoretical education with vocational training. Students not only benefit from this nexus but also from a limited time required to be trained for ambitious tasks. For the examination of the German non-academic schooling level, the quantitative development of apprentice positions can be inferred.

According to Bundesinstitut für Berufsbildung (2018, pp. 14 ff.), the supply of apprentice positions in Germany in 2017 has increased for the first time since 2011. In 2017 around 572.000 positions were offered (peaking in 2011: 600.000). The number of 2017 marks a +1.5% increase, compared to 2016. As usually, the supply side is only one side of the coin. Again, mismatches can occur, when demand does not fit supply. And for Germany, there is a significant gap. Put differently, the divergence between supply and demand dissipates potential for additional employment and welfare development.

The demand for apprentice positions has decreased from around 653.000 to around 604.000 in the time interval considered (2009-2017). A more precise indicator for the performance of the non-academic educational attainment is the number of signed training contracts. From 2009 onwards, this number has decreased (564.000 in 2009) to around 523.000 (2017). Compared to 2016, a first-time increase in the time interval marks a slight improvement in the matching process (+0.6%).

In addition to cold numbers, there is a quality aspect of non-academic training. As stated initially, the German non-academic system provides high-quality training. In Germany, many levels of profession and positions, which require a college degree in other countries, can be obtained through the non-academic channel.

Retraining and Mobility

A big problem connected with drop-out rates is social mobility and (income) inequality. Headwind #6 will discuss the inequality aspect in more detail. For schooling and educational attainment, the financial background (and parental support) still plays a significant role. Despite rather low study costs (especially when compared to the US) and more possibilities to receive financial support from government, Germany still lacks equally distributed possibilities in the schooling system (i.e. Pollak (2012)).

Correlated with mobility in the educational system is the mobility across incomes and earnings (see chapter 9.2.7). Human capital and inequality (of incomes primarily) show mutual leverage. The higher the mobility in the educational system is, the more likely it will prevent an economy from having a high level of any kind of income inequality.

Bönke et al. (2015) explore the relationship between annual and lifetime earnings and the connection to mobility. Even though 'mobility' in this context relates to mobility of persons of the same age (expressed in cohorts; so-called intra-generational mobility) regarding labour incomes, one can find implications for the educational system in total. Flexible educational systems support an individual to move up in the income ladder - lifelong learning becomes possible and supplies employees with the latest tasks required, resulting in higher incomes. The authors show that at the beginning of a (working) life cycle (in a person's twenties) mobility is rather high but steadlily decreases and does not exist any more after the age of forty (Bönke et al. (2015, p. 28)). What can we infer from this result? If an economy does not allow its (older) citizens to move up (or down), this will show a high degree of inflexibility and enforces the issue of inequality.

Besides implying a dysfunctional schooling system, drop-out rates are also subject to unequally distributed possibilities and chances. There is a strong correlation between the rate of poverty of a region and its probability of dropping out (Herzog-Stein et al. (2017) quoting Geis and Schröder (2016)). Even more and regarding social mobility, childrens' careers often exhibit the same development patterns like their parents'. In this context, Pollak (2012) marks Germany with poor grades in terms of social mobility.

Positive implications of education on productivity and economic well-being are usually assumed as self-evident. Berger and Fisher (2013) for example explore this linkage on US-state level and find a positive impact of education on wages. More precisely, higher median wages are associated with a better-educated work-force. But education not only directly increases well-being by higher returns. Positive spill-over effects of higher levels of education are outlined as well as positive implications for the public budget. In the long run, the higher the levels of education, the higher the return and the higher (income) taxes will be. The authors provide empirical evidence for the link (Berger and Fisher (2013, pp. 3-5) making use of data from the Bureau of Labor Statistics): higher education →higher productivity →higher incomes (as a suitable proxy/component for/of well-being). Higher productivity not only allows an economy to pay higher wages and profits. If goods and services can be produced in a shorter amount of time, shorter work weeks and more leisure time are the consequences ultimately increasing economic utility (Berger and Fisher (2013, p. 10 f.)).

In a recent study, Elstner et al. (2018) point on the productivity-labour market linkage. In course of the restructuring of the German labour market (by the already discussed "Hartz reforms") in 2005, around 5 million low-skilled and low-productivity workers (which was an increase by around ten per cent) have been introduced to the German labour market, leading to a decline in the overall rate of productivity. Many of the low-skilled workers newly introduced to the market became employed in the traditional low-productive service sector (compared to the high-productive manufacturing sector), which had strengthened the effect on aggregate productivity (Elstner et al. (2018, p. 19)).

Further, the study states that the magnitude of technological progress has slowed down after 2012, implying an additional depressing factor for productivity growth. Even though decreasing rates of productivity have existed prior to 2012, a slower pace of technological progress further limits current productivity growth. The study also supposes that the gains from technological progress in the ICT-sector have mainly stimulated the employment sector and to a lesser extent GDP, implying only moderate effects on productivity. In addition, the study provides evidence for low spill-over effects regarding technological change from other economies like the US (an explanation is not offered) (Elstner et al. (2018, p. 34 f.)).

In course of the obvious effects the education-productivity-income channel, implications on the base of cost-benefit calculations can be inferred. Expenditures in the educational system usually yield overproportional returns. As an example, French and Fisher (2009) find a cost-benefit ratio of 2:1 (double increase in earnings in relation to a single increase in expenditures) for any postsecondary and technical education in Tennessee (USA). Even more, for the entire US, a (roughly) 5:1-ratio (five times increase in income due to single increase in expenditures) was exhibited by creating more employment, output, labour income and tax incomes (French and Fisher (2009, p. 11) quoting Bureau of Economic Analysis (2008)).

9.2.6 Public Debt (headwind #5)

When discussing the environmental quality and growth potential of an economy, there is an important variable, which limits the leeway of economic policy - public debt. As the public sector provides a huge amount of crucial goods for the economy (i.e. infrastructure, educational system), the costs can be covered by taxes and other submissions - or by loans. The latter technically subsidiary but practically considered as an essential part in public budgets.

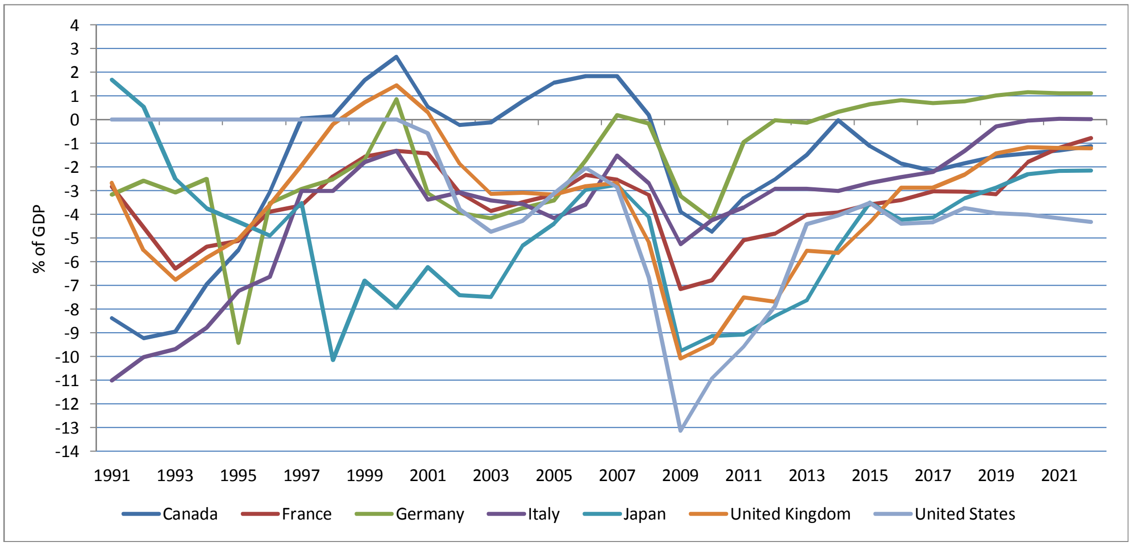
For members of the European Currency Union (ECU) like Germany, the upper ceilings of public indebtedness are defined in the treaty of Maastricht (European Union (1992)). Besides other criteria, which aim for a homogeneous character of the European Currency Union, boundaries for public deficit and debt (cumulative deficit) are defined.

Countries must not overshoot a -3% deficit per annum. Deficit is calculated as net value of expenditures and revenues of the public space and related to a country's national product (GDP). For the debt criterion, a limit of 60% (in relation to GDP) is set. Even though the punishing mechanism of the European Currency Union is rather weak and subject to discussion (with regard to moral hazard aspects), there is the challenge and of course the legal requirement for every country to balance its budget according to the criteria of the Maastricht treaty. Checks on every country's economic situation are executed when joining the currency union and on a regular base afterwards.

Public debt and its boundaries work as a constraint for investment and limit growth potential not only in the short but also in the long run.

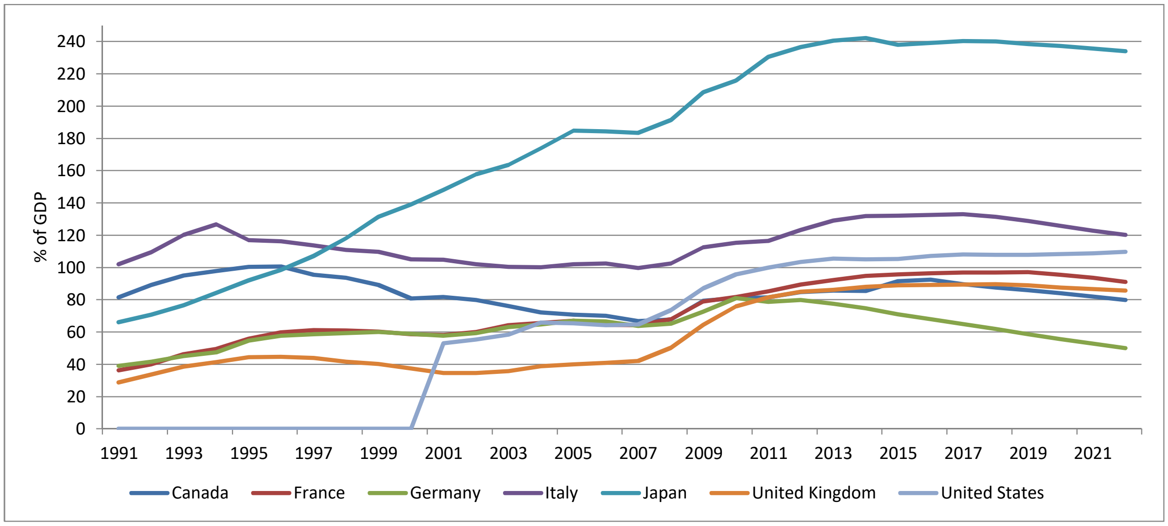
Figure 32 provides the trend for the G7-countries with regard to the annual deficit ratio, whereas figure 33 provides the (cumulative) debt[72]. Data is taken from International Monetary Fund (2018b) and International Monetary Fund (2018a).

Figure 32: Annual Public Deficit, (in per cent of GDP) 1991-2022. Source: International Monetary Fund (2018b); own illustration.



[72]Please note, that any data after 2016 is a forecast only.

Figure 33: Cumulative Public Debt, (in per cent of GDP) 1991-2022. Source: International Monetary Fund (2018a); own illustration.



After German reunification, there have been years of excess budget deficits (i.e. -9.4% (1995), -4.3% (2003), -4.2% (2010)). For the majority of the years, however, Germany fits the Maastricht criterion on annual deficit. As for France, the situation is less positive. Besides some years of moderate deficits around the turn of the millennium, France regularly overshoots the budget criterion. Remarkable at this point is the post-crisis development. Whereas Germany only had to suffer from one year of excess budget deficit (-4.2% in 2010) and reversed the trend to only around +1% (2011) afterwards, France did not follow. Budget deficits in France only shrunk slowly from around -7% in the years after the global financial crisis to -5% in (2011, 2012). In contrast to Germany, it still misses the deficit criterion (-3.4% in 2016) in the latest past.

Coming from substantially high deficit ratios, Italy was able to reduce the deficit within the last decades. Having two-digit deficits (-11%) in 1991 and (-10%) in 1992, the trend can be considered as positive. Despite having some problems of fulfilling the legal requirement, Italy now constantly shows budgetary discipline. Within the last five years (2012-2016) it has performed well, though only little below the -3%-boundary (i.e. 2012-2014 exactly hitting the maximum legal requirement).

Canada, Japan, UK and the US do not require to balance their budgets according to the Maastricht treaty. Whereas Canada can be considered as rather stable, the other three countries offer higher deficit ratios. Besides the beginning of the 1990s and the aftermath of the global financial crisis (2009-2011 deficit ratios of around -3% to -5%), Canada showed a budget that can be considered as almost balanced. Some years even show a surplus (2005-2007 at around +1.5% to 2%).

Connected to the (cumulative) debt, Japan naturally provides deficits over and above -5% (around -5.5% on average for the time-interval considered), which necessarily mounts up a large amount of public debt.

For the UK and US only within the last years, a positive trend is found. Ranging from two-digit values the UK was able to reduce the annual budget to a ratio of around and below -5% within the last four years. After the impact of the global financial crisis slowed down (peaking in 2009 with -10% for the UK and -13% for the US), the trend for the US can be interpreted as positive (though still exhibiting deficit ratios of in between -4% and -5% for the last post-crisis years).

For the second fiscal criterion of the Maastricht treaty - cumulative debt not to exceed 60% (of GDP) - Germany could not provide a single year of fulfilment after 2003 for many years. In 2010, German debt hit the 80%-mark (peaking at around 81% in 2010), since then it was reduced to 68% (2016), 61% in 2018 and is expected to fall below 60% in 2019 - a first year of fitting the threshold. Therefore, the trend for last years can be considered as positive. It was also supported by a phase of decreasing interest rates, which has led to a decline in the interest rate payments (Deutsche Bundesbank (2017b, p. 36) and Deutsche Bundesbank (2019, p. 58*)).

The French trend, in comparison, is monotonously rising to values of almost 100% (2016: 96%). For Italy, the same trend is exhibited, on a higher level, however. Italian debt has exceeded 130% GDP over the last three years (2014-2016). Canada, UK and the US likewise were not able to reduce its cumulative debt. Their values rise without a sign of reversal and improvement (2016: Canada at 92%, UK at 98% and the US at 107%). Japanese debt is extraordinary but in a negative sense. Over nearly three decades Japan has mounted up a significant amount of debt. Starting with a debt to GDP ratio of around 66% in 1991, the cumulative public debt has nowadays peaked to 238% (2015)[73].

How does a change in the trend of public debt affect an economy? The effect is twofold.

[73]No values were available for 2016 at the date of publishing.

Firstly, increasing public debt limits potential policy measures in the future; directly as a potential source of public income dries up and indirectly by increasing interest rate payments. The trend for interest rate payments mainly depends on two factors: on the one hand the amount of public debt, which has to be financed by loans and on the other hand the (average) interest rate, a country has to pay (which itself results from aggregating the individual debt titles).

Even more, increasing public debt can worsen a country's rating and lead to higher interest payments for loans on the international markets in the future - a scenario the so-called PIIGS[74] faced in the aftermath of the global financial crisis. So is the average interest rate (measured over a specific time interval, which is relevant for calculating the interest rate payment costs) separated into a risk-free real interest rate, and other components depending on run-time of the loan, inflation and (overall) risk (Deutsche Bundesbank (2017b, p. 36)). The risk-premium then depends on the expected solvency of a country, so that a higher debt-to-GDP ratio necessarily increases the average interest rate payment costs. It offers potential for a (negative) coil or vicious circle, as interest rate payment costs and public debt mutually influence each other. Currently, interest rate payment costs for Germany, as well as for other member states of the European Currency Union, are on an all-time low for most of the countries (Deutsche Bundesbank (2017b, p. 36)). It implies quite beneficial conditions for commencing further loans (i.e. for investment purposes).

Besides the trend for public debt, average interest rate, as well as interest rate to GDP ratio, have dropped significantly over the last three decades. The interest rate payment to GDP ratio is important for the public budget, as it shows the costs for external financing. Despite positive developments in terms of the total public debt, one has to be careful with a too positive outlook. An inversion of the interest rate trend in the future would lead to significant problems for the German budget, as it nowadays highly benefits from the low-level interest rate environment. At the beginning of the 1990s, the average interest rate for Germany was at about 8%; it was then reduced to almost half at the beginning of the 21st century (around 4.5% in 2005). Since then it steadily declined to values of only 2%, a development, which unburdens German policy and could (should) be seen as a major opportunity for renewing the public capital stock (as discussed in chapter 8.5). The interest rate payment to GDP

[74] Countries experiencing major problems in course of the global financial crisis. The acronym consists of Portugal, Ireland, Italy Greece and Spain.

ratio shows a similar trend. Starting at values of about 3% in the 1990s, the amount of GDP, which has to be used for loan payments was reduced to 1.5% and is expected to decrease further. Deutsche Bundesbank (2017b, p. 40) expects the trend to continue until 2019 (ceteris paribus) and only slightly increasing afterwards (2% in 2021 to be expected).

