Technological Development, Labour Productivity and Jobs:

A study on labour productivity in the Dutch manufacturing sector up to 2100

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July 10th 2017

CONTENT

1 INTRODUCTION

The use of robots in our daily life is not so much science fiction anymore as it used to be. Nowadays it is a rather common sight to see a robot build a car or even vacuum a house in the richer parts of the world. Though ancient Greek writers already fantasized about having golden mechanical handmaidens made by the gods (Gera, 2003), it took until the 19th century before machinery really improved people's working power. Since the industrial revolution labour productivity in the Western world grew almost without a pause (Bergeaud, Cette & Lecat, 2015), meaning a single person could produce and achieve way more within the same time span than before. These improvements should indeed be attributed to the developments of machines and robots.

The recent developments leave a lot of people wonder whether they might soon become unemployed or not due to machines taking over their work. In a widely cited Oxford University article it was estimated that 47 percent of all U.S. jobs are automated within two decades (Frey & Osborne, 2013). The article must have been a reason for many soon-to-be students to reconsider their choice of study. It also caused much debate about what to do in a future world where the labour of humans is obsolete. In his book *Rise of the Robots* Martin Ford tries to prepare his readers for the future (Ford, 2015). He too thinks robots soon take over the largest share of contemporary jobs, but this time is different. While previously every revolution, whether agricultural or industrial, would be accompanied by a growth in jobs in new sectors, he believes that this time there is no possibility for people to change their profession. An argument counterintuitive for many economists who believe people always find new sectors to work in. His book also became criticized for a lack of good research or logic (Wired, 2015). In an attempt to contribute to this uncertain debate, this research looks into future developments for human jobs in the manufacturing sector in the Netherlands. The manufacturing sector is a sector in which a lot of people already have been replaced by machines. Given the historical perspectives on labour productivity in this sector, and the contemporary insights on future developments, it is predicted whether people are still necessary in this sector by 2100 or not. Therefore the following question is answered:

"Will human labour become obsolete in the manufacturing sector of the Netherlands by 2100?"

To answer this question this paper first presents a standard theory of labour productivity. Afterwards, previous empirical research to the determinants of labour productivity is discussed. Then, a model is presented in which labour productivity is dependent on its determinants as discussed in the preceding sections. A data section formulates several assumptions on future values of the determinants of labour productivity and explains how these are constructed. The model is then used to forecast the labour productivity in 2100. Its findings are that possibly more than 90% of workers is not needed anymore. Which mainly seems to be driven by the development of human capital.

2 THEORETICAL FRAMEWORK

To determine the future of labour productivity, first a definition of labour productivity needs to be formulated. The OECD formulates labour productivity as any kind of quantity index of gross output divided by any kind of quantity index of labour input (OECD, 2015). Because the focus point is on the manufacturing sector, gross output does only consist of manufacturing sector output. The labour input quantity is the amount of labourers working in the manufacturing sector of the Netherlands. The labour productivity is thus composed as:

$$LP = \frac{Output\ manufacturing\ sector}{Labourforce\ manufacturing\ sector} \qquad \textbf{\textit{equation 2.1}}$$

This is a useful measure of past values of the labour productivity. Apart for measurement errors it is possible to calculate the past values of labour productivity with certainty as the output and employment rates are known. There is also another way of formulating labour productivity by using standard growth theory and a Cobb-Douglas production function as first developed by Solow (Solow, 1957). Many economists have used the theory and developed variations and adaptions to incorporate other factors.

In this paper such an extended Solow-model first used by Corvers (1997) and later by Aggrey (2010) is adopted and aggregated to the sector wide level. Suppose that total output of the manufacturing sector in the Netherlands is given by Y. Following a standard Cobb-Douglas production function, Y would be a function of capital input K, labour input L and a measure of technology A, also called Total Factor Productivity and hereinafter referred to as such(TFP)(Solow, 1957). The relative importance of capital and labour is given by α & β whereby $\alpha + \beta = 1$. This can be represented by the following equation which gives the output as a function of capital, labour and total factor productivity:

$$Y = TFP\ K^{\alpha}L^{\beta} \qquad \textbf{\textit{equation 2.2}}$$

Because in this paper, labour productivity is defined as the total output divided by the total amount of labourers equation 2.2 is divided by the amount of labourers L, to get;

$$\frac{Y}{L} = TFP(\frac{K}{L})^{\alpha}L^{\beta-1+\alpha} \qquad \textbf{\textit{equation 2.3}}$$

In equation 2.3 shows that labour productivity Y/L can also be stated as a function of three components, next to the formula of equation 2.1. The first component is total factor productivity represented by TFP. The second is capital intensity which is the amount of capital available per labourer given by K/L. And at last, a function of the labourers in the economy. Now assume that human capital can be represented in this function by education shares. Different from, but inspired by Corvers (1997) L is substituted by relative levels of effective labour.

Low skilled workers are represented by LL and high skilled labourers represented by LH. They both add up to the total amount of labourers L, their relative shares are given by $\beta1$ and $\beta2$ for low and high-skilled workers respectively. By using algebra, the equation of labour productivity can then be stated as follows:

$$\frac{Y}{L} = TFP(\frac{K}{L})^{\alpha} LL^{\beta 1} LH^{\beta 2} \qquad \textit{\textbf{equation 2.4}}$$

This equation states labour productivity as a function of TFP, capital intensity and labour differentiated by education levels. The relative shares β1 and β2 of labour add up to $\beta - 1 + \alpha$. Taking the logarithm of both sides results in:

$$\ln\frac{Y}{L} = \ln TFP + \alpha\ln\frac{K}{L} + \beta 1 \ln LL + \beta 2 \ln LH \qquad \textit{\textbf{equation 2.5}}$$

One last term is added to equation 2.5. This is the difference in the capital labour ration in the manufacturing sector. This is done because for this research it is believed that capital deepening has a direct effect on labour productivity in the manufacturing sector next to the level of capital per labourer. This capital deepening can take the form of an investment boom. A sudden addition to the amount of capital available to each worker caused by these booms raises productivity in a measurable way. It is thus not only the change in the level that is important but also the change itself. This can also be considered a novelty effect, a new or extra machine gives a worker an incentive to be more productive because it is an exciting change of environment. Such an effect seems to be inherent in the nature of humans (Clark & Sugrue, 1988).

$$\ln\frac{Y}{L} = \beta_1 \ln TFP + \beta_2\ln\frac{K}{L} + \beta_3\, \Delta \ln\frac{K}{L} + \beta_4 \ln LL + \beta_5 \ln LH \qquad \textit{\textbf{equation 2.6}}$$

The last equation, equation 2.6, is then used to show the effects of the different determinants of labour productivity on labour productivity. However it does not give a level of labour productivity in euros right away. The last two terms of the equation represent relative education levels of the workforce. They are measured as the share of the workforce that has obtained a certain level of education. They could be considered as years of school attainment by labourers or by finishing a certain degree. The second term of the right-hand side resembles the capital intensity. It is defined as the capital per labourer. Capital deepening is when the amount of capital in an economy grows. Think of capital as a machine and it is straightforward that with more capital or machines a single worker can produce more than with fewer machines. According to one of Kaldor's stylized facts, capital per worker grows roughly at a constant rate over time (Kaldor, 1957). In this paper this is checked for the data on the Netherlands and used in forecasting the future capital intensity.