Secondly, decreasing public debt (usually) goes hand in hand with contractionary fiscal policy actions - negative stimuli for the economy via the linkage of aggregate demand. Depending on the channel and tools, the policy actions are executed (i.e. increased taxes or decreased government spending), contractionary fiscal policy reduces private consumption and investment. Negative developments of the economy's national product are inevitable (even further, there will be an absence of positive multiplier-effects via the aggregate demand channel); additionally, technology development and diffusion will suffer from lower investment, too.

Reinhart and Rogoff (2010, p. 574) have set up debt-thresholds for countries and provide numbers on debt for a time interval since the global financial crisis (up to 2010, when their study was published). Whereas the German debt-to-GDP-ratio is 4%, Ireland (44%), Iceland (69%), Spain (42%), UK (72%) and the United States (84%) perform significantly worse (debt-to-GDP ratio expressed as the cumulative increase in real public debt in between 2007-2009).

It is persuasive to mark Germany better and rate its debt-headwind as rather weak. This, however, only provides a little data window and should be treated with a serious amount of care, when discussing long-run economic endowments. The authors define the debt-to-growth connection as "non-linear" and compare war-related and peacetime-related debt occurrence. War-time-debt is usually related to excess government activity and can be considered as "natural", whereas "peace-time debt explosion (which many economies suffer from) often reflects unstable political economy dynamics that can persist or very long periods" (Reinhart and Rogoff (2010, p. 574)).

In order to explain the non-linear behaviour, the authors follow the argumentation and method of Reinhart et al. (2003). They make use of data for more than two centuries and find an important debt-to-GDP-threshold[75]. Any ratio over and above 90% leads to remarkably slower growth in economic

[75]This threshold is valid for emerging markets, as well as for advanced economies. Another threshold is found for emerging markets (60%), causing adverse outcomes. As the focus of this dissertation is on developed countries, the focus is on the 90%-threshold only.

output. From this perspective, the authors provide another argument against the importance of the debt-headwind for Germany. By overshooting the 90% debt-to-GDP ratio, GDP is (roughly) cut in half in the future (Reinhart and Rogoff (2010, p. 573)). When debt ratios overshoot specific boundaries, this results in an increase in the interest rate causing "painful fiscal adjustment[s] in the form of tax hikes and spending cuts, or, in some cases, outright default" (Reinhart and Rogoff (2010, p. 574)).

The approach of Baum et al. (2013) argues in the same direction. Their empirical results state that there is a positive short-run significance for public debt until a debt-to-GDP ratio of 67%. Any further increase shows zero significance, whereas debt-ratios of above 95% provide negative stimuli of additional debt (Baum et al. (2013, p. 17)).

Kaas (2014) focusses on the direct relationship between public debt and (total factor) productivity. His model is set up for the US and separates for two effects from a change in the budget deficit. A reduction (increase) of the budget deficit leads to an increase (decrease) of capital formation (via lower (higher) interest rates and the resulting credit expansion (reduction)). If public budget deficit decreases, the credit expansions will, on the one hand, provide a positive stimulus to economic growth but will keep low productive companies in the market; the latter effect - which dominates the author's computation - then will lead to a reduction in overall (aggregate) productivity (Kaas (2014, p. 2)).

Compared to other benchmarks (G7-countries, member states of the European Currency Union) Germany has performed better over the last decade. Even though public debt still misses the Maastricht criterion, the German trend has improved. Supported by an era of historically low interest rates, Germany was able to find a way back to a balanced budget - a goal, which has been particularly stressed in politics[76]. From the headwind-perspective public debt should play a smaller role on the productivity slowdown, as the average interest rate is expected to remain constant or just modestly rising (Deutsche Bundesbank (2017b, p. 40)).

The less important role of public debt as headwind for German productivity trends is supported by the evaluation of benchmark countries, which perform significantly worse (G7-countries, member states of the European Currency Union). However, when concluding this sub-chapter, one has to keep

[76] In fact, former federal finance minister Wolfgang Schäuble successfully balanced German public budget in 2015 for the first time since 1969 (http://www.die-schwarze-null.de/). There is large controversy about the costs and benefits of these policy measures, however. Criticism often emphasizes on the contractionary moves, a budget consolidation goes hand in hand with (i.e. less investment for infrastructure or the educational system).

in mind that decreasing public deficit and debt is usually associated with contracting (and therefore painful) fiscal policy actions[77], which could falter economic growth and productivity in the future.

9.2.7 Inequality (headwind #6)

The distribution of income and wealth is not just a normative issue. Inequality and wealth concentration provides potential for significant obstacles for economic development. In the course of the global financial crisis and the publishing of Piketty's (2014) *Capital in the Twenty-First Century*, the discussion on income and wealth concentration has been renewed. It is argued, that a concentration of wealth and income can hinder economic progress.

Economic inequality can be measured and expressed through various variables: there is labour and capital income, wealth, wages or more general the questions whether measured per person, on a household level, on annual base or regarding the entire life of a human being (i.e. see Battisti et al. (2016) for a brief overview and data related to Germany).

A strict separation, however, seems inappropriate, as there is mutual dependency. Whereas the accumulation of wealth is only possible if income flows deliver surplusses, higher income flows usually are supported by a certain amount of wealth. Wealth in this context not only contains the financial (asset) situation of an individual but also includes any kind of real asset and of course human capital. The stock of skills and knowledge, accumulated over time, allows an individual to step on a higher level of income, which then, in turn, results in higher wealth accumulation. Financial and real assets, in turn, allow postponing income streams to the future. Mutual dependency of income and wealth shows a reason and a necessity likewise for policy-makers - a reason for the self-reinforcing dynamics of inequality and the need to establish a suitable tax system and other distributional tools by the government. Regarding recent developments (of the twenty-first century), discussions among economists, politicians and the general society have occurred and determined the political agenda (i.e. Fratzscher (2016), Peterson (2017), Atkinson (2015), Stiglitz (2013)).

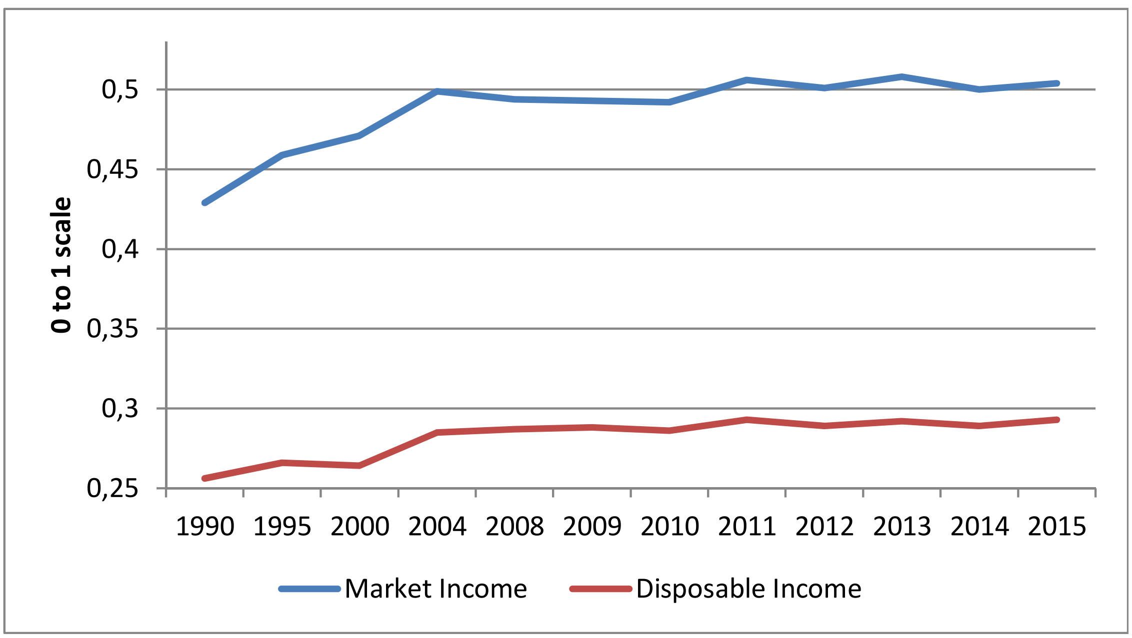
When considering income inequality, Germany is ranked below OECD-average, showing higher

[77] Another possibility is to benefit from a general economic recovery and improving conditions of the economic environment. Deutsche Bundesbank (2017b, 39) has stated, that the decrease of German debt after 2010 (up to 2017) is due to business cycle recovery, large tax incomes, low interest rate payments and good labour market outlook.

levels of income inequality. Market incomes in Germany (before any distributional effects) exhibit a Gini of around 0.51 (2015), the OECD-average of just around 0.45 (2015) (OECD Statistics (2018a)).

Figure 34 shows the trends for the German market and disposable incomes, expressed as Gini coefficients. The higher the value, the higher the degree of inequality. All values from 1990 to 2011 are based on the old definition, whereas values from 2012 to 2015 [and any following, O.Z.] base on the new income definition of the OECD: "Compared to previous terms of reference [the old OECD-definition, O.Z.], these [new values] include a more detailed breakdown of current transfers received and paid by households as well as a revised definition of household income, including the value of goods produced for own consumption as an element of self-employed income." (for additional information please see OECD Statistics (2018a)).

Figure 34: (Gini Market Income and Disposable Income) 1990-2015. Source: OECD Statistics (2018a); own illustration.



After having experienced a sharp increase in inequality in the 1990s from 0.43 (1990) to 0.50 (2004) for market incomes, the values have remained stable since then. Also, this trend is valid for disposable incomes (0.26 to 0.29 for 1990-2004). Fratzscher (2016) acknowledges the developments and relates the discussion to the distribution policy of the government. Germany is among the countries with the highest degree of inequality of market incomes but is very successful in decreasing the level due to distribution policy. The necessity for high government activity is clearly subject to discussion but definitely uncovers a dysfunctional income distribution (Fratzscher (2016, p. 585)).

It is also evident for a lack of a suitable framework of regulatory policy. Fratzscher (2016) claims five parts in Germany to be re-shaped and re-organised: educational policy, family and gender policy, tax system, labour market policy and private precaution - more precisely, these parts should be re-designed and equipped with a higher degree of efficiency. It will then reduce the necessity for the government to intervene so that the benefits of a more solid public budget and higher (social) equality could be realised. From this point of view, (market) income inequality falters economic growth and productivity via an indirect channel. The higher the financial burden of distributional policy, the lower the potential for setting economic stimuli (i.e. investment in public goods). The "slower economic growth due to efforts in reducing inequality"- argument is shared by Conard (2016) and Watson (2015).

In addition to the common measures of inequality as mentioned above, different socio-economic positions have to be taken into account. Depending on the economy considered, there is a type of inequality arising from different perceptions of gender, race or personal characteristics. This type of inequality has been labelled as "existential" or "horizontal" inequality. When deriving implications upon income dispersions, the issue of "horizontal" inequality has to be kept in mind for the sake of completeness (Peterson (2017, p. 2 f.) quoting Therborn (2013)).

Besides internal inequality, which is inequality in an economy itself, there is external inequality, which is an unequal distribution of incomes among countries. Both problems influence the domestic level of inequality likewise. As the degree of global inequality is significantly larger than in any domestic economy, its relevance for the inequality issue is even more important (Peterson (2017, p. 4) quoting Milanovic (2011)). Global inequality determining paths of economic development can be linked to the factor endowment of a country's early state. Engerman and Sokoloff (1994; 2005) show that North and South America, both equipped differently at their very beginnings, have then followed a process of economic divergence.

For the purpose of this study, the effects of inequality on economic performance are of major importance. Peterson (2017, pp. 13-15) states that countries exhibit higher rates of productivity if income inequality after taxes and transfers is low (disposable income). Stiglitz (2013) shares the opinion by emphasizing the savings effect of the wealthy cohort. Two arguments are presented for this channel. First, in relation to their income, wealthy people spend less money on consumption implying lower levels of aggregate demand for the economy, compared to a situation of a more equal distribution of income. Second, a more concentrated distribution might lead to economic inefficiencies and instabilities due to increased lobbyism by politicians, benefitting high-income recipients (who usually prefer less investment in public goods, i.e. infrastructure).

Another linkage is outlined by Ku and Salmon (2012), who emphasize a "discouragement effect". Workers being confronted with an unequal income distribution become discouraged. The implied reduction in individual productivity then, in turn, leads to a reduction in aggregate productivity and economic growth over time (and can translate inequality into a long-run phenomenon if - from a behavioural perspective - no incentives are set to encourage workers improving their poor relative position). Regarding work effort workers not only respond to absolute returns but also to relative returns. According to Ku and Salmon (2012), individuals facing inequality on the job in terms of lesser rewards, respond by less job work effort (Ku and Salmon (2012, p. 47)). A possible counter effect ("encouragement effect") - workers responding to inequality by working even harder - can be denied, according to the authors' study. The "discouragement"-linkage has been exposed by studies before, varying in their explanatory power (i.e. Akerlof and Yellen (1990) and the "fair wage effort hypothesis").

Brueckner and Lederman (2015) emphasize the circumstances for the inequality-productivity linkage. More precisely, there is a difference in the result, depending on the level of development of an economy. Brueckner and Lederman (2015) claim that for poor countries (low level of development) higher levels of inequality can be beneficial. Their estimates are linked to the investment and investment in human capital channels but lack of causal explanation for the positive relationship of inequality and productivity for poor economies (expressed as low GDP per capita).

Gordon's main focus is on headwinds #3-6 (#1-2 have been counted to the demand-side and are often associated with the reviving works of Larry Summers). Additionally, Gordon discusses globalisation and the ecological environment as possible bottlenecks for further (productivity) development. However, there is no explicit quantification of the effects "as the headwinds discussed above [demography, debt, inequality and education, O.Z.] are sufficient to validate the pessimistic forecasts contained in the 2012 paper" Gordon (2014, p. 15). Effects of globalisation are also channelled through the inequality-headwind and hard to be considered isolated.

A last headwind, Gordon names without further elaboration, is the medical system in the United States. There is a study for a hypothetical scenario of the US implementing a medical care system as Canada possesses. It calculates a huge bulk of resources saved, which could be used otherwise (in fact, $1 trn. is calculated by Cutler and Ly (2011) for this scenario) and additionally could raise life expectancy (Gordon (2014, p. 15)).

9.2.8 Ecological Environment (headwind #7) and Globalisation (headwind #8)

In Gordon's studies, ecological environment ("energy and environment" in the original classification in Gordon (2012)), as well as the impact of globalisation, play a neglected role[78] for the US growth path explanation. Instead, the two amplify the other headwinds in a non-stand-alone fashion (Herzog-Stein et al. (2017, p. 16)). For the present study, they shall be strived in short.

Globalisation

Globalisation in this context is mainly linked to the inequality headwind (#6) by the effects of outsourcing and offshoring. Gordon finds a negative impact for the US-middle class. A loss in international competitiveness due to a relative price-disadvantage has forced companies to shift their production abroad, resulting in a loss of job opportunities. In addition, indirect effects[79] shift the wage-level downwards, implying lower standards of living for the middle-class, the primary target of the job-loss scenario (Gordon (2012, p. 20)).

Also for Germany increased outsourcing-activities have been noted over time (Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung (2015, p. 293)), at least until 2009. A

[78] Neglected in this sense also means that the effects of globalisation seem inevitably for modern economies when the gains from technological progress shall be realised; a headwind not subject to discussion (Gordon (2012, p. 20)).

[79] Factor price adaptions in the sense of the Heckscher-Ohlin-Samuelson factor-price equalization theorem due to the import of cheap products from abroad instead of producing in the domestic economy (Gordon (2012, p. 19)).

significant part of the increase in aggregate productivity was realised due to shifting abroad the rather unproductive stages of the value creation process in the manufacturing industry. For the US and Germany likewise, the degree of vertical integration in the manufacturing industry was at around 38%[80] in 1991 and has decreased to around 31% (GER) and 34% (US). Currently, there is stagnation in the US, whereas Germany has even experienced a slight increase in the level of vertical integration (around 34% in 2014).

Outsourcing and the degree of vertical integration has a two-sided effect for an economy's development process. If companies shift unproductive jobs abroad this could, in turn, raise aggregate productivity by getting rid of unproductive tasks in the statistics as well as by increasing the level of labour division and specialization. On the other hand and with negative implications, a loss of job opportunities not only raises probability of unemployment in the respective sectors, it also raises the potential claims for social security actions, as well as the depressing effects on aggregate demand (see Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung (2015, pp. 291-298) for a discussion about outsourcing-effects on Germany with regard to the manufacturing sector).

Nevertheless, an economy has to be prepared for outsourcing-activities in a sense of reintegrating unemployed workers. It is necessary to provide possibilities of retraining and mobility - requirements for the educational system (also discussed in #4). Compared to the US, Germany provides a more flexible and better-equipped labour market policy, allowing better integration of unemployed (Herzog-Stein et al. (2017, p. 16) quoting Bothfeld et al. (2012)).

With regard to the productivity linkage, Mann (1997) explores the relationship between effects of globalisation and productivity in the United States and Germany by providing two channels, the relation flows[81] - effects from changes in demand and international competition. It is interesting to note that the results for the two countries diverge. For the US the author finds a strong link between globalisation and productivity, for Germany not. As a try for explanation, Mann (1997) suspects a difference between "being global" and "going global" (Mann (1997, Abstract)). German exposure to international trade seems to have changed less significantly in the covered time period.

[80] Levels of vertical integration are calculated as the fraction of gross value added in relation to the (total) value of production (Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung (2015, illustration p. 93)).

[81] Results and implications of this study have to be used with care as the time periods covered (1987-1995 for the US and 1981-1994 for Germany) provide a rather calm period of productivity growth.

Ecological Environment

Including "energy and environment" into the discussion reminds of the 1970s-discussion (chapter 9.1), whereas the circumstances have changed a bit. Challenges and requirements for politics to include the ecological sphere into the catalogue of macro goals have gained importance. Providing a vital ecological sphere for the people health is crucial. Within the last years and decades, more legal requirements have been introduced in many countries (Germany as a role model for this issue). Spendings for the provision of a vital ecological environment is crucial for the inhabitants but burdens and limits the government's budget. A large portion of increasing debt (headwind #5) therefore can be associated with environmental regulations (Herzog-Stein et al. (2017, p. 17)). Before setting appropriate policy actions, it is crucial to correctly measure ecological aspects with regard to productivity growth, as for national accounts, only market transactions are included. Moreover, conventional measurements and evaluations do not contain ecological damages (i.e. depletion of natural resources); just the "value of extracting or harvesting"(Forsund (2018, p. 287)). Including environmental concerns has brought up attempts like the formation of an alternative welfare indicator "green national product" (Forsund (2018, p. 291), who refers to Nyborg, K. and Aaheim, A. (1995)). As Forsund (2018) presents in his study, relying on green national product or similar indicators allows for a more comprehensive view of economic welfare, compared to standard national accounts. It is a matter of further research in this field, not only to raise accuracy in productivity measurement but also to imply more suitable policy actions.

It is, however, important to find the right balance for the amount of taxes and regulations. Rising prices for energy decrease disposable income, therefore creating a negative stimulus for aggregate demand. The cost argument is valid even more for the production-side. Taxes for ecological purposes force entrepreneurs to increase prices (with additional implications for the consumption-side) as well as to invest in modern technologies. Whereas the latter can be considered as beneficial for achieving the ecology-goal, it can have depressing effects on economic growth (Herzog-Stein et al. (2017, p. 17)).

In addition to the intuitive discussion about the direct cost argument of ecological taxes and requirements, Gordon provides another linkage. Neglecting the climate goals and requirements in the past has brought up more extreme climate conditions - an outcome, which could force insurance agencies to increase their risk premia (Gordon (2012)). As a result, companies, as well as consumers, could face additional limitations for their budgets and more uncertainty for future investment activities.

According to Bundesminsterium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (2017, pp. 50 - 59) climate policy and the change of the ecological environment has and will have significant effects for Germany in the near future. It provides potential for an increase of job opportunities (around 430.000 new job opportunities are expected until 2020 - the potential job loss in other sectors not taken into account, however).

As mentioned, globalisation and ecological environment seem to amplify other headwinds. By doing so, investment in ecological sectors not only form a healthy environment, but they also create a suitable business enviroment for the future (i.e. providing infrastructure for the efficient use of resources allows companies to produce at lower costs and hereby make Germany attractive as a location for production). Moreover, the current wave of technological change and the effects of digitalization have introduced climate aspects into an entrepreneur's calculation. It seems that international competition is also dependent on the aspect of ecology. Modern and sustainable technologies not only allow for an improvement of the ecological sphere, but they also contribute to aggregate productivity. I.e., the possibility to work together via videoconferences reduces transaction costs (time and cost of travelling), support a higher degree of work-life-balance (home offices) and reduce the impact of the ecological footprint.

An internationally known and highly effective policy action is the opportunity for loans provided by the KfW (a state-owned development bank[82]). These loans represent an investment aid for a variety of projects (usually in the field of construction), provided at low costs in terms of interest rate payments if ecological and sustainable standards are followed. In addition to the availability of state-supported loans, German government actively promotes the implementation of sustainable technologies, as described in the "digital agenda" (Bundesregierung (2017)) - and it seems they have already been successful. As a fraction of the degree of vertical integration, sustainable technologies in

[82] In original, the KfW - Kreditanstalt für Wiederaufbau (engl. Reconstruction Credit Institute) - was part of the Marshall-Plan after WWII, aiming to support economic reconstruction in Germany. See <<https://www.kfw.de/KfW-Konzern/%C3%9Cber-die-KfW/Identit%C3%A4t/Geschichte-der-KfW/KfW-Jahrzehnte/>> for further information.

Germany make up 13%, for the rest of the world only 3% (Bundesminsterium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (2017)). Even though it seems to be an impressive number, "rest of the world" is an imprecise benchmark for one of the most developed economies in the world so that its evaluation has to used with care

9.3 Mismeasurement

> "But part of the job of economics is weeding out errors. That is much harder than making them, but also more fun." (Robert Solow (1963))

9.3.1 General Notes on Mismeasurement

According to a recent study in the analysis of productivity trends, Byrne et al. (2016) have argued that the declining growth in TFP and labour productivity cannot be traced to mismeasurement problems in (IT-)service and -goods sectors, like many studies have suggested before (i.e. Brynjolfsson and McAfee (2014); Mokyr (2014)). Byrne et al. (2016) do not find a significantly (growing) relationship between IT (intensity) and economic performance in the US, an indicator for a potential source for mismeasurement. Even in contrast, US-production of IT-products has shifted to places abroad, leading to an even smaller impact of IT-production in US national accounts over the last years. Also, the authors find similar patterns in IT even prior to the productivity slowdown - a weighty argument against the theory of mismeasurement (Byrne et al. (2016, p. 2)).

Besides, Byrne et al. (2016) also reject the argument that modern technologies create additional value for consumers, which does not appear in the statistics (see also Syverson (2016) for this aspect). This and other general measurement problems cannot account for the large gap, the mismeasurement hypothesis has to explain. Their effect is simply too small (Byrne et al. (2016, p. 48); the "too small"-argument is also shared by Syverson (2016) and will be presented for the US and Germany in this study).

According to Mokyr (2014) mismeasurement in the service and information sectors is a rather natural fact. Productivity numbers and the 'traditional' measurement in statistics (i.e. provided by the Bureau of Labour Market Statistics (BLS) or the Statistisches Bundesamt) "are designed for a steel- and wheat-economy, not one in which information and data are the most dynamic sector (sic!)" (Mokyr (2014, p. 88)).

It could indicate that there is mismeasurement but related to a poor and old-fashioned measurement framework. If there is an "interplay between science and technology [which, O.Z.] creates a self-reinforcing or 'auto-catalytic' process that seems unbounded." Mokyr (2014, p. 87) but "economists are trained to look at aggregate statistics like GDP per capita and its derivatives such as factor productivity." (Mokyr (2014, p. 88)), there is no real problem with poor productivity statistics in the classical sense. As already stated in the previous chapter though, an indirect problem exists, when policy-actions are based on wrong data.

However and even before any of these measurement problems were emphasized (they must have existed earlier, as for example Griliches (1988) correctly states; the decade of the energy price problems of the 1970s offers the vast bulk of research in this field), declining trends in productivity can be identified, which were not able to be explained. As serious analyses of productivity slowdowns can be traced back (at least) to the 1970s, the current era in economic history might work as a starting point (or re-starting) for a discussion on measurement errors.

Falling numbers in productivity trends caused by measurement errors can be explained, at least partly, by emphasizing the effect of better technologies on working and non-working activities, which do not show up in the statistics. A phenomenon Robert Solow (1987) has already questioned many years before. He once famously commented in a review article of Cohen and Zysman (1987) in The New York Times in 1987: "You can see the computer age everywhere but in the productivity statistics" (Solow (1987, p. 36)). A try for explanation has been met by Sichel (1997), emphasizing the small impact factor[83] of computers as part of the capital stock on economic growth and development - an argument not tenable nowadays. Besides the "too-small" argument by Sichel (1997), David (1990) argues on the base of a "diffusion-lag" explanation, so that there is a lag between the actual invention and the time when the effects become visible (see chapter 9.2.1 for further details on this discussion).

Non-working activities' utility, more precisely non-market activities' utility, is derived from a com-

[83]More precisely, Sichel (1997) argues that the share of computer hardware in relation to the US economy's capital stock is too small. It seems highly doubtful, whether this explanation still holds for today.

bination of market products, sold at a market price, and the 'investment' of the consumer's time (Byrne et al. (2016) relating to Becker (1965)). These activities are not limited to the provision of a higher degree of consumer benefits (i.e. gaining more benefit or utility from the same amount of leisure-time). Availability of information almost everywhere and every time (i.e. due to modern information and communication technology) make consumers use their living time more efficiently in general. This also includes less waiting time for public transport, less time spending searching due to availability of modern GPS-based services and many more.

When discussing welfare effects in the context of productivity numbers, the missing link towards people's utility has to be established and explored. National accounts and any GDP-related indicators, however, do not provide information on the final utility of a person.

Cardarelli and Lusinyan (2015) argue in the same way in a study based on US-state level. Tremendous effects of superior technology have improved efficiency of consumers, using their non-market time to produce services they value. Modern communication via smartphones, to provide an example, has shifted efficiency in data availability by years, more likely by decades. Information nowadays is available '24/7' and can be shared with others immediately. Business communication via email can be executed whilst walking across the streets or riding public transport; saving up time which was spent as "non-productive" prior to the modern communication age.

The authors also reject an ICT-service-productivity-pattern (declining numbers in productivity-growth correlated to ICT-producing and ICT-using sectors). Not only do certain states in the US or only specific sectors show poor TFP-developments[84]; it is also shown, that such effects are widespread over the entire country. If the source of measurement errors were found in the ICT-industry, a statistically robust relationship between labour productivity developments and the so-called 'ICT-intensity' is required.

Syverson (2016) and the subsequent analysis on mismeasurement in this study tackles this proposition and finally rejects it. No stable (and statistically significant) relationship between labour productivity and the ICT-sector of an economy is identified. Even though there is the possibility of measurement error patterns arising in many countries simultaneously (independently from their spe-

[84] Cardarelli and Lusinyan (2015) use multifactor-productivity (MFP/TFP) as a relevant measure for productivity. For the purpose of the hypothesis and as trends of labour and MFP both decrease, the statement can be transferred.

cific ICT-intensity), this makes the validity of the mismeasurement hypothesis less likely, however.

Cardarelli and Lusinyan (2015) argue that TFP-decline in the US indeed reflects a true loss of efficiency and/or market dynamism over the last two decades. If ICT-impact were to account for the missing portion in national accounts, then this pattern should appear in more countries. Their conclusion draws a rather dark picture of the (US) economy, as declining efficiency is ultimately linked to international competitiveness and finally less welfare for the US economy.

However, data and a bulk of studies show that there is no significant relationship between a countries' ICT-sector and the decrease in productivity trends (see Syverson (2016), Cardarelli and Lusinyan (2015), Byrne et al. (2016), Mas and Stehrer (2012), Connolly and Gustafsson (2013), Pessoa and Van Reenen (2014) for example, who provide studies on the ICT- and productivity relationship in other countries).

Syverson (2016) instead uses labour productivity as the relevant measure for productivity but also dismisses mismeasurement as an explanation for the slowdown. Addressing to the mismeasurement-hypothesis, the author provides four reasons (patterns) not to believe in mismeasurement causing decreasing productivity in the statistics. As a side note on his study, he also shows that there is no significant relationship between the size of an economy's ICT-sector and productivity trends.

9.3.2 Price Effects, Real Values and Hedonic Price Indexes

Another category, offering potential for measurement errors, is price deflation of (nominal) variables in national accounts. In order to set up indexes (i.e. the consumer price index (CPI)) various methods for the calculation are available. Commonly, price indexes are set up according to a Laspeyres-, Paasche- or Tornqvist-Index.

In order to calculate an index, the mathematical product of price and quantity is taken. Depending on the base year chosen, the results vary - more precisely, the weights, which make up the quantity. The Laspeyres-Index chooses the weights from a base period, whereas the Paasche-Index makes use of the current period (Goodridge (2007)). The CPI calculated accordingly is:

Laspeyres-Index:

$$CPI^L = \frac{\sum_i P_{it}Q_{i0}}{\sum_i P_{i0}Q_{i0}} \tag{13}$$

Paasche-Index:

$$CPI^P = \frac{\sum_i P_{it}Q_{it}}{\sum_i P_{i0}Q_{it}} \tag{14}$$

Both indexes take the sum of all products $i = 1, ..., n$ (price P times quantity Q) of period 0 and t (i.e. the price of the base period 0 is P_{i0}).

An alternative possibility is provided by so-called Tornqvist-Indexes, often used for long historic time-series. The main property of the Tornqvist-Index is that its weights are calculated as averages from the current and base period (Goodridge (2007, p. 56)). The respective Tornqvist-Index, which is calculated geometrically instead of arithmetically then becomes:

Tornqvist-Index:

$$I_{0t}^T = \prod \frac{P_{it}}{P_{i0}}^{(\frac{w_{it}+w_{i0}}{2})} \tag{15}$$

with weight w expressed as $w_{it} = \frac{P_{it}Q_{it}}{\sum P_{it}Q_{it}}$

Also, Tornqvist-Indexes avoid 'time-reversal'-problems and the allowance for the weights to change (Goodridge (2007, p. 57)). A Tornqvist-Index also is not subject to the so-called "item substitution-bias". If, for example, prices for goods with a high weight increase and goods with a low weight remain constant, a substitution in the consumer's demand behaviour would lead to an overestimation (under-estimation) of the price level, if a Laspeyres-Index (Paasche-Index) would be in use. Put differently, a Tornqvist-Index restrains from changes in the consumption behaviour due to a change in the relative price system (Neves and Sarmento (1997, p. 27)).

Price deflation of national products and implications on the change in prices regarding the standards of living is then executed by converting nominal values into real values by making use of an index like the CPI. Many goods and services, however, provide significant obstacles in the measurement process (i.e. Griliches (1988, pp. 17-19), Fixler et al. (1999, p. 2)). In order to capture quality effects in the national accounts in an accurate way, an alternative measurement possibility is provided by the so-called hedonic price indexes - more precisely by the hedonic correction for quality changes. Put differently, hedonic price correction separates for the individual properties of a good and "view[s] products as bundles of characteristics" (Baltas and Freeman (2001, p. 601)). A hedonic price index (correction) therefore not only displays the actual change in the price level but also lays out the effects arising from technological progress (Fixler et al. (1999, p. 3)).

One of the pioneering studies with regard to quality correction is provided by Chwelos (2000). The author measures the change in costs of a computer by separating for its main properties (Chwelos (2000, pp. 43-46), i.e. computer performance, compatibility, RAM or network connectivity). As properties change and comparison over longer time horizon offers weaknesses, other studies (i.e. Nordhaus (2007)) focus on a single task of computing (in his study: computer performance) and its development over time.

According to the Statistisches Bundesamt, it is crucial to correct for quality changes in price indices, as otherwise, a liable interpretation of the prices is not possible (see Statistisches Bundesamt (2019c) for an explanation of the construction of (consumer) price indexes). The method has a long-lasting history, going back at least to the 1960s. Examples here include Griliches (1961) for an application of the hedonic price method on automobiles, the study of Moulton (2001), the implementation of an entire research area for hedonic price measurement at the Zentrum für Europäische Wirtschaftsforschung (ZEW) [85] or works even going back to the beginning of the 20th century (i.e. Waugh (1928)). Griliches (1961) also emphasized the problem of changing properties of goods over time: "The common notion of quality change relates to the fact that many commodities are changing over time and that often it is impossible to construct appropriate pricing comparisons because the same varieties are not available at different times and in different places." (Griliches (1987, p. 4)).