In the standard Cobb-Douglas function, total production would be a function of the amount of capital, the amount of labour and the total factor productivity, TFP. Because the function of labour productivity in this paper is the total production function divided by the amount of labour and adjusted for human capital, the TFP is a human capital adjusted TFP. The change in quality of the capital stock is implicit in the TFP. The TFP can therefore be seen as a measure of change, besides change in human capital and the capital stock.

3 LITERATURE REVIEW

This section first gives an overview of previous research on past productivity rates, the ones that are possible to determine with certainty apart from measurement errors. Then it outlines some empirical evidence of the theory and the determinants of labour productivity as presented in section 2. Afterwards, it discusses research that has been done to the size of labour productivity determinants and at last studies that make an attempt at forecasting those determinants for the future.

3.1 PAST PRODUCTIVITY

Previous research indicates that before the Industrial revolution there was not much growth in labour productivity. Robert Allen (2000) concludes that between 1300 and 1800 agricultural output per worker, which was almost the only source of output by then, even declined in several European countries such as the Netherlands (Allen, 2000). So growth in productivity came only after the Industrial Revolution of Europe. The trends in productivity have been studied more recently as well. A long run view on productivity between 1890 and 2012 by French researchers led to the conclusion that productivity grew almost every year. However it can be characterised in big waves, one for the second industrial revolution and another for the ICT-revolution (Bergeaud, Cette & Lecat, 2015). If we are to believe Martin Ford in his book about the rise of robots, it might be that another big wave or revolution in the manufacturing sector awaits us. This would be a revolution in the form of an ongoing quick robotization in the coming decades (Ford, 2015). Furthermore, Bergeaud et al. concluded that these productivity growth waves occur some time after the corresponding revolution and are highly influenced by the measures of institutions.

3.2 PREVIOUS RESEARCH ON DETERMINANTS OF LABOUR PRODUCTIVITY.

The determinants of labour productivity as presented in the theoretical framework have been the subject of numerous studies already. Previous findings on the determinants of labour productivity are discussed hereafter. First, earlier studies to the effects of human capital in the form of education are examined. Afterwards, studies to the influence of capital and total factor productivity on output are discussed.

A lot of research has been done on the effects of education on economic growth. Barro (2001) conducted research on the effects of education in hundred countries between 1965 and 1995. He showed that growth is significantly related to average schooling years of adult males in a positive way. The human capital stock thus has a positive effect on the productivity of labour. The research also compared similar international test scores between nations on several subjects to say something about the quality of education. A higher average score on a science test was significantly related to higher growth (Barro, 2001). Other researchers found difficulties in explaining growth by both human capital stock and human capital quality. According to Hanushek (2013), while developing countries have gained a lot in school attainment their growth often cannot be contributed to that matter. Quality of schooling seems to be much more important. A Chinese study handled this difficulty in another way. When investigating the human capital stock on a city basis, it was possible to show the positive effect of the human capital stock on growth (Yaqin & Zhiqiang, 2015). They concluded that a lot of the effects of the human capital stock may get lost when aggregating data to a broader level. There is however a lot of evidence that on an individual level, higher education of a single person provides a higher income for that person (Card, 1999). If the total workforce in the manufacturing sector is an aggregate of those individuals then it is possible to assume that higher education leads to higher total output.

The second factor that influences labour productivity in the presented theory is the capital/labour ratio. This is the amount of capital that is used per labourer. Capital deepening itself can also be regarded as the growth of the total capital stock. Case studies for 75 countries between 1960-2000 and three Middle-Eastern countries after the discovery of oil both find that GDP growth is causally related to capital accumulation (Bond et al, 2010; Darrat, 1999). Thus, the growth in capital most likely has a positive effect on the labour productivity growth which is compatible with the theory. In a study that analysed the differences of labour productivity growth between several countries it was found that the growth in capital itself however, is influenced by varying government policies and social infrastructures (Hall & Jones, 1999).

In the Netherlands, capital growth slowed after the oil-crisis of 1973. Caselli et al. (2003) showed that in the last fifty years of the 20th century Dutch capital accumulation as a percentage of GDP was on average 5% before 1973 and around 1.5% after the oil crisis of that year. This diminishing capital deepening seemed to have an effect on the growth of labour productivity. A study to the gap in productivity growth between Europe and the United States concluded that the high growth in the United States was mainly due to high investment in that area, implying that capital accumulation has a positive effect on labour productivity (Ark, O'Mahony & Timmer, 2008). Another study by Salvador, Musso, Stocker and Turunen (2006) found robust evidence by studying the slowing pace of labour productivity growth in Europe in the late 90's that labour productivity slowed because capital deepening and the growth of TPF slowed. A report for the European Commission added on the same subject that capital deepening itself slowed because the European economies moved more and more from manufacturing industries to service industries (Carone et al., 2006). Service industries tend to be more labour intensive because of their social and interactive nature where customer contact is an important aspect. When only studying the manufacturing sector the slowdown of overall capital deepening is therefore less important. To conclude: several studies thus state in favour of the theory presented above that capital deepening has a positive effect on labour productivity. For Europe however in a declining rate if one looks at the whole economy, including other sectors than solely the manufacturing sector.

The last part of the function as described in the theoretical framework is the total factor productivity. It accounts for changes in labour productivity growth that cannot be explained by capital accumulation or human capital. Technological change is therefore embedded in TFP. Salvador et al. (2006) found robust evidence that labour productivity in Europe slowed because of the slowing pace of TPF growth. This indicates a positive relation between TPF growth and labour productivity growth. Comparably, Ark et al. (2008) found in their study to the productivity gap between the United States and Europe that Europe lacked productivity growth because multifactor productivity growth in particularly trade slowed. It is therefore legitimate to assume that TFP has a positive effect on the labour productivity. This is in accordance with the presented theory.

3.3 Size of labour productivity determinants

Several studies have tried to identify the relative importance of the different determinants of labour productivity. In a study on combinations of the effects of technological change, technological catch-up and capital deepening, Kumar and Russel found that it is primarily capital, as opposed to technological change or human capital, that is responsible for the growth in output per worker (Kumar & Russel, 2002). Another study on differences in growth between U.S states found results that make a difference between total output and output per worker. Capital accumulation accounted for most of the total output growth in all the states but TPF accounted for three-quarters of the differences in output per worker growth per state(Turner & Tamura, 2013). That TPF explains the largest part in differences per country is confirmed by a study to differences in labour productivity per country that found that the biggest part of those differences should be explained by the Solow residual, which is a measure of technological change (Hall & Jones, 1999). This might imply that opposed to capital accumulation, TFP is the forecast element that gets the largest share in forecasting future labour productivity. Schwerdt and Turunen (2007) at least agree with the previous mentioned studies that human capital is not the most important share of labour productivity. According to their research the share of labour quality, which is a broader definition of the skills a worker has than human capital, in explaining labour productivity is relatively small, but growing, opposed to TPF and capital deepening. Because labour quality is a term that encompasses more than human capital, human capital probably only has a small share in forecasting labour productivity.

3.4 Previous studies that forecasted determinants of labour productivity

Previous studies already forecasted the determinants of labour productivity in the future. The future values of educational attainment levels for several countries have been forecasted by KC & Lutz

(2017). In order to do so, they used Shared Socioeconomic Pathways (SSPs) and these will be briefly explained hereafter for a better understanding. In an attempt to analyse the impact of future developments on climate change, the climate change research community developed these SSPs (Riahe et al., 2017). For five different future worlds they constructed plausible storylines that can be used in forecasting all sorts of developments. The five different states of the world have been explained by O'Neill et al. (2012) and are briefly summarized here as they are used more often in this paper.

The first world, SSP1, is a world that makes a good effort in challenging sustainability problems in the future. There is high investment in education worldwide and inequality diminishes with respect to income and education. Consumption is less oriented towards material gain than nowadays. The second world, SSP2, is a business as usual world. The world changes at historic rates. Growth in education, consumption and income change likewise. Growth speed is determined by current trends. SSP3 is characterized by a fragmented world. Countries turn inwards, which has a dampening effect on economic growth. Institutions change unfavourably for economic growth. The same world but worse is envisioned in SSP4. Inequality grows in this world and investment in education is low. The last world, SSP5, is a world that is mainly conventional. Social issues are solved by an emphasis on economic growth and self-interest. This world does not face many socioeconomic challenges.

KC & Lutz (2017) used this different SSPs to forecast demographic scenarios up to 2100 for 195 countries. By doing so they also constructed a forecast for educational attainment of the Dutch population up to 2100. For example, the higher educated share of the male population between 60 and 64 is around 39% in the pessimistic SSP3 scenario and 54% in the optimistic SSP5 scenario.

There have been several attempts at the difficult task of forecasting TFP. Wang and Fernald (2015) made such an attempt. Because 75% of the past decades, apart from the decades after recessions, showed a TFP growth of around 1.5% they claim that future growth must be at least that figure. But they also claim this figure neglects the IT-revolution between 1995 and 2003 that might be re-accelerating after the 2008 crisis. Taking this into account, they believe that TFP growth should be at least 1.9% per year. On the one hand it is possible to say that IT until now has been less important than previous technological revolutions, on the other hand they claim it is easy to imagine that IT its possibilities are still underdeveloped.

This claim can be supported by findings of Oliner & Sichel (2013). They see a reasonable prospect that the labour productivity growth can exceed its long-run average level. Based on, amongst other things, the still developing sectors that were key ingredients to the IT-revolution in the first place. For the case study of this paper some evidence can also be found in recent growth figures of the IT-sector in the Netherlands. The CBS concluded that IT-consultancy and services almost doubled between 2007 and 2017 and is still growing (CBS, 2017). This indicates that the market still sees possibilities for technology improving IT-solutions for other companies.

The previously mentioned study by Dellink et.al (2015) to several macroeconomic growth rates showed lower rates for TFP growth. They used the previously mentioned SSP scenarios and concluded that they should use a long-term TFP growth rate between 0.7% as a base line scenario and 0.35% and 1.05% for a lower and a uppercase scenario respectively. Another sceptic of continuing TFP growth is Gregory Clark. He believes that the output of the manufacturing sector decreases, as opposed to services, and because manufacturing output is generating the most R&D expenditures, TFP decreases as well (Clark, 2016).

There have not been done many studies yet on forecasting the future of the capital labour ratio. The rationale behind future values of this ratio is explained in the data section of this paper.

4 METHODOLOGY

The research question is stated as: *"Will human labour become obsolete in the manufacturing sector of the Netherlands by 2100?"* To answer this question, the theoretical framework in section 3 is used together with a two-step procedure. First, using regression analysis, the relation between labour productivity and its determinants is estimated for past values. Second, the coefficients derived from the first step are used to forecast the future labour productivity.

For the first step, equation 2.1 for labour productivity is used to determine the past values. That variable is called LP. The independent variables of the regression equation are constructed like equation 2.6. They consist of the log of total factor productivity TFP, capital intensity CL, the difference in capital intensity and human capital as HCT instead of LH. The last one is defined as the share of higher educated workers in the labour force. LL of equation 2.6 is deliberately left out because a rise in the share of higher educated persons should be equal to a decline in the share of the not higher educated workers. At last, the lag of labour productivity is added to the equation. This is done because labour productivity is a persistent phenomenon. The following equation based on equation 2.6 is estimated:

$$\ln(LP_t) = c_t + \beta_1 \ln(LP_{t-1}) + \beta_2 \ln(TFP_t) + \beta_3 \ln(CL_t) + \beta_4 \Delta\ln(CL_t) + \beta_5 \ln(HCT_t) + e_t$$

equation 4.1

Here, the log of labour productivity in the manufacturing sector is dependent on the log of the lagged labour productivity and determinants TFP, CL, HCT, the difference of the log of CL, a constant c and the error term e. Regression analysis is used to estimate the parameter values β_1, β_2, β_3, β_4 and β_5 besides the constant term. These parameter values, or coefficients, then indicate with how much percent labour productivity rises if one of the independent variables increases with one percent. The coefficients are used to forecast labour productivity with supposed future values for the independent variables as given in the regression equation. This is the second step of the procedure.

In the second step of the procedure the estimated coefficients are used to forecast the labour productivity of the manufacturing sector up to 2100. This is done by inserting presupposed values for $\ln(LP_{t-1})$, $\ln(TFP_t)$, $\ln(CL_t)$, $\Delta\ln(CL_t)$ and $\ln(HCT_t)$ into the estimated equation 4.1. For every one of these independent variables a baseline scenario is constructed next to a lower case or pessimistic and an upper case or optimistic scenario. For the differenced variable $\Delta\ln(CL)$ the scenarios of $\ln(CL)$ are used. A detailed description of the values of these variables in the future for all the scenarios is given in the data section, as well as an explanation for the choice of the lower, base-line and upper case scenarios. The constructed independent variables are used together to predict the productivity of labour in the future. For these predictions it is assumed that government institutions either do not change or change in favour of capital markets over time. It was explained earlier that institutions influence the productivity through the effectiveness of capital (Bergeaud, Cette & Lecat, 2015).

The future values of the independent variables are denoted by TFP, HCT and CL with a number for the scenario. TFP1, HCT1 and CL1 represent the values for the lower case or pessimistic scenarios. TFP2, HCT2 and CL2 represent the future values for the baseline scenarios, and TFP3, HCT3 and CL3 represent the values for the optimistic or upper case scenarios. The future values of the independent variables for every scenario are then used together with other independent variables for the same scenario to come to a conclusion for the labour productivity in each one of the three scenarios. It is not always possible to use different scenarios for the independent variables as they sometimes are derived from different SSPs. These SSPs are different scenarios for the world and it is impossible that different worlds exist at the same time.

For all the scenarios, labour productivity is then forecasted up to the year 2100. After a value of labour productivity per person is obtained, it is compared with the value of labour productivity in 2007, before the economic crisis. It is then possible to say something about the amount of people that can be substituted by one person. If labour productivity in 2100 has risen up to a level as large as all manufacturing production nowadays, we assume that no more workers are needed and all work can be done by one person. This means that this study assumes that the output of the manufacturing sector does not change from 2007 to 2100. In the end the next hypothesis is either accepted or rejected:

H1: *"Labour productivity of one person in the manufacturing sector in 2100 is as high as the gross output of the manufacturing sector in 2007."*

This one person can be seen as the one that presses a button which gets the whole manufacturing system working. If this is not the case it is still possible to make some remarks about the need for people in the manufacturing sector up to 2100. For such an analysis the ratio of the labour productivity in any year vis-à-vis the labour productivity in 2007 is used. With this ratio it is possible to say how many workers can be substituted by one. It is then possible to say how much fewer people are needed to do the same work as is done nowadays.