After having dismantled a good into its properties or tasks, a regression analysis is executed in order to measure the respective influence of the properties on the price. The result is a separation for quality-induced price effects on the one hand and pure price effects (Linz and Eckert (2002)) on the other hand. Please note that quality-induced price-effects also include the 'simple' change (quality-

[85] <<https://www.zew.de/forschung/european-hedonic-centre/>>.

neutral) of the good's properties (in this context Fixler et al. (1999, p. 2) names it the 'new goods problem'). A picturesque example of a change of the characteristics of a good over time and the problem associated with the price measurement is given by Linz and Eckert (2002). Over time, air conditioning in cars has become standard equipment. If prices of cars shall be measured, this can lead to biased results, as before air conditioning was not an essential part of a car - it was an additional one, subject to an 'extra-fee'.

Without correcting for the change of the properties, one would clearly compare heterogeneous goods, implying false conclusions on prices (Linz and Eckert (2002, p. 859 f.)). In addition to the description of changing products (or product properties), Fixler et al. (1999, p. 2) names three ways how products can change and exhibit problems regarding quality measurement. Products can either change regarding their characteristics (see the air condition example), new products can pop up and provide the same functions but perform in another way or completely new products arrive, which fulfil latent consumer needs (increasing the "value of variety" for a consumer).

For the purpose of the present study, hedonic price correction might offer potential for the missing gap in output and therefore productivity. Real output values, representing the quantitative change in the production, are obtained by deflating nominal values with a price index. If prices decrease or grow slower, the results would show higher growth rates for real output values. Assuming that prices for goods, which are subject to rapid technological change, are overestimated, this could account for a missing portion in the productivity statistics (Linz and Eckert (2004, p. 688 f.)). Correcting for (quality) changes is crucial, as from the consumer's view they do matter for economic welfare and would be underestimated otherwise. In addition, any price increase could be indicated as a rise in quality if not corrected for the quality-effect (Statistisches Bundesamt (2013, p. 2)).

In line with the general argument of wrong measurement in national accounts, correction for quality-effects can exhibit explanatory power for a missing gap in the productivity statistics. Statistisches Bundesamt (2013), however, admits that the potential for Germany has to be considered as rather small (i.e. around 0.1 percentage point for the consumer price index on yearly average for 2005-2010). In the US, there has been an increase in national products; for Germany, however, also Linz and Eckert (2004) do not expect significant changes.

In Germany, the Statistisches Bundesamt has introduced hedonic price correction with the beginning of the 21st century. Before, there have already existed similar methods to correct for quality changes (i.e. the so-called Matched-Model-Index Method). For a comparison between the matched model-index and the hedonic price index please see Kim and Reinsdorf (2015) and Chwelos (2000, especially pp. 30-32). Matched model indexes do not use a hedonic form and only seem applicable, when the price change of the goods in the market equal the price change of the goods leaving the market (i.e. so-called "discontinued goods", due to innovation), substituted by new goods, which have not existed in the previous period (Chwelos (2000, p. 31)).

However and quoting Erickson and Pakes (2011), Kim and Reinsdorf (2015, p. 296) state that price effects arising from technological or quality change tend to be higher than price effects arising from product replacements. The former can be measured by Hedonic-Price-Indexes, the latter displayed by matched model indexes. In contrast, other studies provide similar trends for both methods (i.e. see Doms et al. (2003), who are in line with Chwelos (2000) and show that when the matched model index faces low entries and exits - the relation between discontinued and new goods - , the results are similar to hedonic measurement approaches). A central concern for hedonic price indexes is the (sometimes) limited possibility to separate for the individual components of a product (Kim and Reinsdorf (2015, p. 323)). Another possibility to account for a swap in products (when a product or item disappears) is to take a substitute into account (Fixler et al. (1999, p. 5)). Substitutes have to be chosen with care as they still might offer potential for over- or underestimation - they are a proxy to the original good at best with regard to price measurement.

Currently, in Germany, the prices of a hand full of goods are corrected with the hedonic price index method, including personal computers, printers, hard disks, notebooks, processors, RAM, servers, used cars and residential properties (Statistisches Bundesamt (2013, p. 2)). The reason for inclusion is that these goods show rapid changes (in technology or quality) over time. For the calculation of certain price indexes, a specific fraction of goods then are subject to the adjustment for quality changes; depending on the index, this fraction varies (i.e. the consumer price index only contains around 1% of corrected goods, the housing price index in contrast contains 100%) (Statistisches Bundesamt (2013)). For the US' CPI currently there is hedonic price correction for apparel, televisions, computers and housing

(Fixler et al. (1999, pp. 6-12)).

A study by Nordhaus (2007) provides a performance-based approach. Instead of focusing on the components of a product, the study analyses the change in the tasks of goods. In order to separate for the price- and property-changes of a good (property here represented by performance as measured in computations of certain tasks per second), it would be an ideal method to have data for both. Computer performance (the task and main object of the author's study) could ideally be calculated as a standard Tornqvist-Index with a bundle of (changing) tasks (i.e. mathematical addition, flight simulation or internet access. See Nordhaus (2007, p. 135)) multiplied with their respective price behaviour. It seems, however, not as a realistic project due to data shortcomings. Tasks change over time so that instead the author measures "computer power as the number of times that a given bundle of computations can be performed in a given time; and the cost of computation as the cost of performing the benchmark tasks" (Nordhaus (2007, p. 135)). His purpose is to provide a time series for computer performance over time for a long time horizon (from around 1850 to present)[86].

The author finds an enormous increase in computer performance from manual calculating up to present. Depending on the variable chosen, performance has increased by a factor of in between 2 mil. to 73 mil., so did average annual growth rates between 18% and 21%. The measures provided are computer power (calculated in millions of computations per second (MCPS)), price per calculation (MCPS in 2003-$) and labour cost of computation (MCPS per hour worked).

For the purpose of productivity analyses, especially the price per calculation, as well as the performance index, seem important. Nordhaus (2007) finds an improvement in pure computer performance over time. Especially after WWII there is a sharp increase. Total increase from 1850 to 2006 is at around a factor of 2 trillion. For the cost per computation, a sharp decline is stated by a factor of around 7 trillion. Improved computer performance and a decrease in prices (in relation to labour costs) have not only led to a higher degree of computer utilisation; it also offers potential for a "correction" of productivity statistics.

[86] In addition to shortcomings of his method compared to the ideal approach, Nordhaus (2007) also admits that the missing incorporation of the change in complementary inputs is a problem due to being solved, as distortion in output and productivity statistics might arise from the change of complementary inputs, too. The change in complementary facilities has already been discussed in this section (see also Fixler et al. (1999) for further details).

9.3.3 The Mismeasurement Approach of Syverson

Syverson (2016)[87] explicitly asks for a general separation between 'real' economic causes and a 'simple' mismeasurement issue. His interpretation of the mismeasurement hypothesis is, that the gains from new and better products (in the sense of technological progress) are not reflected in the productivity statistics - however, these gains are present and create utility for the consumption side, for the person's utility respectively. More precisely, these gains are not reflected in prices, so that technologies, created from 2004 onwards (almost anything related to ICT-innovations, such as social media, smartphones or the general use of internet-services like Google) create utility for the user's welfare, but are available at (almost) zero costs (Syverson (2016, p. 2) and Mokyr (2014, p. 88)). If there is additional incremental value, which is not reflected in the statistics, this must raise GDP and GDP per capita ceteris paribus.

The additional gains in output in Syverson's analysis, which have to be explained by the mismeasurement hypothesis, are represented and calculated by a so-called 'counterfactual' scenario (Y_C; the amount of output 'lost' due to the productivity slowdown). Syverson's counterfactual scenario states that \$2.7 trn. of additional incremental value is not reflected in the statistics of the United States [88] - the amount, that has to be explained by insufficient measurement. The author provides four challenges (patterns), the validity of the hypothesis faces. In other words, four obstacles challenge the hypothesis and raise doubts on its informative and explanatory content. Other studies support this amount of the calculation of the counterfactual scenario (i.e. Byrne et al. (2016), who calculate \$3 trn. in a similar study). Syverson's results also show, that although poor measurement cannot be ruled out, its impact (the effect of the combined weight of all four patterns),

> "makes clear, that the intuitive and plausible empirical case for the mismeasurement hypothesis faces a higher bar in the data [in order to] to account for a substantial portion of the measured output lost to the productivity slowdown" (Syverson (2016, p. 19)).

He concludes that even though measurement problems might exist, the shrinking numbers in the

[87] As already indicated, for the current study, the working paper version Syverson (2016) was used (published later as Syverson (2017) with some minor modifications).

[88] In fact, Syverson (2016) creates a range of a minimum of \$2.4 bn. and \$3.5 trn., so that the \$2.7 bn. are considered as rather conservative and in a sense of in favour of the validity of the hypothesis.

productivity statistics imply a 'real' economic/productivity slowdown (Syverson (2016, p. 19 f.)) and therefore shares the view of the "true loss in efficiency"-hypothesis (i.e. see Cardarelli and Lusinyan (2015)).

The first out of the four patterns, Syverson's mismeasurement-hypothesis faces, is referred to the ICT-intensity of a country and a general country-by-country comparison. Information and communication technology (ICT), more precisely the ICT-intensity of a country, is often blamed for the majority of a countries' measurement problems, as services generally are subject to mismeasurement - compared to 'physical' goods of the manufacturing sector (i.e. see Hartwig and Krämer (2017)).

Following other studies (Syverson (2016) quotes Mas and Stehrer (2012) for Europe, Connolly and Gustafsson (2013) for Australia, Pessoa and Van Reenen (2014) and Haskel et al. (2015) for the UK), the author finds, that a slowdown has occurred in other countries as well (all of them having different degrees of ICT-intensity). The possibility of measurement errors in all countries similarily exists, a missing (strong) correlation between the ICT-intensity and amount of the slowdown makes is less likely though (the author hereby follows the results of Cardarelli and Lusinyan (2015)). Connecting ICT and productivity reminds of the discussion of the 1970s and the debate on whether declining R&D has caused the 1970s-slowdown (i.e. see Griliches (1988, pp. 13-15) as well as chapter 9.2.1 of the present study).

The second pattern is attributed to the consumer surplus of internet-linked technologies (consumption side). By using broadband internet access as the relevant proxy, the author presents his calculation in the course of other studies. They all have in common, that they contain additional utility from 'unpriced' technologies (i.e. internet, social media platforms, Google). The results range from \$17 bn. (Greenstein and McDevitt (2009)) up to \$132 bn. (Nevo et al. (2015)) of potential additional value, which can be considered as ridiculously small compared to the missing gap of \$2.7 trn. of US-American output (as calculated in the counterfactual scenario and which is already very much in favour of the validity of the mismeasurement-hypothesis).

Syverson (2016) himself follows an approach of Goolsbee and Klenow (2006), who evaluate the time people spend online as their relevant indicator. By fixing leisure time with the average US-after-tax wage of \$21.90 they calculate the gap, the indicator has to close. The result is an amount of \$842 bn.

and still stands for roughly a third of what needs to be explained ($2.7 trn.).

The third pattern concerns the industries, which provide the incremental output related to ICT-technologies (production side). More precisely, the amount of real value added (and revenues as second potential calculation method) of these industries considered has to be a multiple times higher, if the measurement hypothesis can be made responsible for the missing output in the productivity statistics. In more detail, the author finds that the incremental real value added must be five times higher and industry-wide productivity must have risen by 363% over around one decade (Syverson (2016, p. 3)). A result the author correctly doubts on, as its values are simply too high to believe.

The fourth pattern compares time-series of gross domestic product (GDP) and gross domestic income (GDI). A 0.4%-gap p.a. in relation to GDP has grown over the last two decades between the two numbers (GDI outperforming GDP). If incomes have risen at a faster pace than products' prices, this could confirm the hypothesis of the 'products given away for a smaller price or even for free'-argument (compared to the costs of production). In the context of the mismeasurement hypothesis, it could suggest evidence that the growing gap between the two series reflects the missing data. The author, however, rejects evidence in this case, too. By comparing the labour income share with gross operating surplus, Syverson finds, that the GDI gains are not related to missing data but growing capital income (reflecting a structural change in the national income situation in the US). All the four patterns shall be explained in more detail in course of the evaluation of and application on the German case.

Providing four reasons not to believe in mismeasurement, the author comes to the conclusion that the declining numbers in the productivity statistics reflect a true economic problem and not a measurement one. The drop in productivity then correctly represents a true loss in efficiency and/or as a result of poor economic circumstances - a result in favour of real economic causes and hereby promoting the importance of the "headwinds"-discussion of chapter 9.2.

In the remainder of this part, Syverson's calculatory base and findings are accepted and applied on Germany by connecting German data with the Syverson (2016)-study and its underlying measurement methodology.

10 Applying the Syverson - Approach on Germany

Syverson (2016) has delivered an analysis for the US, challenging the mismeasurement hypothesis and the argument, that the current productivity slowdown is mainly illusory. This section applies his calculations on Germany and therefore asks, if the developments in the German productivity statistics can be traced to mismeasurement or whether other (real) explanations have to be considered.

In order to have the same (at least close to the same) conditions and assumptions as provided in Syverson (2016), I make use of data from the Statistisches Bundesamt Germany[89] and the OECD [90] for international comparisons for the same time-intervals, except the non-used post-WWII-intervals from 1947 to 1994 due to a lack of availability. Also, any German data before 1991 has to be treated by a certain amount of care. The German Reunification process has clearly led to structural changes in the economy, implying potential biases in the statistics. A separation between the two intervals (1991-2004 and 2005-2015) is taken, because an inflexion point in the growth process of global productivity indicators is identified at the end of 2004 (Syverson (2016) quoting Byrne et al. (2013)). Applying the same time intervals makes sense here to have the same conditions as in the base study (Syverson (2016)).

In order to have the highest degree of independence in the data set, I make use of the original values, not being subject to seasonal or business cycle adjustments (hereby following the Statistisches Bundesamt, which admits, that any adjustment (might) distort(s) the original values and conceivably biases the statistic's message, i.e. see Statistisches Bundesamt (2015b, p. 15)). With regard to the discussion on which denominator to take (8.2), I also make use of the per hour worked approach, in order to adjust for potential changes in the average working day and other developments on the labour markets. Also, and in contrast to Syverson, I use annual labour productivity data instead of quarterly data due to better availability (data source: Statistisches Bundesamt (2015c)).

[89] <<www.destatis.de>>

[90] <<http://stats.oecd.org/>>

Calculating the Missing Output

Following the method of Syverson (2016), at first, the missing output of the German economy has to be calculated. Hereby the following steps are executed:

1. Taking annual labour productivity growth for the calculation of the time intervals 1995-2004 and 2005 to 2015 from (Statistisches Bundesamt (2015c)).

2. Deriving the 'drop' between the two intervals out of step 1.

3. Calculating the 'counterfactual' output according to

$$Y_c = Y_a(1 * drop)^q \tag{16}$$

   where Y_c represents counterfactual output, Y_a represents actual output, q represents the number of periods (here: years) used and 'drop', which simply stands for the difference in average annual labour productivity growth between the two intervals, as calculated in step 2.

4. Adjusting current annual GDP by the percentage value resulting from step 3.

5. The missing portion of output calculated in the previous four steps can then be interpreted as aggregate value, as per capita value or on a household level.

Germany

The results for Germany are displayed in the illustration 10 for convenience, their calculations and explanations can be found below.

Figure 35: Overview of missing output calculations for Germany

	Per person employed, whole economy	Per person employed, producing sector	Per hour worked, whole economy	Per hour worked, producing sector
Drop in average annual labour productivity [%]	-1.111	-0.7578	-0.71169	-0.89935
Missing output in 2015 [bn.€]	391.96	262.61	246.05	313.90

Even the calculation variant in most favour of the validity of the mismeasurement hypothesis calculates a missing portion of output of €246.05 bn. for Germany. In short, the calculations for the measurement per person employed and per hour worked are provided - both variants calculated on the base of the entire economy and on the production sector only.

I. Per Person Employed

1. Producing Sector For the interval 1991-2004 (Q4) the average annual growth rate of labour productivity in the producing sector[91], calculated as per person employed is 2.32143% and for the interval 2005-2015 (Q4) it is 1.56363%. These values imply a drop of -0.7578% on average each year. In the next step, I calculate the counterfactual output, which has to be explained by mismeasurement.

First, I derive the percentage of the lack in growth:

$Y_c = Y_a(1.007578)^{11} = Y_a * 1.08659 \Rightarrow 8.659\%$

By taking the actual annualized value of nominal GDP in 2015 and adjusting it by the percentage value, this yields:

$Y_c = Y_a * 8.659\% = €3032.82bn. * 1.08659 = €3295.43bn.$

The 'missing' gap, therefore, is $€262.61bn.$ $(= €3295.43bn. - €3032.82bn. = Y_c - Y_a)$.