5 DATA

This data section first describes the collection, properties and particular details of the data necessary in estimating the regression equation. This is the so-called historical data used in this research. Thereafter, the collection of future data is discussed: how this data is constructed and why it is appropriate data for forecasting the determinants of labour productivity in the future.

5.1 HISTORICAL DATA

For the first step of the presented method, estimating the regression equation, past values of the output of the manufacturing sector in the Netherlands are needed together with the amount of persons employed in that sector. This data is collected from the STAN Rev. 3 Database of the OECD (OECD, 2014). The database provides a number of persons employed in the manufacturing sector in the Netherlands for the period 1970-2009 on a yearly basis. It turns out to be the smallest restrictive dataset for all the variables in this research. Therefore, the period for all the historical data mentioned hereafter runs from 1970 to 2009 and is collected on a yearly basis. The same dataset also provides the gross output of the manufacturing sector in the same period at current prices in euros. When the total gross output in the sector is divided by the amount of persons working in the sector the variable labour productivity per person working in the manufacturing sector is constructed, referred to as LP. This variable shows an average growth of 11% up to 1984 and an average growth of 3% for the period thereafter. The growth is slightly accelerating before the crisis and there is a decline in labour productivity after the 2008 crisis. LP is shown in figure 5.1 for the period 1970 to 2009.

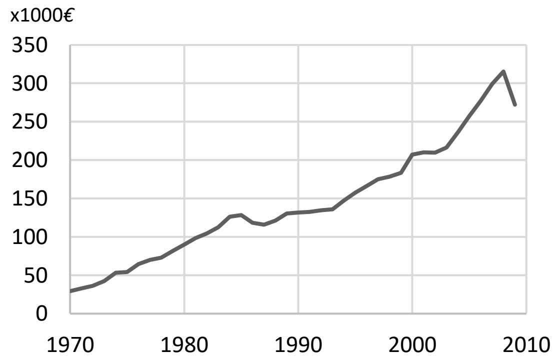

Figure 5.1: LP.

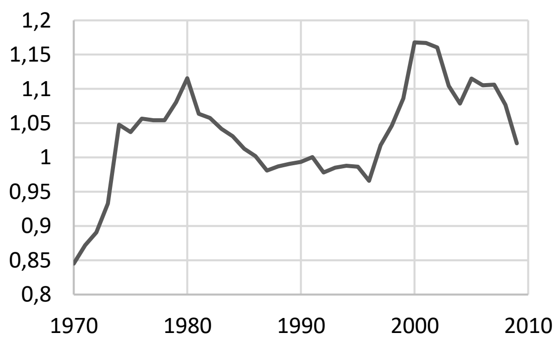

Figure 5.2: Dutch TFP as index.

Next to LP, past values for TFP are needed for the first step. The Groningen Growth and Development Centre provides a database with historical TFP-values for the Netherlands. This data is collected from the Penn World Table 9.0 (PWT 9.0) (Feenstra, Inklaar & Timmer, 2015). The TFP used in this research is a TFP level at current PPP denoted in PWT 9.0 as ctfp. The index for TFP shows growth in the period 1970 to 2009, visible in figure 5.2. However, after a peak in both 1980 and 2000 TFP shows declining values. This is consistent with research discussed in the previous sections about TFP (Salvador et al., 2006; Ark et al., 2008).

The Capital Labour ratio CL is computed for the sector level and graphed in figure 5.3. This data comes from the STAN rev. 3 Database as well. The database provides the amount of persons working in the manufacturing sector as well as the gross fixed amount of capital in that sector. The ratio is then computed by simple division. It shows an average annual growth of 4% for 1970 to 2007. Furthermore does the growth in the ratio accelerate right before a slow-down in respectively 1984-1985 and 1994-1996.

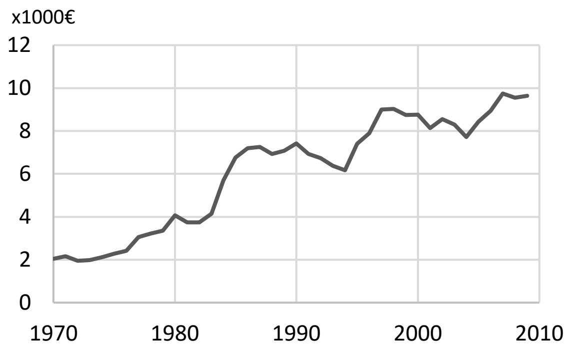

Figure 5.3: CL-ratio in euros per person.

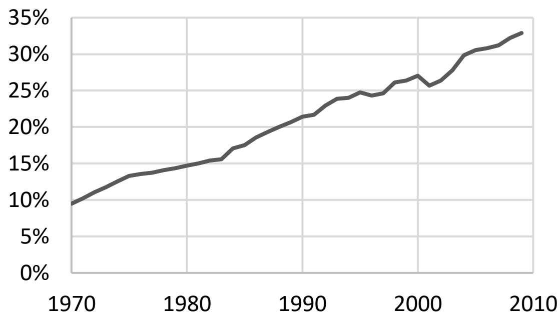

Figure 5.4: Higher educated workforce in %

In this research human capital is represented by shares of the total labour that obtained higher education measured by Dutch qualifications for higher education. Which is all education after high-school that is not vocational education. The data is collected from a dataset of the CBS about the labour force (CBS, 2014) and graphed in figure 5.4. Conveniently, CBS collects the amount of people in the labour force sorted by their highest qualification. This data is converted to shares of higher educated people in the workforce. In the dataset of the CBS higher education is denoted as Hbo and Wo. These figures are used as higher education for this research as well. Figure 5.4 shows that the share of higher educated persons in the Dutch workforce is steadily increasing.

5.2 FUTURE DATA AND ASSUMPTIONS

For the future of human capital it is possible to use the extensive analysis by KC & Lutz (2017). They converted the Shared Socioeconomic Pathways (SSP) storylines into demographic scenario's. These SSP's can be considered as scenario's for the future evolution of society. They are constructed as reference pathways that describe the most plausible alternative developments for the society for the entire 21st century (O'Neill et al., 2013). For five different SSP's KC & Lutz computed among other things the population size and education attainment level of the population of 195 countries. By doing so they also constructed a forecast for the educational attainment of the Dutch population up to 2100. For every scenario the data set provides an amount of people in every age-group by gender that have obtained either primary, secondary or tertiary education.

In this study, the data up to the year 2100 for all age-groups from 20 to 69 are summed. The amount of working age people that obtained tertiary education in every SSP is then divided by the amount of all working age to get the respective shares. The most pessimistic, average and optimistic scenarios are used as future variables. The results are depicted in figure 5.5. below.

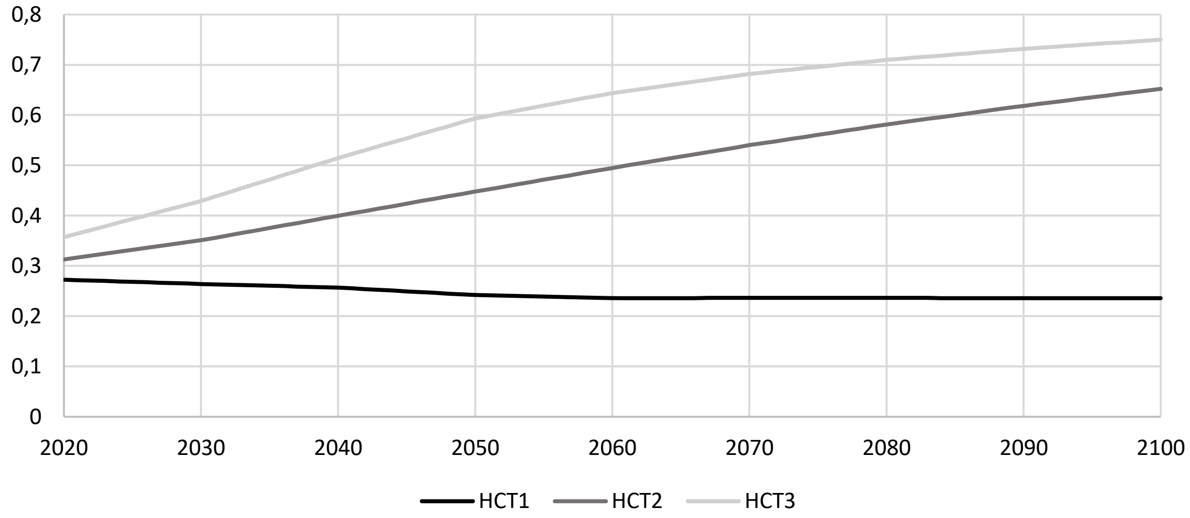

Figure 5.5: Share higher educated workforce in the Netherlands for three scenarios up to 2100.

In this study data from SSP4 by KC & Lutz is the pessimistic scenario, SSP2 the baseline scenario and SSP1 the optimistic scenario. As future variables for three different scenarios they are denoted as HCT1, HCT2 and HCT3 respectively. In the pessimistic scenario HCT1, the share of higher educated people in the Netherlands actually declines up to 2050. By then there is only a small elite of higher educated people of around 23% of the population. This share roughly stays the same up to 2100. In the baseline scenario the share of higher educated people increases to 65% by 2100. In the optimistic scenario the share of higher educated people increases rapidly up to 60% by 2050. From 2050 to 2100 it increases even further, but relatively slow, to 75%.

As mentioned earlier capital growth rates for the Netherlands were different before and after 1973. These growth rates are studied by Caselli et al. (2003) with data from an OECD International Sectoral Data Base (ISDB). In this research the growth rates derived by Caselli et al. (2003) are used while acknowledging the Kaldor Stylized facts (1973). The Kaldor fact states that that growth of capital remains constant over time. Though this is different from the findings of Caselli et al. it is considered to be true for longer periods of time. The growth rates are used in three different ways.

First, in a pessimistic scenario the average growth of capital in the Netherlands after 1973 is used to forecast. It is then assumed that the growth before 1973 was exceptional and the growth does not change anymore in the future. For this scenario the assumption is made that the institutions that regulate capital remain the same as in the period 1973-2000. They do not change in the future or in a way that is neutral for the capital markets. In this scenario CL1 capital grows with 1.5% every year. For CL1, the capital per labourer by 2100 is roughly 35,000€.

For the optimistic scenario it is then assumed that the growth from 1950 to 1973 is long-run growth and corresponds to the long run stylized Kaldor fact. The average capital growth between 1950 and 1973 returns because of changing institutions. The optimistic scenario assumes for example that the European Union will create a capital market with lower burdens in favour of free capital movements. The Dutch capital markets are not optimally efficient now but are so in the future at a rate of 5% again. For this scenario, CL3, it is thus assumed that institutions do change in the future and are not neutral for the capital markets. By 2100, the amount of capital for each labourer is about 890,000€.

The baseline scenario is constructed by using the average capital growth between 1950 and 2000. Variations between 1.5% and 5% are assumed to be common for the Netherlands but the long run capital growth lies in the middle at 3.3% For this scenario it is thus assumed that institutions are not always neutral but on average they act and change in such a way that capital growth is around 3.3%. For CL2 the amount of capital per labourer by 2100 is roughly 190,000€. All three growth scenarios are shown in figure 5.6.

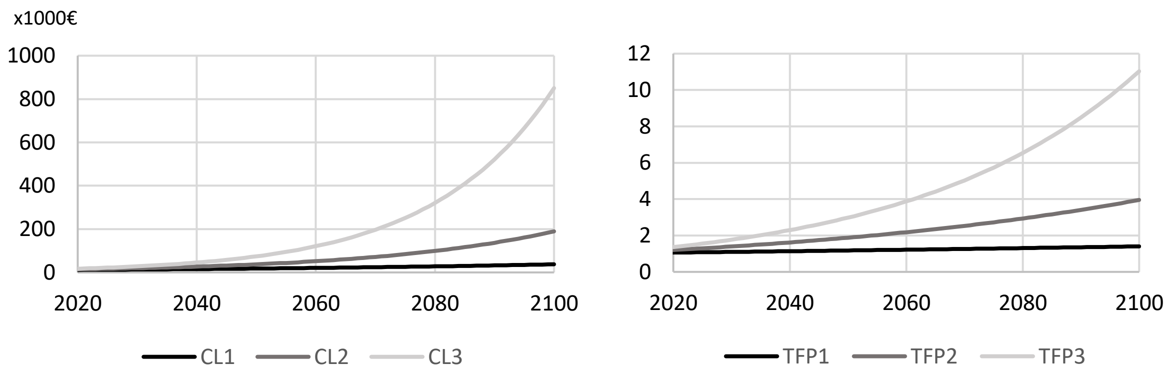

Figure 5.6 & 5.7: Showing three growth scenarios for CL (per person) and TFP (as index) respectively.

Then the last determinant of labour productivity, total factor productivity, needs to be discussed. It was mentioned in section 3 that there have been several attempts in forecasting TFP. Wang and Fernald (2015) claimed that TFP growth must be at least 1.5%. However together with Oliner & Sichel

(2013) they believed it could easily be higher because of an ongoing and still developing IT-revolution. A study by Dellink et. Al (2015) established a pessimistic scenario of only 0.35% TFP growth.

This study takes all this into account and constructs a lower case scenario of 0.35% TFP growth in the future, a baseline scenario of 1.5% TPF growth assuming that the IT revolution is over and the growth of TFP is lower than its long term average and a higher case scenario of 2.65%. The latter is constructed in such a way that the difference between the optimistic and the base line scenario can be related to the difference between the pessimistic and the baseline scenario. All three scenarios are graphed in figure 5.7.

At last, to test hypothesis 1, a value for the total manufacturing output in 2007 is needed. It was already mentioned that output from the manufacturing sector is measured as gross output. This data is collected from the STAN Rev. 3 Database again. The gross output of the manufacturing sector is roughly 278 billion euros.

6 RESULTS

To begin with, the results of several test validating the data are presented. Then the choice for a regression estimation is discussed and thereafter several diagnostic tests on the model. The results continue with the forecast of labour productivity for the future and an analysis of possible job loss in every scenario.