2. Whole Economy For the whole economy average annual labour productivity, measured as per person employed, is 1.99286% (1991-2004) and 0.88182% (2005-2015), implying a drop of -1.11104%. This yields a lack in the growth process of:

$Y_c = Y_a(1.0111104)^{11} = Y_a * 1.12924 \Rightarrow 12.924\%$

The missing output then is calculated in the same way as above:

$Y_c = Y_a * 12.924\% = €3032.82bn. * 1.12924 = €3424.78bn.$

The 'missing' gap then is $€391.96bn.$ $(= €3424.78bn. - €3032.82bn. = Y_c - Y_a)$.

[91] Producing sector excludes farming and services.

II. Per Hour Worked

1. Producing sector As discussed above, the per hour worked approach usually is more robust against developments on labour markets and shall be provided therefore, too.

For the interval 1991-2004 (Q4) the average annual growth rate of labour productivity, calculated as per hour worked is 2.53571% and for the interval 2005-2015 (Q4) it is 1.63636%. These values imply a drop of -0.89935% on average each year. In the next step, I calculate the counterfactual output, which has to be explained by mismeasurement.

First, I derive the percentage of the lack in growth:

$Y_c = Y_a(1.0089935)^{11} = Y_a * 1.1035 \Rightarrow 10.35\%$

By taking the actual annualized value of nominal GDP in 2015 and adjusting it by the percentage value, this yields:

$Y_c = Y_a * 10.35\% = €3032.82bn. * 1.1035 = €3346.72bn.$

The 'missing' gap then is $€313.90bn.$ ($= €3346.72bn. - €3032.82bn. = Y_c - Y_a$).

2. Whole Economy For the whole economy, average annual labour productivity measured as per hour worked is 1.25714% (1991-2004) and 0.54545% (2005-2015), implying an average drop of -0.71169% per year. This yields a lack in the process:

$Y_c = Y_a(1.0071169)^{11} = Y_a * 1.08113 \Rightarrow 8.113\%$

The missing output then is calculated in the same way as above:

$Y_c = Y_a * 8.113\% = €3032.82bn. * 1.08113 = €3278.87bn.$

The 'missing' gap, therefore, is $€246.05bn.$ ($= €3278.87bn. - €3032.82bn. = Y_c - Y_a$).

In 2015 Germany has consisted of 40 774 thsd. households (approx. 40.7 mil.) (Statistisches Bundesamt (2017c)) and a population of around 82.2 million (Statistisches Bundesamt (2017c) Code: 12411-0001).

Before proceeding and discussing the gap in output, there is an important point to note. German consumers have benefited from this missing output, which is not reflected in the data. The additional value of missing output does not represent consumer surplus. GDP measures and values products (and services) at their respective market prices. Consumer surplus is the willingness to pay for prices above any market price. The 'lost' or 'missing' output, calculated by the comparison between the two intervals does not capture additional consumer surplus. It measures the (possibly) missing benefit over and above any market price + consumer surplus, not captured or included in any kind of calculation Syverson (2016, p. 6).

Several results for the gap are likely as calculated above (see table 10). In favour of the plausibility of the mismeasurement hypothesis, I use the lower bound of the results, implying a €246.05bn. gap in 2015. This makes an additional value of €6034 per household and around €3000 per person (based on the entire population) over and above market price and consumer surplus, the hypothesis needs to explain. It is the "incremental and unmeasured value above and beyond any consumer surplus that already existed in goods and services present in 2004 and was brought forward to 2015" (Syverson (2016, p. 7)).

After having calculated the missing portion in output, the four obstacles (patterns) for the validity of the mismeasurement hypothesis shall be checked for Germany.

10.1 Labour Productivity Drop and ICT-Intensity (Pattern 1)

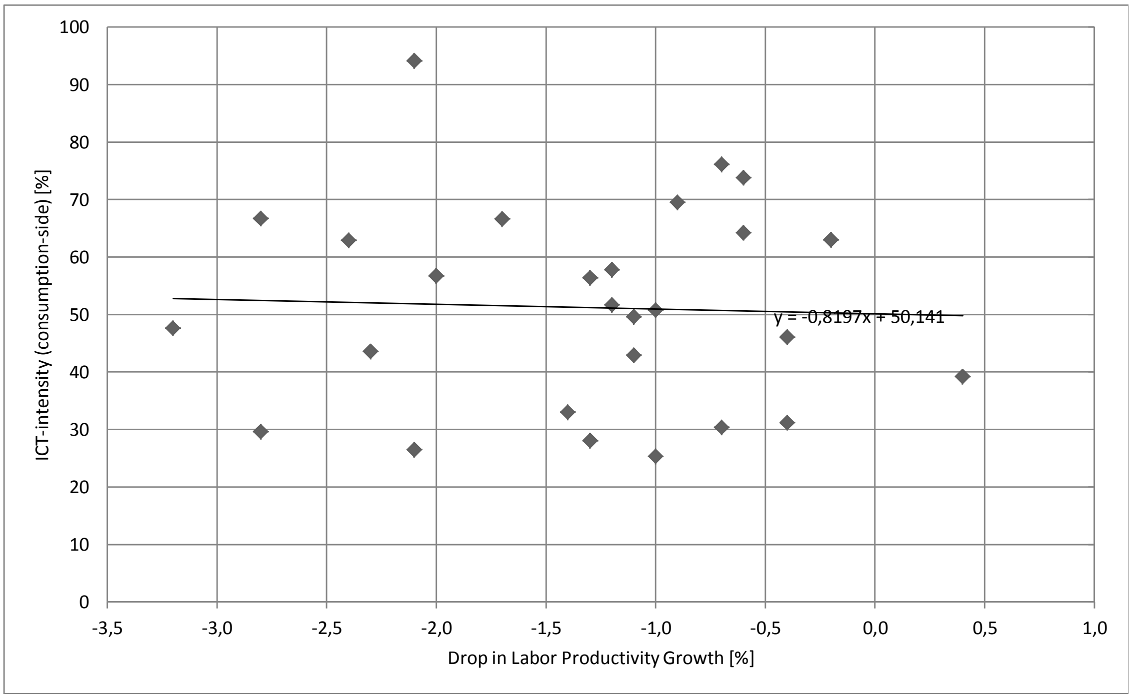
For the first pattern, values of labour productivity and ICT-intensity of several countries are considered. More precisely, it is examined whether there is a link (more precisely a correlation) between the development in labour productivity and the dependency of a country's national product on ICT. Information and technology sectors are often blamed for poor measurement, as already discussed in chapters 9.1 and 9. Even more, it is of popular opinion to believe that structural changes, leading to a higher focus on services and modern technologies, represent a key challenge for measuring wealth (i.e. see Mokyr (2014, p. 88), who asks for a more appropriate framework to quantify 'modern' technologies and services; the 'classical' framework, still used in the national accounts, infers problems when it comes to the quantification of modern developments).

Nevertheless, and even by using the 'classical' measurement framework, the relationship between the trend in labour productivity and ICT-intensity can be set up. Making use of the same procedure as in the base-study of Syverson (2016), I first take a look on the trend in labour productivity by using data from the OECD and indicators for the ICT-profile of an economy. Contrary to Syverson's study (24), I find 27 countries, which show a sufficient data set. The data set includes multiple years of measured and reported labour productivity growth from 1991 onwards until 2015 and data for the ICT-intensity of the respective countries considered. The extent, an economy is 'dependent' on ICT can either be measured and interpreted from the production- or consumption side.

Production-side measured ICT-intensity here is calculated as the share of the country's value added accounted for ICT-related industries, whereas consumption-side ICT-intensity is measured as the fraction of a country's households, equipped with broadband internet access (which is merely a proxy-solution). Labour productivity in this scenario is measured as ratio of GDP per hour worked (in constant prices). The magnitude of the (potential) slowdown of the countries then is measured as provided above (see chapter 10), by calculating the 'drop' between two intervals of time (1991-2004 vs. 2005-2015). It seems noteworthy, that for some countries data was not available for all the years of the first interval (1991-2004). These (average) growth rates then base on less values but should not distort the overall results (trends). A more detailed calculation and the respective data can be found in appendix V.

Figure 36 depicts the result from the calculation for the consumption-side, figure 37 for the production-side respectively.

Figure 36: Labour Productivity vs. ICT-intensity (consumption-side). Source: OECD Database (2014, 2017); own calculations and illustration.



Without going into detail, the first intuition from figure 36 is that a relationship between the magnitude of the slowdown and their broadband coverage percentage does not exist. All 27 countries, by the exception of Spain, show a drop in (average) labour productivity growth. Spain's labour productivity growth has risen from 0.8% (1991-2004) to 1.2% (2005-2015) on average each year. The largest losses in this calculation are reported for Estonia (-3.2%), Norway (-2.8%) and Poland (-2.8%), the most decent ones for Switzerland (-0.2%), Ireland (-0.4%) and Austria (-0.4%), and of course Spain as an outlier. Note that Greece, commonly taken as an example for rather poor economic development in the latest past (drop of -2.7%), was excluded from this calculation, as it lacks of data for the production side.

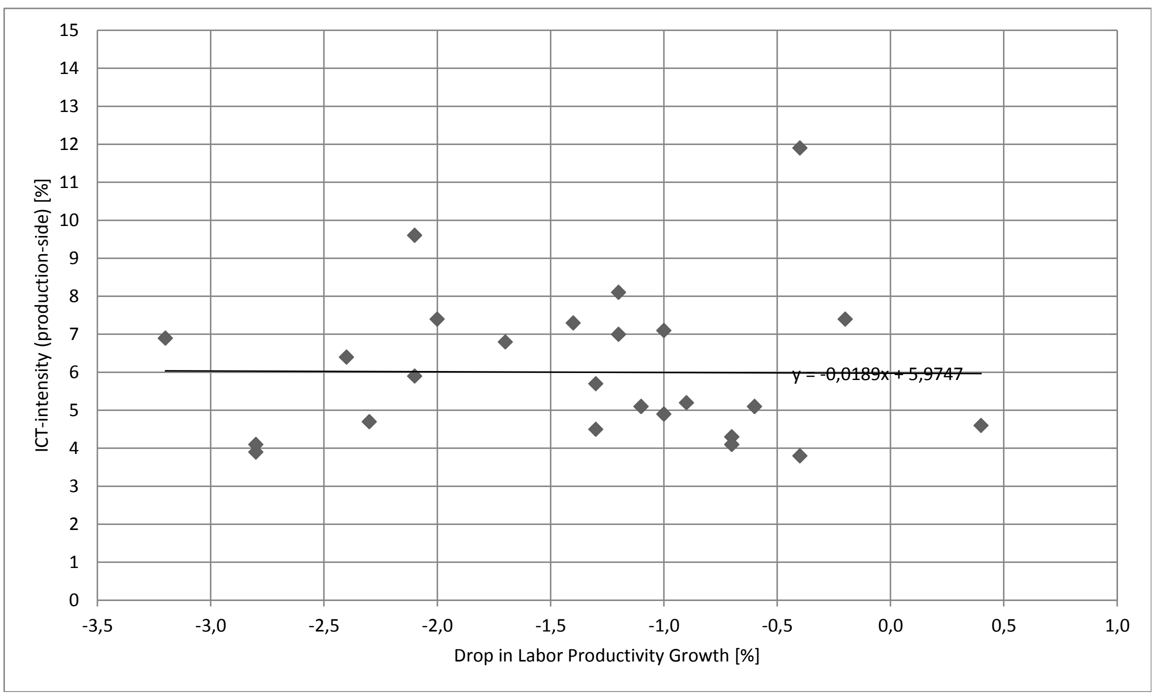
Values for broadband coverage among the countries included in this sample range from 94.1% (Korea) to 25.3% (Italy). Germany's value was 49.6%. All values are from 2011 and might have changed significantly meanwhile (i.e. as discussed in 10.2, in 2015 Germany has reported around 82%

broadband penetration). Due to the problem of simultaneous availability of data for all countries and years, 2011 was the only year possible to be taken as a reference scenario.

Covariance for the consumption-side measurement is -0.6097, the coefficient on correlation -0.0409. As the covariance provides a statement on the direction between two variables' relationship, the negative covariance indicates an inverse relationship between labour productivity drop and broadband penetration and implies positive importance for labour productivity growth of a country. However and a bit surprising, as the correlation coefficient is rather low, this indicates a weak relationship (an interpretation in a sense of 'no relationship' seems reasonable, too).

Figure 37 then provides data for the production-side measurement, with ICT as the share of a country's value added for ICT-related industries.

Figure 37: Labour Productivity vs. ICT-intensity (production-side). Source: OECD Database (2014); OECD Statistics (2019); own calculations and illustration.



For the production side a similar result can be obtained. No stable relationship is identified at first glance. The share of ICT in an economy (production-side), measured as value added in national accounts, has a smaller standard deviation, however, compared to the share of households with broadband internet access (consumption-side), which implies less mean variation. Ireland (11.9%), Korea (9.6%) and Japan (8.1%) can be considered as 'ITC-heavy', whereas Norway (3.9%), Iceland (4.3%) and Austria (3.8%) as rather 'ICT-light'. Germany provides a value of 5.1%. Covariance for the production-side is -0.0141, correlation coefficient -0.0088. Like adopted for the consumption-side, also the production-side analysis shows a negative covariance (inverse relationship between labour productivity drop and share of ICT, relative to the economy's GDP). As the coefficient on correlation is also close to zero, a relationship between the two variables can be rejected.

Pattern 1 works on the connection between the information and technology sector and the development in labour productivity of several countries. If a relationship between the two variables exists, one could argue in favour of the mismeasurement hypothesis, as ICT-sectors are often identified as having issues providing correct measures in terms of national accounts. As there is no stable relationship, however, (possible) poor measurement in these sectors are not the reason for the productivity slowdown. No pattern could have been identified, making ICT-sectors unlikely as a source for potential mismeasurement.

10.2 Consumer Surplus of the Internet (Pattern 2)

The second pattern concerns the large consumer surplus of the internet (or more broadly speaking: the surplus of internet-linked technologies). It shares the belief that modern technologies require (broadband) internet access to fully exploit their entire utility (i.e. Greenstein and McDevitt (2009), Rosston et al. (2010), Goolsbee and Klenow (2006)). Broadband coverage works as an excellent proxy, therefore. Unmeasured surplus for the consumption side hereby exceeds expenditures and might lead to an understatement in the productivity statistics. In order to derive implications from this connection, unmeasured surplus has to to be calculated or at least estimated.

Syverson (2016) follows the approach of Goolsbee and Klenow (2006), who take 'time people spend online' as the indicator for “full expenditure” (Syverson (2016, p. 11)) and define[92]:

$$\text{Total Utility of a Good} = \text{Financial Expenditure} + \text{Consumption Time}$$

Goolsbee and Klenow (2006) conclude that internet-related surplus now made visible could represent around 3% of total income, creating additional $3000 per person. Total income per definition, in this case, is the sum of disposable income and the (estimated) value of leisure time. Syverson exceeds the 'value-of-time'-analysis (Syverson (2016, p. 12)) by evaluating and measuring leisure time more accurately. A total of $86.300 of annual value of leisure time per person is calculated as average after US tax wage in 2015, which is $21.90. Then times the daily non-working-related time according to the American Time Use Survey[93], which is 10.8h, multiplied by 365 days makes up average annual leisure time per person.

Full income per person then is $42.100 (disposable income) plus the added value of leisure time ($86.300), resulting in $128.400. Broadly speaking, it is the amount, which captures and values the living time for an average person in the United States in 2015. As assumed in Goolsbee and Klenow (2006), a surplus of around 3% of full income can be traced to broadband internet access. Equivalently, this is $3.850 per-person in 2015. In the last step, Syverson estimates the aggregate effect for the entire economy by multiplying with population data.

Adjusting the calculation by 80% (for 2015; and 12% in 2004) due to broadband internet coverage/availability in the US, the author finds an incremental, additional surplus from internet-linked technologies of around $990 bn. (2015) and $842 bn. in 2004 (less broadband coverage) for the entire US economy. Compared to the missing gap/missing output calculated ($2.7 trn., Syverson (2016, pp. 4-6)) the additional surplus created by the internet only yields for around one third. Missing gains from internet access cannot account for the entire explanatory power of the mismeasurement hypothesis. Its impact is simply too small.

Applying the calculation on Germany yields similar results. In order to value leisure time, I also

[92] An extensive overview of various studies, dealing with the internet-linked technology-connection can be found in Syverson (2016, 9-12).

[93] The American Time Use Survey (ATUS) is measured by the American Bureau of Labour Statistics <<https://www.bls.gov/tus/>>.

take the average after-tax wage for the entire economy[94]. The after-tax wage in my calculation is defined as the sum of aggregate labour income (net value, after taxes) divided by the total volume of working hours in Germany. To have a common base with Syverson, for 2004 an average after-tax wage of €13.42 per hour and for 2015 of €16.60 per hour is the result. Note that the total volume worked includes full-time-, part-time- and also side-jobs (see Statistisches Bundesamt (2015a) and Institut für Arbeitsmarkt- und Berufsforschung (2016) for the data) - a definition, that clearly offers potential for discussion.