6.1 ESTIMATING THE REGRESSION EQUATION

The first step for this study is to estimate a regression equation by using the historical values of the log of labour productivity and its determinants. To arrive at an appropriate model, all variables have been tested for a unit root. This has been tested with an Augmented Dickey-Fuller test (ADF), from which the results are depicted in table 6.1. Only the log of the capital labour ratio shows a unit-root. The test-statistic is not lower than its 5% critical value. Therefore the null-hypothesis that the variable contains a unit-root cannot be rejected. The differenced ln(CL) is stationary and can be used in the analysis.

	Test	Z-statistic	5% critical value	p-value
ln(LP)	ADF	-3.676	-2.961	0.005
ln(TFP)	ADF	-2.990	-2.961	0.036
ln(HCT)	ADF	-8.232	-2.961	0.000
ln(CL)	ADF	-1.610	-2.961	0.479
ln(CL)	ADF, (allows for trend)	-1.105	-3.544	0.928
Δln(CL)	ADF	-4.716	-2.964	0.000

Table 6.1. Tests for non-stationarity

An correlogram of the log of the labour productivity in the manufacturing sector (LnLP) gave an indication that the variable was autocorrelated. This correlogram is added in the appendix. Because of the autocorrelation, the first lag is included in the final model. This lag is defined as LnLPL1.

After checking for stationarity and autocorrelation, the empirical model is first estimated with the non-stationary variable ln(CL) included according to equation 4.1 from the methodology. The results of this model are depicted in table 6.2. The table contains the values of the estimated coefficients for all variables from equation 4.1. In the parentheses the standard errors are shown. These are heteroskedasticity-robust standard errors. They allow the fitting of a model that contains heteroscedastic residuals. From table 6.2 it is visible that the non-stationary variable ln(CL) is insignificant. As an insignificant variable it has no use in forecasting labour productivity later on so therefore it will be excluded from the model to forecast labour productivity. The model without the insignificant ln(CL) is estimated for several subperiods. The results are depicted in table 6.3. The first column depicts the estimated coefficients for the whole sample period from 1970-2009. The second column shows the results for a sample with 10 fewer years included. It would be consistent to fill the third column with again an estimation based on 10 fewer year but this would leave us with less than 20 periods to base the regression on.

	Coefficient
LnLP	
L1.	0.776***
	(0.103)
LnTFP	0.473**
	(0.220)
LnHCT	0.333***
	(0.104)
LnCL	-0.040
	(0.084)
ΔLnCL	0.167*
	(0.086)
constant	3.535***
	(0.950)
T	39
R^2	0.9940

Robust standard error in parentheses, ***=P<0.01, **=P<0.05, *=P<0.1

Table 6.2: equation 4.1 estimated

The third column therefore, depicts the period 1989 to 2009. The time period for the third column is rather short. The results of this regression should thus be interpreted with caution. In the last column the results are shown for a timeframe where the economic crisis of 2008 is excluded.

A comparison between table 6.2 and 6.3 shows for the two longest periods with 39 and 37 years of data only a small difference in the values for the coefficients. It gives an indication that the non-stationary variable ln(CL) does not change and influence the model a lot whether it is included or excluded.

Table 6.3. furthermore shows that the coefficient values are higher for the smaller periods with the crisis year 2008 included. The coefficient values of the first and the last column are the most alike. The least alike are the estimated coefficients for 1989-2009 but those values are from a period that is almost too small to estimate. All variables except for ΔLnCL show at least a 5% significance value in every period. The significance therefore, is robust for the sample size. The variable ΔLnCL is significant for the 5% level only in the 1980-2009 time frame. In all other periods it is only significant for a 10% level. If the R-squared values

of the different timeframes are to be compared, then the last column shows the highest value that is slightly higher than the value of the first column. The period 1970-2007 therefore has the most explanatory power and is used for forecasting the future labour productivity in this study.

Variables / Sample	1970-2009	1980-2009	1989-2009	1970-2007
LnLP				
L1.	0.744***	0.677***	0.559***	0.763***
	(0.068)	(0.121)	(0.151)	(0.068)
LnTFP	0.531***	0.751***	0.599**	0.457***
	(0.153)	(0.250)	(0.314)	(0.147)
LnHCT	0.326***	0.373**	0.765***	0.305***
	(0.107)	(0.141)	(0.203)	(0.110)
ΔLnCL	0.156*	0.252***	0.228*	0.158*
	(0.083)	(0.079)	(0.116)	(0.080)
constant	3.552***	4.415**	6.371***	3.292***
	(0.950)	(1.64)	(2.060)	(0.973)
T	39	29	20	37
R^2	0.9940	0.9849	0.9768	0.9946
Robust standard error in parentheses, ***=P<0.01, **=P<0.05, *=P<0.1				

Table 6.3: estimation results for 4 different sample periods.

To test this model several econometric tests are performed with the results depicted in table 6.4. The error terms of the 1970-2007 model are tested with a Breusch-Godfrey and Breusch-pagan test. The first tests for autocorrelation of the error terms, the latter tests for autocorrelation of the variance of the error terms, or heteroskedasticity. The results of these tests are presented in table 6.4. For the Breusch-Godfrey test, the null hypothesis that states there is no serial correlation in the error terms cannot be rejected with a chi-value of 0.177 and a p-value of 0.674. The test thus concludes in favor of the used model that there is no significant autocorrelation of the error terms. For the Breusch-Pagan test a p-value of 0.510 is obtained(chi2 = 3.29). This means the null hypothesis that states there is homoscedasticity cannot be rejected. Therefore it is assumed that there is no significant heteroskedasticity in the model.

	Test statistic	**P-value**	**H0**
Breusch-Godfrey	chi^2 = 0.177	p = 0.674	no serial correlation
Breusch-Pagan	chi^2 = 3.29	p = 0.510	homoskedasticity

Table 6.4. Results for diagnostic tests.

The tests thus do not disqualify the model. Before going to the next step of forecasting, is possible to discuss the coefficients of the 1970-2000 model shown in table 6.3. Because the coefficients are in ln values it is possible to say something about the influence of every coefficient. A one percent increase in the labour productivity in the previous year leads to a 0.763 percent increase of the labour productivity in the current year. A one percent change in TFP or HCT of the current year leads to respectively a 0.457 and a 0.305 percent change of the labour productivity in the current year. The elasticity of labour productivity in the manufacturing sector with respect to TFP and HCT is thus respectively 45.7% and 30.5%. A one percent change of the difference of CL leads to a 0.158 percent change in the labour productivity. We thus conclude that growth or decline in labour productivity is for 76.3% driven by its previous value and for the other part by changes in the other determinants discussed.

6.2 FORECASTING LABOUR PRODUCTIVITY

The second step of this study is to forecast the labour productivity in the future with the estimated regression equation. The regression of table 6.3 for the period 1970-2007 is used. The formula that is constructed from the model is given by equation 6.1, where the log of labour productivity in the manufacturing sector at time t is given by an initial value of 3.292 and a sum of its other determinants:

$$\ln(LP_t) = 3.292 + 0.763 * \ln(LP_{t-1}) + 0.457 * \ln(TFP_t) + 0.305 * \ln(HCT_t) + 0.158 * \Delta\ln(CL_t)$$

equation 6.1

For every t up to 2100, the log of labour productivity is computed. Those values have been transformed to non-ln values so they can be measured in euros, the antilog has been taken. Table 6.5 shows the computed labour productivity in euros for five respective years in the future. The ratio between the future value and the value of labour productivity in 2007 is computed for comparison. That ratio is depicted in italics.