To evaluate leisure time per person and year I apply the 10.8 hours, a person on average does not spend working per day (Syverson (2016, p. 12)). It yields a value of leisure time of €52.900 per person and year (2004) and respectively €65.400 per person and year in 2015[95].

Total income can then be defined in different ways, depending on which income the calculation is related to. In national accounts, personal income is defined as the sum of labour income and capital income. Disposable income is defined as personal income minus taxes ('after-tax income'). As I have calculated leisure time by using the after-tax wage rate, I also make use of the after-tax variable when it comes to income. Total income in Germany, as already indicated above (see the 'original' calculation by Syverson), the sum of disposable income and the value of leisure time per person is €70.400 (2004) and €87.000 in 2015 (data for disposable income for Germany can be found in Statistisches Bundesamt (2016)).

According to the data, Germany's population in 2004 and 2015 has been 82.5 mil. and 82.2 mil. respectively (Statistisches Bundesamt (2017c), Code: 12411-0001). Taking total income per-person, I adjust it by the 3% 'impact factor' of the internet (as estimated in Goolsbee and Klenow (2006) and also used by Syverson (2016)) and multiply it by the number of inhabitants of the two years.

In a final step, the estimated broadband coverage has to be taken into account. In 2004 around 18% of households in Germany had access to broadband internet, according to the OECD Database

[94]Several aspects are noteworthy at this point. Average after-tax wages can either be calculated based on the entire working volume or only based on full-time jobs only. It is possible to calculate after-tax wages based upon households, so that the wage income has to be spread out on all persons living in the household or it can directly be linked to the person, who brings in the workload. A calculation can also be based on producing sectors only, as services might offer additional biases.

[95]Calculated as average after-tax wage per hour times 10.8 hours of leisure time per day times 365 days.

(2017). In 2015 it was already 82% according to the Statistisches Bundesamt (2017a)[96]. As a final result, I receive around €31 bn. in 2004 and around €176 bn. in 2015 of (potential) additional value created by the internet, which does not show up in the statistics. The incremental gains result from the difference between the two values (€176 bn. - €31 bn. = €145 bn.). All calculations for this pattern can be found in appendix V.

Under the assumptions of having similar broadband coverages as in the US (even though there might be larger differences, the overall statement would change only slightly) one can compare this to the missing output (as shown in table 10). The scenario in most favour of the validity of the mismeasurement hypothesis (around €246 bn.) is still not entirely explained by possibly hidden incremental gains from the internet. In fact, the internet-hypothesis only explains around 59% of the missing data (€145 bn. in relation to the missing output of €246 bn.).

Having in mind that the scenario was set up in favour of the mismeasurement hypothesis, one is confronted with a disappointing result. Only 59% of the missing could be explained, which is insufficiently small and therefore provides another argument to reject the mismeasurement hypothesis. As Syverson finds for the US, German data also insist that real economic causes are responsible for the productivity slowdown in Germany.

10.3 Incremental Real Value Added from ICT-industries (Pattern 3)

As for the third obstacle, Syverson analyses products and respective industries, associated with 2004-technologies which could be associated with problems resulting from the migration of value added to consumer surplus (Syverson (2016, p. 13)). More precisely, the author extracts data for real value added (and for the second potential calculation method revenues[97]) of those industries, providing the goods which are most likely of the character of underestimating consumer surplus.

Firstly, the relevant sectors at central concern for the mismeasurement hypothesis are defined. Secondly, the growth in real value added of the industries within the period 2004-2015 is calculated.

[96] A combination of the two sources had to be used as the OECD does not provide data further than 2010 in this category, nor does the Statistisches Bundesamt provide data going back before 2008.

[97] The present study focusses on the value-added calculation only.

Real values for 2004 are expressed in 2015-$ in order to provide the same price base[98]. As a result, Syverson (2016) receives $545 bn. in total for the change in real value added in these industries. If the problem of (missing) migration from output to consumer surplus is to account for the gap in productivity (and therefore in favour of the mismeasurement hypothesis), the incremental consumer surplus has to be equal the missing portion of $2.7 trn. or at least close to it. Total change in real value added of $545 bn., however, is just around 20% of the 'gap' in the statistics and makes underestimated growth in the 'problem'-industries very unlikely as potential explanation.

Data for the German calculation is taken via Eurostat from the Structural Business Statistics database (SBS). The statistics describe the "structure, activity, competitiveness and performance of economic activities within the business economy down to the detailed level of several hundred sectors" (see Eurostat (2018b)). Applying the method from Syverson for this pattern forces to include the same sectors like in his study. As the US and Germany make use of different sectoral classification systems, this does not only provide the need for a comparison of the NAICS-classification system (used in the US) and the NACE-classification system (used in Germany). In addition, the results of this calculation have to be used with an extra amount of care. At first, I make a comparison for both systems in order to filter the relevant sectors, which shall be included in the calculation. In original, Syverson includes (Syverson (2016, p. 13)):

- computer and electronic products manufacturing (NAICS 334)
- the entire information sector (NAICS 51) and
- computer systems design and related services (NAICS 5415)

The comparison and resulting sectors (and sub-sectors) for the German analysis can be found in appendix V. The relevant sectors used for the German calculation (according to NACE 2) are:

- for the manufacturing sector: reproduction of recorded media (18.20), manufacture of electronic components (26.11), manufacture of loaded electronic boards (26.12), manufacture of computers

[98] Syverson approximates values for 2015 and for the price base 2015, as at the date of publication data was restricted to 2014.

and peripheral equipment (26.20), manufacture of communication equipment (26.30), manufacture of consumer electronics (26.40), manufacture of instruments and appliances for measuring, testing and navigation (26.51), manufacture of watches and clocks (26.52), manufacture of irradiation, electromedical and electrotherapeutic equipment (26.60), manufacture of optical instruments and photographic equipment (26.70), manufacture of other electrical equipment (27.90), manufacture of railway locomotives and rolling stock (30.20), manufacture of air and spacecraft and related machinery (30.30).

- for the service sector: book publishing (58.11), publishing of directories and mailing lists (58.12), publishing of newspapers (58.13), publishing of journals and periodicals (58.14), other publishing activities (58.19), publishing of computer games (58.21), other software publishing (58.29), motion picture, video and television programme production activities (59.11), motion picture, video and television programme post-production activities (59.12), motion picture, video and television programme distribution activities (59.13), motion picture projection activities (59.14), sound recording and music publishing activities (59.29), radio broadcasting (60.10), television programming and broadcasting activities (60.20), wired telecommunications activities (61.10), wireless telecommunications activities (61.20), satellite telecommunications activities (61.30), other telecommunications activities (61.90), computer programming activities (62.01), computer consultancy activities (62.02), computer facilities management activities (62.03), other information technology and computer service activities (62.09), data processing, hosting and related activities (63.11), web portals (63.12), news agency activities (63.91), other information service activities n.e.c. (63.99), photographic activities (74.20),

- Sector 91.01 "library and archive activities" is not included in this calculation, as no data are provided[99]. Its weight for aggregate value added in the sectors is limited and can be neglected without concern.

In a next step, data from the SBS is taken (Eurostat (2019a) and Eurostat (2019b)), in order to calculate value added for the sectors chosen. I aggregate value added for these sectors for the years

[99] Please see <<https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Structural_business_statistics_overview>> and the explanations on "Coverage, units and classifications" for further information.

2015 and the 2004[100]. This results in nominal value added for the selected sectors. For the year 2004 it is €74.386,2 mil. and for the year 2015 the value is €102.592,6 mil.. In order to receive real value added for the sectors, I make use of sectoral price-deflators (the alternative approach of the Syverson-calculation, see Syverson (2016, p. 14 footnotes)). For the manufacturing sector, the calculation was pretty straightforward. A sectoral deflator is available and real value added of the industries can be constructed (Statistisches Bundesamt (2017c), Genesis Code: 61241 - 0001). GDP deflators for the service sector are not provided back to 2004 by the Statistisches Bundesamt. In fact, data only for a certain amount of services are available (Statistisches Bundesamt (2017c), Genesis Code: 61311-0003). In order to calculate real values, I make use of an approximation by taking the unweighted average of all service subsectors, providing data for 2004. The respective calculations can be found in the appendix V. Expressed in 2015-€ this yields real value added for 2004 of €62.410,8 trn. and €102.592,6 trn. for 2015, implying a change of €40.181,81 trn. for the selected sectors. Compared to the missing portion (€246 bn.) this is around 16% and provides similar results and implications as for the US by the Syverson-study (around 20%) - a result of minor value for the validity of the mismeasurement hypothesis.

10.4 GDI versus GDP (Pattern 4)

The last pattern relates to the argument that there has been income created without respective output or result in production (value). If products are sold at lower prices (compared to the costs of production) or even given away for free, then aggregate income necessarily must outpace national product. In theory, GDP and GDP are supposed to be equal, as they are connected by an identity. In practice, however, they diverge by a small amount - so-called statistical discrepancy[101](Bartelsman and Beaulieu (2004, p. 9)). For the US no significant trend of a growing gap was observable - even though for most of the years, gross domestic income (GDI) was slightly larger than gross domestic product (GDP) (Syverson (2016, pp. 16-18 and p. 26)).

[100]As data is missing for several years, I calculate the missing points by applying the average annual growth rates, as Syverson did, too. The average annual growth rate for value added in the manufacturing sector from 2008-2015 was 2.783563546%. Please see the appendix V for further information.

[101]Statistical discrepany is explained by different methods of calculations. In this case data sources for expenditures and incomes are used (Syverson (2016, p. 17)).

As mentioned, one way of calculation and interpretation of GDP is that it is the aggregate value of products and services produced in a specific period of time and within geographic boundaries (expenditure approach). As production generates income, GDP can also be calculated via incomes generated in the geographic boundaries (income approach, here: GDI). For the income calculation not only labour and capital compensation are relevant but also taxes & subsidies (net taxes) and depreciation (capital consumption), as well the balance of primary incomes with the rest of the world. More precisely, the method for calculation is (Statistisches Bundesamt (2019e)):

NI (National Income= labour compensation + capital compensation)

Plus Balance of (+Taxes and −Subsidies)

Plus Depreciation

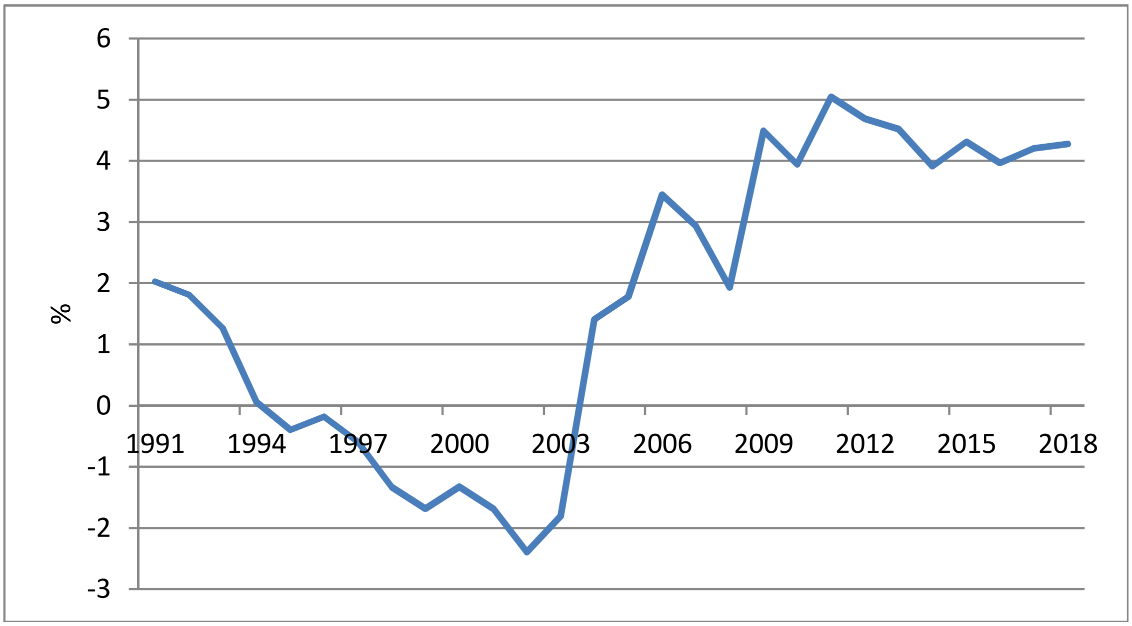
Plus Balance of Primary Incomes from (+) and to (−) the Rest of the World (here: PIRW)

Equals Gross Domestic Product (GDP)

For the calcluation, data is taken from Statistisches Bundesamt (2018c) and Statistisches Bundesamt (2017c) (Code: 81000-0005). Results are presented table in appendix V. If incomes (GDP income approach, here: GDI) exceed products' values (GDP expenditure approach), this could indicate and verify the hypothesis, that some part of the missing amount is embodied (and hidden) in products, given away for a lower price or even for free. Syverson (2016), however, rejects the hypothesis as the worker's share has in fact fallen within the last decade (from around 55% to 53% for the US).

Figure 38 shows the trend for the gap between GDI and GDP for Germany.

Figure 38: Gap GDI vs. GDP. Source: Statistisches Bundesamt (2018c, 2017c); own calculations and illustration.



For Germany, the potential gap (calculated as GDI minus GDP in relation to GDP) between the income and expenditure approach (GDI vs. GDP; which reflects statistical discrepancy) can be separated into two parts. In the 1990s, most of the years exhibit negative gaps, implying GDI being larger than GDP. For the year 2003 and every subsequent one, however, GDP outperforms GDI, which is very much against the supposition that products were given away for free. Moreover and like in the US, labour share has decreased little from around 54% at the beginning of the 1990s to 49% in 2018. These two results ("wrong" prefix of the gap and the slightly declining labour share) indicate that there is no wisdom in the hypothesis that products were given away for free.

11 Concluding Remarks on Part III

At the beginning of part II, an empirical investigation with regard to productivity variables and relatives was set up. It has been shown that Germany, as well as other developed economies, is exposed to declining numbers of productivity. Several possibilities to capture the efficiency of the production factor labour were outlined - all of them pointing into the same direction. Over the last decades, Germany was not able to maintain its rates of productivity growth. Depending on the denominator chosen, rates have decreased from around 3% to 5% to values of slightly below the 1%-mark. The same applies for total factor productivity, which captures all production factors in use and - as the first part of the present study has suggested - represents (at least approximately) technological progress. Even though Germany has performed relatively better compared its fellow countries (i.e. the US), its negative trend cannot relieve. As investment and productivity are linked to each other, capital formation - with a specific focus on infrastructure - has been analysed. Negative trends for productivity indicators, as well as for other economic variables (i.e. capital formation), are outlined. They seem to confirm the fact that there is the necessity for a trend reversal. Even though it has been argued correctly (i.e. by the Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung (2014)) that it is also a matter of defining appropriate benchmarks (or some kind of optimal amount), these negative developments over the last decades are definitely faltering economic development in Germany.

The empirical analysis represents the base for the further elaboration of the productivity puzzle in Germany, as it argues in favour of the existence of real economic causes as potential explanation. On the opposite, studies have claimed poor measurement for the loss in the statistics. Their central argument is that if measurement is executed properly, then this can account for the missing portion in the data sheets.

At first, a short revival (and some kind of recycle) of the arguments of the 1970s-slowdown has been brought up. In course of the oil price shocks and other economic turmoils in the 1970s (and of course its ramifications still working in the 1980s), there already has been an ongoing debate on the causes of slowing rates of productivity growth. Interestingly, many of the arguments brought up then, still play a role for the current slowdown (i.e. insufficient capital formation or energy-price related developments burdening the public budget).

On the basis of the so-called theory of secular stagnation, the “real” causes were examined, laying the scope on Germany (and for the reason of comparison on the US). Applying Robert Gordon’s classification as “headwinds faltering economic growth”, business development in Germany is analysed. His main argument of simply having less (important) technological innovations nowadays and the acceptance that it is some kind of natural rebound now, has been laid out - the major argument is not set up country-specific, so it is presented without specific application on Germany. An insufficient level of effective demand, usually associated with short-run business-cycle developments, plays a role - but more in a sense of amplifying the other channels (headwinds). I.e., by the need of setting an expansive stimulus for the level of demand, a government’s budget faces additional burdens. The evaluation of the headwind of public debt then allows for argumentation in both directions. On the one hand, the issue of public debt does not represent a strong headwind as, compared to other countries of the European Currency Union, Germany provides deficit- and debt-ratios at the lower end of the scale. However, it constantly shows years of missing the (legal) financial requirements, set by the Treaty of Maastricht.

A headwind clearly providing explanatory power is the one with respect to capital spending and infrastructure. Not only does Germany show decreasing trends of capital formation (especially for the public sector), it is also exposed to an insufficiently equipped infrastructure (i.e. traffic, broadband technologies). As the endowment with capital goods not only supplies the capacity in any sense, it also delivers and diffuses technological change. Shrinking degrees of modernity for fixed capital assets in Germany do not fit the image of an economy, which is ready for the developments in course of the current wave of technological change.

The evaluation of headwind #3, the demographic one, is a little complicated. Germany has an ageing and shrinking population and expects to diminish further, which limits the potential labour market supply as well as the probability of finding high-quality employees in order to avoid mismatch situations. In addition, the average working week in terms of hours has declined from almost 40 hours per week in the 1980s, to 32 in 2016. One could be tempted to attest a negative impact. By taking overall working volume into account, which has remained (almost) constant over time, employment must necessarily have gone up (from around 36 mil. in 1991 to around 41 mil. in 2017). It seems that the demographic headwind is of big concern for the future of the German economy but works less as an explanation for the declining trends of productivity over the last decades.

Headwind #4 concerns the educational system and its effects on human capital. Compared to the US, a better non-academic system is provided in Germany, hereby functioning as complementary rather than substitutional for education purposes. Germany was also able to catch up over the years with regard to the requirements of secondary education (here represented by the PISA-testings). A big advantage, one might speak of a tailwind instead, is the easy access to the academic system by the meaning of student fees. Whereas the US limits its potential by excess financial needs, Germany provides academic schooling almost at zero costs.

A headwind of major concern for Germany is the effect of rising inequality - expressed in terms of income, wealth or any other variable. Studies and data show that Germany exhibits a high degree of inequality. This not only amplifies other channels (headwinds) but itself represents a headwind by providing unequal conditions for citizens and the danger of social imbalances.

Headwinds and the elaboration of "real" economic causes represents one major strand of explanation. Potential mismeasurement of aggregate variables in national accounts represents the other one. A first step into mismeasurement is made by pointing on the process of deflating. Prices generally do not only contain a component that captures the true price effect, but another part of the price behaviour is also related to the changing property of a good. Hedonic Price Indexes try to separate and correct for these changing properties or tasks. The main hypothesis is that if the effect of changing properties and qualities can be corrected for, the remaining (true) price effect is lower, implying a lower effect of deflating nominal values. Higher real values could then fill the gap in productivity statistics. Besides the fact that not all goods and services are corrected for quality by national accounts and the problem of general problems in the measurement process, the effect seems too small to account for the missing productivity.

In line with the "too small"-argument is the mismeasurement hypothesis of Chad Syverson. After calculating a counterfactual scenario, which works under the premise of constant productivity growth rates over time, the author elaborates whether false mismeasurement can account for the missing gap in productivity. More precisely, four obstacles hinder the validity of the mismeasurement hypothesis. The obstacles are related to the problems of correct measurement of ICT-related data (sectors and intensity), an underestimation of the benefits from the internet or the estimation of prices of goods differing from production costs. For the US (Syverson-study) as well as for the application on Germany (present study), it can be concluded that there is some wisdom in the argument of mismeasurement. However, the amount, due to be explained ($2.7 trn. for the US and €246 bn. for Germany), is simply too large.

Part IV

General Conclusion

In course of a wave of technological progress, shrinking rates of productivity puzzle scientific research. It seems illogical at first glance that - to speak with the famous words of Robert Solow - we can find the ICT-age everywhere but in the statistics. As technological progress is the ultimate driver of welfare of an economy, the productivity statistics provide puzzling results - if the fruits of innovations are not in reach, this will imply a negative outlook for economic development. For an evaluation of potential reasons for productivity puzzles, at first, the general linkage between technology and productivity has to be examined. If all factors in production are measured regarding efficiency, the resulting variable must be of technological taste.

In the first main part (part II), the present study elaborates on the variable commonly used to represent technology, which is total factor productivity (TFP). Robert Solow once promoted the TFP-residual as major source of explanation for US economic growth and labelled it as effects in technology. It is discussed to what extent the residual actually describes technological effects. Moreover, the debate on it has brought up three potential views on how to interpret the catch-all variable. Additionally, the history and evolution of the corresponding measurement framework - the growth accounting approach - has been presented. It allows to theoretically analyse the individual contributors to economic growth and provides a possibility to take it over for empirical analyses.

In the subsequent main part (part III), at first, an empirical section is outlined in order to draw an image on productivity trends - hereby laying the focus on Germany as the main object of the study. In order to avoid structural changes at best, the starting point of the empirical section is set after German Reunification 1989/90.

Labour productivity and TFP are presented in several ways, all of them showing a rather dark image for Germany. This view is also shared by the outline of several other economic variables (i.e. labour market dynamics or data on demographics). Summing up the empirical section allows for stating that over the last (almost) three decades, Germany is subject to declining trends in productivity and is exposed to other negative developments (i.e. insufficient capital formation).

At the heart of the present study, there is the dichotomy of poor measurement and the existence of real economic causes for the explanation of the decreasing rates of productivity, implying less (significant) technological progress. By following the supply-side theory of secular stagnation by Robert Gordon, the present study adopts Gordon's concept for the evaluation of the real economic causes argument. German (economic) environment is discussed under the notion and logic of headwinds faltering economic development. Based on the empirical section, the relevance for the individual headwinds for Germany is analysed. Whereas a minority of aspects provide fair marks for Germany, most of the headwinds and respective components state that Germany is exposed to obstacles and depressing effects for the economic and business environment. Rising inequality, ageing population and insufficient capital formation (especially in the public sector) are a few examples.

For the second strand of explanation, potential mismeasurement is examined. Mainly by applying a study of Chad Syverson on Germany, which asks for insufficient measurement ability of national accounts. More precisely, it is asked whether the increasing importance of services and developments in the ICT-sector provide potential sources of 'lost' productivity. Explanatory power of the mismeasurement would make the productivity puzzle illusory.

As a result for Germany, similar to the one by Syverson for the US, the present study's calculations find that the amount, the mismeasurement hypothesis has to explain, is simply too large. Acknowledging that the measurement system of national accounts seems not perfect for the recording of output in the 21st century, it cannot function as a reason for 'the' explanation of productivity puzzles in Germany.

To put the results in a nutshell, real economic causes must offer the explanatory potential, as mismeasurement is not able to do so. Though there does not exist one single reason, one could infer the decreasing trend to - it seems that a combination or nexus of several aspects in the economic environment in Germany play its role. And like the variety of potential reasons increases, so do policy implications.

Unfortunately, there is no call for a single policy action. Many deficiencies in the economic environment in Germany build the challenge to correctly identify the responsible aspects. In example, one could ask for higher amounts of investment, especially in digital infrastructure, supplying the prerequisites for a successful implementation of the current wave of technological progress - the developments in course of "economy 4.0" or "work 4.0". Also, it seems important to apply labour market changes of any type in order to prepare for ageing and shrinking population and labour supply side, therefore (i.e. by promoting high-quality migration or a better financial payment of jobs in the health care sector). Based on the study, it has been shown that inequality not only is a problem per se but enforces other headwinds. Appropriate elements in the system of distributional politics have to be implemented, supported by the perpetuation of the German social service system.

The variety of potential aspects faltering economic growth and productivity in Germany also calls for further research in the respective fields. Moreover, neglected headwinds of globalisation and ecological environment have to be taken into consideration as their relevance is still increasing.

In addition and as a general claim, there is the necessity to re-evaluate the system of measuring economic output by national accounts. Even though there have been adaptions in the past to improve its accuracy (i.e. Hedonic Price Indexes to correct for quality effects), it still seems to offer deficiencies with regard to the increasing relevance of services as a fraction of national output.

Part V

Appendix

Appendix A

Pattern 1, Germany

Figure 39: Broadband Coverage and ICT Value Added, Pattern 1 (Germany)). Sources: OECD Database (2014); own illustration.

Broadband Coverage

Austria	46,10
Belgium	56,40
Canada	64,20
Czech Republic	28,1
Denmark	69,50
Estonia	47,60
Finland	62,90
France	42,90
Germany	49,60
Hungary	33,00
Iceland	76,10
Ireland	31,20
Italy	25,30
Japan	51,70
Korea	94,10
Luxembourg	57,80
Netherlands	73,80
Norway	66,70
Poland	29,60
Portugal	30,40
Slovak Republic	26,50
Slovenia	43,60
Spain	39,20
Sweden	66,60
Switzerland	63,00
United Kingdom	56,70
United States	50,80

ICT Value Added

Austria	3,80
Belgium	4,50
Canada	5,10
Czech Republic	5,70
Denmark	5,20
Estonia	6,90
Finland	6,40
France	5,10
Germany	5,10
Hungary	7,30
Iceland	4,30
Ireland	11,90
Italy	4,90
Japan	8,10
Korea	9,60
Luxembourg	7,00
Netherlands	5,10
Norway	3,90
Poland	4,10
Portugal	4,10
Slovak Republic	5,90
Slovenia	4,70
Spain	4,60
Sweden	6,80
Switzerland	7,40
United	7,40
United States	7,10

Data for labour productivity growth, annual changes, %, real GDP per hour worked was extracted from OECD Statistics (2017).

Figure 40: Summary and Estimates, Pattern 1 (Germany)). Sources: OECD Database (2014); own illustration.

	GDP per hour, constant prices			ICT (cons.)	ICT (prod.)
	1991-2004	2005-2015	drop		
Austria	1,6	1,2	-0,4	46,10	3,80
Belgium	1,9	0,6	-1,3	56,40	4,50
Canada	1,5	0,9	-0,6	64,2	5,10
Czech Republic	3,4	2,1	-1,3	28,1	5,70
Denmark	1,8	0,9	-0,9	69,50	5,20
Estonia	5,8	2,6	-3,2	47,60	6,90
Finland	2,9	0,5	-2,4	62,90	6,40
France	1,9	0,8	-1,1	42,90	5,10
Germany	2	0,9	-1,1	49,60	5,10
Hungary	3,5	2,1	-1,4	33,00	7,30
Iceland	2	1,3	-0,7	76,10	4,30
Ireland	4,4	4	-0,4	31,20	11,90
Italy	1,1	0,1	-1	25,30	4,90
Japan	2	0,8	-1,2	51,70	8,10
Korea	5,6	3,5	-2,1	94,10	9,60
Luxembourg	1,6	0,4	-1,2	57,80	7,00
Netherlands	1,3	0,7	-0,6	73,80	5,10
Norway	2,7	-0,1	-2,8	66,70	3,9
Poland	5,3	2,5	-2,8	29,60	4,10
Portugal	1,7	1	-0,7	30,40	4,10
Slovak Republic	5	2,9	-2,1	26,50	5,90
Slovenia	3,9	1,6	-2,3	43,60	4,70
Spain	0,8	1,2	0,4	39,20	4,60
Sweden	2,6	0,9	-1,7	66,60	6,80
Switzerland	1	0,8	-0,2	63,00	7,40
United Kingdom	2,5	0,5	-2	56,70	7,40
United States	2,1	1,1	-1	50,80	7,10
Statistical Mean	2,66296296	1,32592593	-1,33703704	51,24	6,00
Standard Deviation	1,45949099	1,02002737	0,87887522	17,6362421	1,88169318
Variance	2,13011396	1,04045584	0,77242165	311,037037	3,54076923
Correlation ICT-consumption and ICT-production				0,10879241	
Sample Size	27	27	27	27	27
SqRo. Sample Size			5,19615242	5,19615242	5,19615242
Standard Error of the Mean			0,16913961	3,39409638	0,36213202

Appendix B

Pattern 2, Germany

1. Average after-tax wage per employee and month (Source: Statistisches Bundesamt (2017c), Code: 81000-0007)

2004: €1.498

2015: €1.804

Multiplied with total population in the respective year (Source: Statistisches Bundesamt (2019b)) yields total sum of wages:

2004: €628.51 bn.

2015: €834.56 bn.

Amount of hours worked (including full-time, part-time and self-emplyoyed):

2004: 46.817 (in mil. h)

2015: 50.393 (in mil. h)

Dividing sum of wages by amount of hours worked yields **average wage per hour worked** (hours worked taken from Institut für Arbeitsmarkt- und Berufsforschung (2016)):

2004: $\frac{€628.51bn.}{46.817mil.h} = 13.42\frac{€}{h}$

2015: $\frac{€834.56bn.}{50.393mil.h} = 16.60\frac{€}{h}$

2. Calculating average value of leisure-time per person:

Average leisure-time per person = average wage per hour worked x average amount of leisure time per person and day x 365 days [102]:

2004: $13.42\frac{€}{h}$x$10.8h$ x 365 = €52.901

2015: $16.60\frac{€}{h}$x 10.8h x 365 = €65.437

3. Calculation of total income (income per person taken from Statistisches Bundesamt (2016)) :

Total income = average income per person + value of leisure time (rounded)

[102]The average amount of leisure time (10.8 hours per day on average) is taken over by Syverson (2016).

2004: €17.500 + €52.900 = €70.400

2015: €21.600 + €54.437 = €87.000

4. Adjusting with the influence of the internet (3%-estimation taken from Goolsbee and Klenow (2006)):

2004: Total income x 3% = €70.400 x 3% = €2.112 per person

2015: Total income x 3% = €87.000 x 3% = €2.610 per person

Multiplying with total population (rounded):

2004: €2.112 x 82.5 mil. = €174 bn.

2015: €2.610 x 82.2 mil. = €214 bn.

5. Adjusting by availability of broadband internet coverage (rounded):

2004: 18% broadband coverage ⇒€174 bn. x 18% = €31 bn.

2015: 82% broadband coverage ⇒€214 bn. x 82% = €176 bn.

⇒Difference (€176 bn. - €31 bn. = **€145 bn.**) yields **potential increase of non-visible consumer surplus**.

Appendix C

Pattern 3, Germany

Figure 41: Sectors included for Germany, Pattern 3 (NACE 2-classification)). Sources: Eurostat (2018a); own illustration.

26.20	Manufacture of computers and peripheral equipment
26.20	Manufacture of computers and peripheral equipment
26.20	Manufacture of computers and peripheral equipment
26.20	Manufacture of computers and peripheral equipment
26.70	Manufacture of optical instruments and photographic equipment
26.30	Manufacture of communication equipment
26.30	Manufacture of communication equipment
26.51	Manufacture of instruments and appliances for measuring, testing and navigation
30.30	Manufacture of air and spacecraft and related machinery
26.30	Manufacture of communication equipment
26.51	Manufacture of instruments and appliances for measuring, testing and navigation
27.90	Manufacture of other electrical equipment
30.20	Manufacture of railway locomotives and rolling stock
26.40	Manufacture of consumer electronics
26.11	Manufacture of electronic components
26.11	Manufacture of electronic components
26.11	Manufacture of electronic components
26.11	Manufacture of electronic components
26.11	Manufacture of electronic components
26.11	Manufacture of electronic components
26.11	Manufacture of electronic components
26.12	Manufacture of loaded electronic boards
26.11	Manufacture of electronic components
26.60	Manufacture of irradiation, electromedical and electrotherapeutic equipment
26.51	Manufacture of instruments and appliances for measuring, testing and navigation
26.51	Manufacture of instruments and appliances for measuring, testing and navigation
26.51	Manufacture of instruments and appliances for measuring, testing and navigation
26.51	Manufacture of instruments and appliances for measuring, testing and navigation
26.52	Manufacture of watches and clocks
26.51	Manufacture of instruments and appliances for measuring, testing and navigation
26.51	Manufacture of instruments and appliances for measuring, testing and navigation
26.60	Manufacture of irradiation, electromedical and electrotherapeutic equipment
26.52	Manufacture of watches and clocks
26.51	Manufacture of instruments and appliances for measuring, testing and navigation
18.20	Reproduction of recorded media
18.20	Reproduction of recorded media
58.13	Publishing of newspapers
58.14	Publishing of journals and periodicals
58.11	Book publishing
58.12	Publishing of directories and mailing lists
58.19	Other publishing activities
58.11	Book publishing
58.19	Other publishing activities
58.21	Publishing of computer games
58.29	Other software publishing
59.11	Motion picture, video and television programme production activities
59.13	Motion picture, video and television programme distribution activities

59.14	Motion picture projection activities
59.14	Motion picture projection activities
59.12	Motion picture, video and television programme post-production activities
59.12	Motion picture, video and television programme post-production activities
59.13	Motion picture, video and television programme distribution activities
59.20	Sound recording and music publishing activities
59.20	Sound recording and music publishing activities
59.20	Sound recording and music publishing activities
59.20	Sound recording and music publishing activities
59.20	Sound recording and music publishing activities
60.10	Radio broadcasting
61.20	Wireless telecommunications activities
60.10	Radio broadcasting
61.20	Wireless telecommunications activities
60.20	Television programming and broadcasting activities
61.20	Wireless telecommunications activities
60.20	Television programming and broadcasting activities
61.20	Wireless telecommunications activities
61.10	Wired telecommunications activities
61.30	Satellite telecommunications activities
61.20	Wireless telecommunications activities
61.30	Satellite telecommunications activities
61.90	Other telecommunications activities
61.90	Other telecommunications activities
61.90	Other telecommunications activities
63.11	Data processing, hosting and related activities
74.20	Photographic activities
63.91	News agency activities
91.01	Library and archives activities
58.11	Book publishing
58.12	Publishing of directories and mailing lists
58.13	Publishing of newspapers
58.14	Publishing of journals and periodicals
58.19	Other publishing activities
58.21	Publishing of computer games
58.29	Other software publishing
59.20	Sound recording and music publishing activities
60.10	Radio broadcasting
60.20	Television programming and broadcasting activities
63.12	Web portals
63.99	Other information service activities n.e.c.
91.01	Library and archives activities
62.01	Computer programming activities
62.02	Computer consultancy activities
62.03	Computer facilities management activities
62.09	Other information technology and computer service activities

Figure 42: Calculations, Pattern 3 (Germany)). Sources: Eurostat (2019a,b); own illustration.