Scenario Year	Lower	Base	Upper
2020	227,142.55	323,489.14	456,564.03
	0.76	*1.08*	*1.53*
2040	240,269.41	742,160.47	1,860,215.46
	0.80	*2.48*	*6.22*
2060	246,366.13	1,753,054.75	7,063,936.01
	0.82	*5.86*	*23.61*
2080	279,192.02	3,534,543.46	22,353,618.70
	0.93	*11.82*	*74.72*
2100	319,152.40	8,032,541.04	66,249,424.14
	1.07	*26.85*	*221,46*

Table 6.5: Labour productivity for five periods together with the ratios vis-a-vis 2007 in italics.

What stands out in table 6.5 is that in the lower case scenario labour productivity in the manufacturing sector does not increase at all. This is mainly due to a decline in the share of higher educated people in the workforce in the pessimistic scenario. Furthermore, this scenario is characterized by a small elite of only a little more than 20% that is tertiary educated. TFP reaches an index in 2100 of 1.4. There has not been an IT-revolution or much technological change in this scenario. Capital grows in this world with a meagre 1.5% on a yearly basis. This positive effect together with the positive effect of an increase in TFP brings labour productivity back to the 2007 level by 2100. An average person in the manufacturing sector only produces 1.07 times as much as a person in 2007 and has a productivity of around 319 thousand euros. In figure 6.1. the development of labour productivity in the lower case scenario is graphed together with a 90% prediction interval. According to this model for the 90% prediction interval, labour productivity is in between 280,000€ and 350,000€ by 2100 in the lower case scenario.

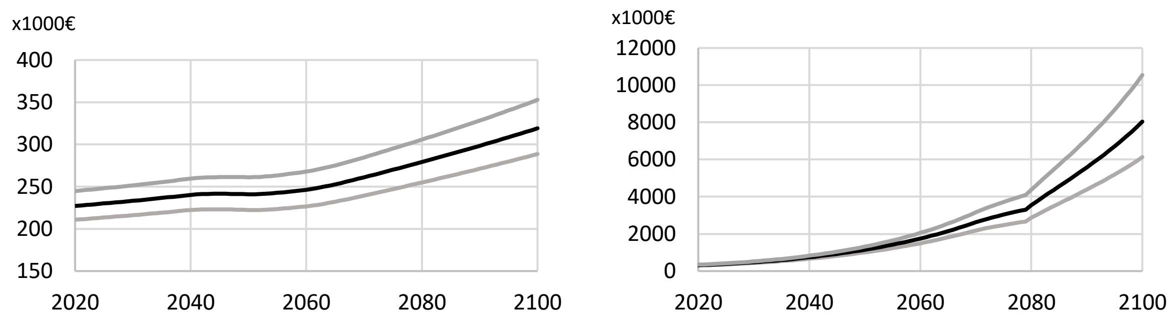

Figure 6.1 & 6.2: showing the labour productivity in the lower case and baseline scenario respectively.

In the baseline scenario things look rather different. The education level of the workforce has increased. 65.2% Of the workforce is higher educated by 2100. Overall, development trends stay as they were at the beginning of the 21st century. Technological development occurs, but at its regular pace as before 2000, not in the form of any sort of technological revolution. Capital grows with 3.3% on a yearly basis. The labour productivity of a worker in the manufacturing sector more than doubles every twenty years. In 2100 it reaches a value of more than 8 million euros per person. In figure 6.2. the development of labour productivity in the baseline scenario is graphed together with a 90% prediction interval. It is safe to say for the 90% prediction interval, labour productivity is between 6 and 10,5 million euros by 2100.

If we assume that the Netherlands does not need any more manufacturing output than it does today it is possible to calculate the percentage of jobs that become obsolete. With a future/2007 ratio it is visible how many workers can be substituted for one. A ratio of 26 in the baseline scenario for 2100 basically states that 25 out of 26 workers become obsolete as their work can be done by the other one. This means that 96% of people that work in manufacturing today are obsolete by 2100. The results for this assumption and way of thinking are depicted as a graph in figure 6.3 for all three scenarios together with the 90% prediction intervals. The upper and lower bounds of the prediction intervals are shown by grey lines. The prediction intervals of the scenario forecasts do get more uncertain and therefore wider towards the future as is shown by figures 6.1, 6.2. and 6.4. However, because figure 6.3. depicts the results after a calculation which does not allow for values at or above

100% and the calculation is done after the forecast intervals for the labour productivity in every scenario are computed, it does not get wider. The figure shows that in the baseline scenario half of all workers would lose their jobs by 2035 already. At the lower and the upper bound of the prediction interval for the baseline scenario, 80% of all workers in the manufacturing sector will lose their job by 2060.

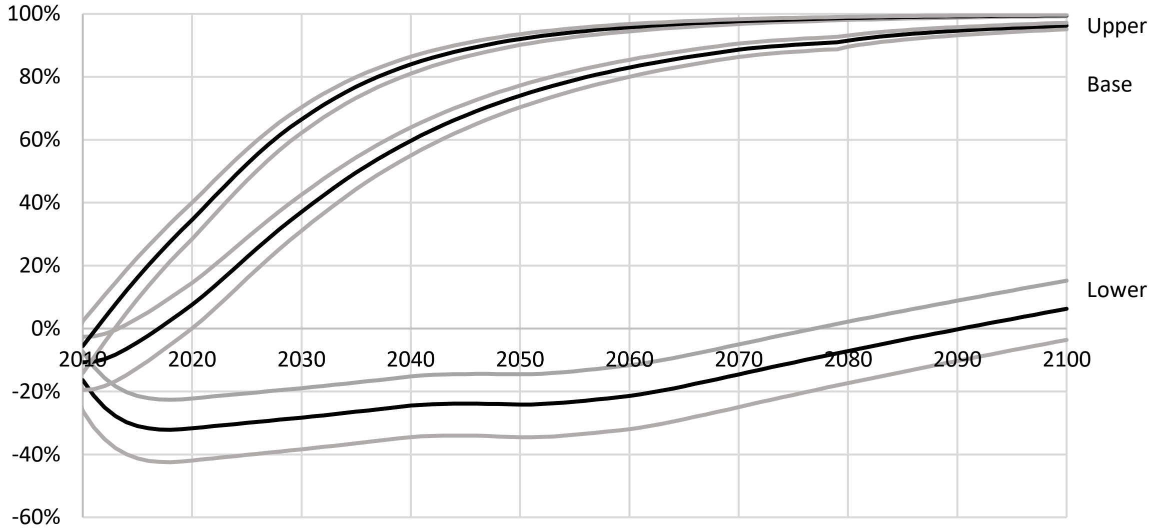

Figure 6.3: The percentage of job loss in the manufacturing sector for three scenarios.

An attentive reader might note that for the lower case scenario the model forecasts a need for extra workers of more than 20% by 2020. This seems rather odd for the state of the manufacturing sector in the Netherlands in 2017. The reason the model makes this prediction is because the share of higher educated people in the pessimistic SSP is predicted lower for 2020 than it already is nowadays. However, for the future it might still be true the share of higher educated people declines because of a cut in school funding for example. There is no need therefore, to exclude this scenario right away.