Value Added in factor costs, expressed in Mil. €

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Manufacturing sectors (selection)	266,2	266,2	266,2	266,2	273,66	263,4	286,2	309,2	306,2	311,9	317,2	334,6
Services sectors (selection)	74141,0	76419,9	79499,8	85027,3	91542,3	86458,3	89402,4	90411,7	91603,2	96911,8	102000,1	102258,0
Sum (nominal)	**74407,2**	**76671,9**	**79758,8**	**85293,5**	**91815,96**	**86721,7**	**89688,6**	**90720,9**	**91909,4**	**97223,7**	**102317,3**	**102592,6**

	2004			2015
GDP-deflator manufacturing	2004 = 84,2	(taken directly from GENESIS database, Code: 61241 - 0001)		2015 = 100
GDP-deflator services	2004 = 83,9	(calculated indirectly as unweighted average of secors available for 2004, GENESIS database, Code: 61311-0003)		2015 = 100
Manufacturing (real)	206,5			334,6
Services (real)	62204,3			102258,0
Sum (real)	62410,8	change (2004-2015):	40181,81 (= €40.18 trn.)	102592,6

Calculated via average annual growth rate extrapolation.

Real values are calculated as nominal values adjusted by GDP-deflator to obtain values expressed in 2015-€.

Appendix D

Pattern 4, Germany

Figure 43: National Accounts Germany, Pattern 4 (in bn. €)). Sources: Statistisches Bundesamt (2018c, 2017c); own calculation and illustration.

	Labour Compensation	Capital Compensation	Taxes & Subsidies	Depreciation	Balance PIRW	GDI (income)	GDP (expenditure)	GDI (income) minus GDP (expenditure) ("GAP")	"GAP" in % of GDP (expenditure)	Labour Share**
(Source / Digit)	Digit 1.3	Digit 1.3	Digit 1.3	Digit 1.2	Code: 81000-0005	Own Calculation	Digit 1.1	Own Calculation	Own Calculation	Own Calculation
1991	856,75	369,76	123,27	246,01	15,994	1611,79	1 579,80	31,99	2,024813268	53,15550184
1992	928,75	377,86	136,92	267,17	15,374	1726,07	1 695,32	30,75	1,813698889	53,80720806
1993	950,55	376,21	148,20	284,69	11,109	1770,77	1 748,55	22,22	1,270652827	53,68032402
1994	975,54	399,97	158,93	296,39	0,544	1831,38	1 830,29	1,09	0,059444132	53,26797635
1995	1 010,68	418,48	158,54	307,42	-3,755	1891,37	1 898,88	-7,51	-0,395496293	53,4365037
1996	1 019,83	429,18	160,45	315,09	-1,777	1922,77	1 926,32	-3,55	-0,184496864	53,03957944
1997	1 024,16	447,65	166,18	323,26	-5,842	1955,41	1 967,09	-11,68	-0,59397384	52,3757726
1998	1 045,82	455,37	172,44	331,16	-13,444	1991,34	2 018,23	-26,89	-1,332256482	52,51830173
1999	1 075,96	444,25	187,63	339,62	-17,429	2030,02	2 064,88	-34,86	-1,688136841	53,00213495
2000	1 117,39	437,51	193,16	354,35	-14,063	2088,35	2 116,48	-28,13	-1,328904596	53,50572748
2001	1 134,33	462,52	198,36	366,28	-18,359	2143,13	2 179,85	-36,72	-1,684427828	52,9285177
2002	1 141,86	464,80	201,58	374,57	-26,486	2156,32	2 209,29	-52,97	-2,397693377	52,95401699
2003	1 143,60	469,08	208,63	378,71	-20,06	2179,96	2 220,08	-40,12	-1,807142085	52,4597699
2004	1 146,15	546,39	208,14	385,90	15,956	2302,53	2 270,62	31,91	1,405431116	49,77767953
2005	1 144,02	572,83	211,65	392,81	20,439	2341,74	2 300,86	40,88	1,776640039	48,8532449
2006	1 164,38	646,75	220,54	402,82	41,225	2475,70	2 393,25	82,45	3,445106027	47,03215252
2007	1 197,19	685,13	244,85	423,03	36,966	2587,16	2 513,23	73,93	2,941712458	46,27414132
2008	1 241,65	655,26	249,23	440,30	24,703	2611,15	2 561,74	49,41	1,928611022	47,55176463
2009	1 246,67	574,87	243,22	450,79	55,275	2570,83	2 460,28	110,55	4,493390996	48,49305477
2010	1 283,81	639,41	247,95	459,73	50,832	2681,72	2 580,06	101,66	3,94037348	47,87237613
2011	1 339,73	688,36	267,71	475,54	68,213	2839,55	2 703,12	136,43	5,046982746	47,18102823
2012	1 391,20	663,34	276,12	492,28	64,687	2887,63	2 758,26	129,37	4,690420773	48,17798932
2013	1 429,92	674,04	279,98	506,19	63,897	2954,03	2 826,24	127,79	4,521696671	48,40557015
2014	1 485,44	701,71	288,08	520,85	57,487	3053,56	2 938,59	114,97	3,912556702	48,6460084
2015	1 542,90	736,89	298,49	536,36	65,773	3180,41	3 048,86	131,55	4,314596275	48,51270561
2016	1 600,98	762,75	306,61	552,08	62,655	3285,06	3 159,75	125,31	3,965820081	48,73503071
2017	1 668,81	787,58	316,76	573,13	68,942	3415,22	3 277,34	137,88	4,207192418	48,86385198
2018	1 746,04	785,30	327,00	600,04	72,382	3530,76	3 386,00	144,76	4,275369167	49,45221487

*PIRW = Primary Incomes with the Rest of the World.

**Calculated as labour compensation in relation to GDI.

Appendix E

PISA data

Figure 44: PISA, category: Mathematics. Sources: OECD (2018); own illustration.

	Ranking 20		Ranking 20		Ranking 20		Ranking 20		Ranking 20	
1	Finland	544	Finland	548	Korea	546	Korea	554	Japan	532
2	Korea	542	Korea	547	Finland	541	Japan	536	Korea	524
3	Netherlands	538	Netherlands	531	Switzerland	534	Switzerland	531	Switzerland	521
4	Japan	534	Switzerland	530	Japan	529	Netherlands	523	Estonia	520
5	Canada	532	Canada	527	Canada	527	Estonia	521	Canada	516
6	Belgium	529	Japan	523	Netherlands	526	Finland	519	Netherlands	512
7	Switzerland	527	New Zealand	522	New Zealand	519	Canada	518	Denmark	511
8	Australia	524	Belgium	520	Belgium	515	Poland	518	Finland	511
9	New Zealand	523	Australia	520	Australia	514	Belgium	515	Slovenia	510
10	Czech Republic	516	Estonia	515	Germany	513	Germany	514	Belgium	507
11	Iceland	515	Denmark	513	Estonia	512	Austria	506	Germany	506
12	Denmark	514	Czech Republic	510	Iceland	507	Australia	504	Poland	504
13	France	511	Iceland	506	Denmark	503	Ireland	501	Ireland	504
14	Sweden	509	Austria	505	Slovenia	501	Slovenia	501	Norway	502
15	United Kingdom	508	Slovenia	504	Norway	498	Denmark	500	Austria	497
16	Austria	506	Germany	504	France	497	New Zealand	500	New Zealand	495
17	Germany	503	Sweden	502	Slovak Republic	497	Czech Republic	499	Sweden	494
18	Ireland	503	Ireland	501	Austria	496	France	495	Australia	494
19	Slovak Republic	498	France	496	Poland	495	United Kingdom	494	France	493
20	Norway	495	United Kingdom	495	Sweden	494	Iceland	493	United Kingdom	492
21	Luxembourg	493	Poland	495	Czech Republic	493	Latvia	491	Czech Republic	492
22	Poland	490	Slovak Republic	492	United Kingdom	492	Luxembourg	490	Portugal	492
23	Hungary	490	Hungary	491	Hungary	490	Norway	489	Italy	490
24	Spain	485	Luxembourg	490	Luxembourg	489	Portugal	487	Iceland	488
25	Latvia	483	Norway	490	United States	487	Italy	485	Spain	486
26	United States	483	Latvia	486	Ireland	487	Spain	484	Luxembourg	486
27	Portugal	466	Spain	480	Portugal	487	Slovak Republic	482	Latvia	482
28	Italy	466	United States	474	Spain	483	United States	481	Hungary	477
29	Greece	445	Portugal	466	Italy	483	Sweden	478	Slovak Republic	475
30	Turkey	423	Italy	462	Latvia	482	Hungary	477	Israel	470
31	Mexico	385	Greece	459	Greece	466	Israel	466	United States	470
32			Israel	442	Israel	447	Greece	453	Greece	454
33			Turkey	424	Turkey	445	Turkey	448	Chile	423
34			Chile	411	Chile	421	Chile	423	Turkey	420
35			Mexico	406	Mexico	419	Mexico	413	Mexico	408

2003: For Chile, Israel, Estonia, Slovenia no data available.

Figure 45: PISA, category: Reading. Sources: OECD (2018); own illustration.

	Ranking 20		Ranking 20		Ranking 20		Ranking 20		Ranking 20		Ranking 20	
1	Finland	546	Finland	543	Korea	556	Korea	539	Japan	538	Canada	527
2	Canada	534	Korea	534	Finland	547	Finland	536	Korea	536	Finland	526
3	New Zealand	529	Canada	528	Canada	527	Canada	524	Finland	524	Ireland	521
4	Australia	528	Australia	525	New Zealand	521	New Zealand	521	Ireland	523	Estonia	519
5	Ireland	527	New Zealand	522	Ireland	517	Japan	520	Canada	523	Korea	517
6	Korea	525	Ireland	515	Australia	513	Australia	515	Poland	518	Japan	516
7	United Kingdom	523	Sweden	514	Poland	508	Netherlands	508	Estonia	516	Norway	513
8	Japan	522	Netherlands	513	Sweden	507	Belgium	506	New Zealand	512	New Zealand	509
9	Sweden	516	United Kingdom	507	Netherlands	507	Norway	503	Australia	512	Germany	509
10	Belgium	507	Belgium	507	Belgium	501	Estonia	501	Netherlands	511	Poland	506
11	Iceland	507	Norway	500	Estonia	501	Switzerland	501	Switzerland	509	Slovenia	505
12	Norway	505	Switzerland	499	Switzerland	499	Poland	500	Belgium	509	Netherlands	503
13	France	505	Japan	498	Japan	498	Iceland	500	Germany	508	Australia	503
14	United States	504	Poland	497	United Kingdom	495	United States	500	France	505	Sweden	500
15	Denmark	497	France	496	Germany	495	Sweden	497	Norway	504	Denmark	500
16	Switzerland	494	United States	495	Denmark	494	Germany	497	United Kingdom	499	France	499
17	Spain	493	Denmark	492	Slovenia	494	Ireland	496	United States	498	Belgium	499
18	Austria	492	Iceland	492	Austria	490	France	496	Denmark	496	Portugal	498
19	Czech Republic	492	Germany	491	France	488	Denmark	495	Czech Republic	493	United Kingdom	498
20	Italy	487	Austria	491	Iceland	484	United Kingdom	494	Italy	490	United States	497
21	Germany	484	Latvia	491	Norway	484	Hungary	494	Austria	490	Spain	496
22	Hungary	480	Czech Republic	489	Czech Republic	483	Portugal	489	Latvia	489	Switzerland	492
23	Poland	479	Hungary	482	Hungary	482	Italy	486	Hungary	488	Latvia	488
24	Greece	474	Spain	481	Latvia	479	Latvia	484	Spain	488	Czech Republic	487
25	Portugal	470	Luxembourg	479	Luxembourg	479	Slovenia	483	Luxembourg	488	Austria	485
26	Latvia	458	Portugal	478	Portugal	472	Greece	483	Portugal	488	Italy	485
27	Israel	452	Italy	476	Italy	469	Spain	481	Israel	486	Iceland	482
28	Luxembourg	441	Greece	472	Slovak Republic	466	Czech Republic	478	Sweden	483	Luxembourg	481
29	Mexico	422	Slovak Republic	469	Spain	461	Slovak Republic	477	Iceland	483	Israel	479
30	Chile	410	Turkey	441	Greece	460	Israel	474	Slovenia	481	Hungary	470
31			Mexico	400	Turkey	447	Luxembourg	472	Greece	477	Greece	467
32					Chile	442	Austria	470	Turkey	475	Chile	459
33					Israel	439	Turkey	464	Slovak Republic	463	Slovak Republic	453
34					Mexico	410	Chile	449	Chile	441	Turkey	428
35							Mexico	425	Mexico	424	Mexico	423

2000: For Estonia, Slovak Republic, Slovenia, Turkey and Netherlands no data available.
2003: For Chile, Slovenia, Estonia, Israel no data available.

Figure 46: PISA, category: Overall Science. Sources: OECD (2018); own illustration.

	Ranking 20		Ranking 20		Ranking 20		Ranking 20	
1	Finland	563	Finland	554	Japan	547	Japan	538
2	Canada	534	Japan	539	Finland	545	Estonia	534
3	Estonia	531	Korea	538	Estonia	541	Finland	531
4	Japan	531	New Zealand	532	Korea	538	Canada	528
5	New Zealand	530	Canada	529	Poland	526	Korea	516
6	Australia	527	Estonia	528	Canada	525	New Zealand	513
7	Netherlands	525	Australia	527	Germany	524	Slovenia	513
8	Korea	522	Netherlands	522	Netherlands	522	Australia	510
9	Slovenia	519	Germany	520	Ireland	522	United Kingdom	509
10	Germany	516	Switzerland	517	Australia	521	Germany	509
11	United Kingdom	515	United Kingdom	514	New Zealand	516	Netherlands	509
12	Czech Republic	513	Slovenia	512	Switzerland	515	Switzerland	506
13	Switzerland	512	Poland	508	Slovenia	514	Ireland	503
14	Austria	511	Ireland	508	United Kingdom	514	Belgium	502
15	Belgium	510	Belgium	507	Czech Republic	508	Denmark	502
16	Ireland	508	Hungary	503	Austria	506	Poland	501
17	Hungary	504	United States	502	Belgium	505	Portugal	501
18	Sweden	503	Czech Republic	500	Latvia	502	Norway	498
19	Poland	498	Norway	500	France	499	United States	496
20	Denmark	496	Denmark	499	Denmark	498	Austria	495
21	France	495	France	498	United States	497	France	495
22	Iceland	491	Iceland	496	Spain	496	Sweden	493
23	Latvia	490	Sweden	495	Norway	495	Czech Republic	493
24	United States	489	Austria	494	Hungary	494	Spain	493
25	Slovak Republic	488	Latvia	494	Italy	494	Latvia	490
26	Spain	488	Portugal	493	Luxembourg	491	Luxembourg	483
27	Norway	487	Slovak Republic	490	Portugal	489	Italy	481
28	Luxembourg	486	Italy	489	Sweden	485	Hungary	477
29	Italy	475	Spain	488	Iceland	478	Iceland	473
30	Portugal	474	Luxembourg	484	Slovak Republic	471	Israel	467
31	Greece	473	Greece	470	Israel	470	Slovak Republic	461
32	Israel	454	Israel	455	Greece	467	Greece	455
33	Chile	438	Turkey	454	Turkey	463	Chile	447
34	Turkey	424	Chile	447	Chile	445	Turkey	425
35	Mexico	410	Mexico	416	Mexico	415	Mexico	416

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