In the upper case scenario the share of higher educated people is 10% bigger than in the baseline scenario. It predicts that by 2100 75% of people is higher educated and besides, TFP increases a lot in accordance with the assumptions of this study. It was stated that for the uppercase scenario a new IT, AI or robotic revolution awaits. The last determinant of labour productivity, capital, grows at a high rate in this scenario as well. This leaves a worker with a productivity of more than 66 million euros per person in 2100. That is about 221 times the labour productivity of 2007. In figure 6.4, the graph of the upper case scenario is depicted with a 90% prediction interval. In the upper case scenario, labour productivity will be between 40 and 111 million euro by 2100. Following the same reasoning as earlier, it is possible to conclude that by 2100 around 99.5% of workers lose their job in the manufacturing sector. This figure is already about 80% in 2040. The upper case scenario furthermore forecasts that labour productivity more than triples every 20 years.

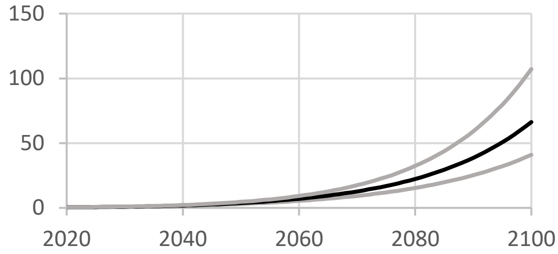

figure 6.4: productivity growth, upper case scenario

In every case, labour productivity of one person is not as high as the total output of the manufacturing sector by 2007 (278 billion euros). Hypothesis one stated that***:*** *"Labour productivity of one person in the manufacturing sector in 2100 is as high as the gross output of the manufacturing sector in 2007."* For every scenario, this hypothesis can be rejected. Up to 2100 there are still people needed in the manufacturing sector but their number declines very rapidly in the upper and baseline scenarios.

7 DISCUSSION

A lot is uncertain when forecasting the future. One might even argue it is an impossible task by definition. With significant relations between variables however, some stories become more plausible than others. But the problem is still in the assumptions. This research presents values for the labour productivity in the manufacturing sector with given values for future determinants. Values that only present their true selves when it really is the future. Those values and the assumptions of this research are discussed in this section together with possible suggestions for further research.

The first obvious shortcoming is in the historical and future variable for human capital. Both the past and future values are based on the whole workforce. Any disparity between the higher educated share of the manufacturing workforce and the total workforce might render different results for the labour productivity in 2100. There is however no data available on future educational attainment levels for the manufacturing sector in the Netherlands. To be consistent historical data on attainment levels for the whole workforce have been used as well. If one wants to perform even more substantial forecasts for labour productivity, it is a suggestion to study the future of higher education in the manufacturing sector as well.

Another problem was mentioned regarding the assumptions. To be able to say something about job loss in the future, this study relied on two debatable assumptions. First, it was assumed that manufacturing output for the Netherlands is constant for the future. While it indeed might be possible that other sectors such as services or IT-sectors become more important, it is unlikely that manufacturing output doesn't change at all. When underdeveloped countries evolve to mature economies the demand for Dutch manufacturing output might increase in the future. An opposite effect could emerge when the development of underdeveloped countries causes manufacturing industries to be relocated to those places. The assumptions of a constant manufacturing output is thus questionable. The need for manufacturing output in the Netherlands in the future is an interesting topic to investigate on its own. Second, it was assumed that the relationship between labour productivity and its determinants does not change for the future. It might well be that the relation changes in the future which would render different results for the estimated coefficients. When human capital becomes more important than physical capital because of more complex machines for example, the true future coefficients might differ.

Assumptions regarding the future evolution of the values of the determinants (so not the coefficients) of labour productivity used in this study have been more substantiated by previous research. They are therefore more credible but are still assumptions. It is possible to do the same research to labour productivity again when more research to future values for its determinants become available.

Yet another possibility when doing similar research is to include more variables that determine labour productivity. Labour quality was mentioned before in the data section. These are matters such as the age or the suitability for one's job that influence productivity. For a future research to future labour productivity, one might want to incorporate labour quality in human capital besides educational attainment. It is also possible but more extensive to add a variable for the quality of capital. Then TFP becomes TFP adjusted for labour and capital quality. First however, research needs to be done to the future developments of the quality of capital and the quality of labour.

All the aforementioned research possibilities could render the possibility of obtaining more precise coefficients for a regression equation that is even better equipped to forecast labour productivity.

There is one last thing to discuss about the results: intuitively, the predictions for the pessimistic scenario might seem a bit unlikely for a Dutch reader. In this scenario the share of higher educated people in the workforce is as low as 23%. This is lower than the share of higher educated people nowadays which is around 30% (CBS, 2014). With regards to historic trends for educational attainment this would be unprecedented. If one would take contemporary political trends into account however, such as the tendency to let governmental study allowances cease to exist, it becomes more plausible that people would indeed become less educated. Therefore it remains a scenario with relevance not to be forgotten.

8 Conclusion

From the results of this study the answer to the research question is unambiguous. The question was stated as: *"Will human labour become obsolete in the manufacturing sector of the Netherlands by 2100?"* It is clear that this is not the case although the loss of jobs will inevitably be huge. Even in the most optimistic scenario, the Dutch manufacturing sector would still need thousands of workers to produce the same output as in 2007. This research found that in an optimistic, baseline and pessimistic scenario labour in the manufacturing sector would become respectively 221.46, 26.85 and 1.07 times as productive in 2100 as it is was in 2007. Most likely this is going to diminish the amount of jobs in this sector tremendously. If it is assumed that manufacturing output roughly stays the same and increasing wealth and productivity creates other sectors in the economy than it is possible to say something about the job loss in all three scenarios. In the optimistic scenario 99% of all people would need to find a job in a different sector in the long run and even 80% would need to do so by 2040. In the baseline scenario there is more time left. However, even in that scenario by 2040 already, 60% should find another job.

Because all these figures, whether called an optimistic or pessimistic scenario, might sound very pessimistic for someone working in the manufacturing sector it is important to note that 2040 is quite some time away. There is plenty of time to reschool working adults in the in between period. Besides, a lot of people working nowadays are retired by then. Managers could plan maintaining fewer positions together with the retiring of people.

With this research in mind however, it seems plausible that indeed a lot of jobs in the manufacturing sector have disappeared by 2100. Further research could be done to the future of those people that become unemployed. The government might want to know what specific jobs are likely to disappear, what kind of sectors opposed to the manufacturing become more labour intensive in the future or what kind of sectors arise out of the blue. With research answering those questions it is possible for the governments and people to focus their education towards more fruitful sectors. Knowing that job positions in the manufacturing sector declines so much and knowing that already by now it might not even be necessary to reschool people. Acknowledging the problem in the manufacturing sector in advance might solve the problem before people even start to work if prospective students would focus on non-manufacturing jobs. The fear of job loss is however supported by this research that states that for most scenarios plenty of jobs in the manufacturing sector gradually disappear up to 2100.

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10 APPENDIX

LAG	Q	Prob>Q	Autocorrelation
1	34.931	0.000	------------
2	62.690	0.000	---------
3	84.085	0.000	--------
4	100.360	0.000	------
5	112.990	0.000	---
6	122.260	0.000	---
7	129.120	0.000	--
8	133.970	0.000	--
9	137.050	0.000	--
10	138.860	0.000	

Appendix 1: Correlogram of lnLP.