Chapter 10
The Impact of Ageing on Welfare and Labour Productivity: An Econometric Analysis for the Netherlands

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10.1 Introduction

Currently, the ageing population is an important policy topic in many Western economies. Ageing may have a negative impact on welfare because of falling labour supply and productivity, rising demand for healthcare and pension provisions, changing housing preferences and so on. Many countries have taken action to overcome the most obvious problems of ageing by raising the retirement age. Increasing the retirement age is one way of maintaining the proportion of the population working and thus limiting the share of retired people in the population.

If no actions were undertaken, the proportion of workers' income being paid to fund old age benefits would rise strongly given the post-World War II birth wave that started to retire in 2011. As a result, workers' net wages would grow less because a rising share of gross wages would be spent on retirement benefits. In other words, the level of welfare, defined as per capita income, would likely grow only slowly or might even fall. There would simply be fewer working people having to pay for more people in retirement. However, raising the retirement age is not the only possible

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response. Other ways to maintain an appropriate welfare are an increase in annual working hours, a rise in the participation rate or a rise in labour productivity.

The Netherlands has a high level of net labour participation (Auer 2000) but a relatively low number of annual working hours, because about 20% of males and 60% of females work part-time. In fact, Statistics Netherlands reports a falling number of annual working hours per employee over the past 20 years. It has even been said that there is a part-time culture in the Netherlands (OECD 2014b, p. 47 and p. 131). As such, a rise in the annual working hours per worker would seem an obvious candidate to maintain the wealth level (see Noback et al. 2014). Another option, the possibilities of which are the topic of this paper, is to increase labour productivity.

It is also relevant to study if the phenomenon of ageing, and its solution in terms of productivity growth, differs by region. Even in a relatively small country like the Netherlands there can be remarkable variations in the age distribution of its population. Here, Statistics Netherlands reports that, in the peripheral provinces of Friesland, Drenthe, Limburg and Zeeland, the ratio of pensioners (65+) to the potential labour population (20–64) is relatively high and will be increasing from ≈35% in 2014 to ≈62% in 2040. In comparison, in the economic core regions, largely comprising the provinces Utrecht, Noord-Holland and Zuid-Holland, the share of pensioners was around 27% in 2014 and is only expected to reach 46% in 2040. As such, ageing in the peripheral provinces will become a bigger problem than in the economic core due to its much faster growth in an ageing population.

Labour productivity, in terms of GDP per hour, is high in the Netherlands, one of the top 10 global countries in terms of labour productivity levels (van Ark et al. 2010, Table 8). However, the growth rate of labour productivity is rather low in the Netherlands (ibid., Table 5). Although the latest economic crisis, together with congestion problems in the core region, may have had a negative influence on productivity growth, these factors are also present in other countries. According to the OECD (2014a), another possible explanation for this slow growth is the Dutch polycentric city structure that spreads agglomeration benefits across a larger number of Functional Urban Areas (FUAs) and consequently concentrates them less in the largest cities. In the five largest functional urban areas in the Netherlands (i.e. Amsterdam, Rotterdam, The Hague, Utrecht and Eindhoven), the agglomeration benefits and labour productivity growth rates are lower than in other OECD FUAs of similar size (more than 500,000 inhabitants). Focusing on the Netherlands, productivity growth is in fact higher in the peripheral areas outside of the economic core (the Randstad). So, as with ageing, there are also substantial regional differences in productivity growth among Dutch regions. Broersma and Van Dijk (2008) and the OECD (2014a) identified a shift in the highest productivity growths from the core towards peripheral regions at the turn of the millennium, a trend that was found in other countries in northwest Europe by Dijkstra et al. (2013). This study will investigate this matter in greater depth using a new and unique micro-level dataset for the Netherlands that relates labour productivity growth in firms to regional characteristics and to those of workers employed within these firms. In this way, we aim to answer the question as to whether the threat of ongoing ageing, that is particularly present in the periphery, can be compensated for by rising productivity growth in these regions.

This paper is organised as follows. First, Sect. 10.2 provides the motivation for this study and relates it to earlier work in this field. Section 10.3 briefly justifies our model specification in the light of other productivity micro-studies. In Sect. 10.4, we formally derive the specification of our labour productivity growth model that is the basis for this paper. Section 10.5 describes the data and databases at the heart of the empirical part of this investigation. Section 10.6 provides our estimations and test results using these data. Finally, in Sect. 10.7, we draw conclusions.

10.2 Motivation for This Study

An ageing population poses a threat to Western countries in keeping up their level of welfare. There are naturally differences between countries in the extent to which they face the problem of ageing. Ageing is likely to become a particular problem in countries such as Italy, Spain and particularly Japan. In these countries, the ratio of pensioners (over 65) to inhabitants of a working age (20–64) will ultimately reach 70–80% by 2050. In other countries, such as the USA and Sweden, this percentage will also rise, but to much more manageable levels of around 40% in 2050. Figure 10.1 shows ageing, defined as the population older than 64 as a percentage of those aged 20–64, for the Netherlands, the EU-15 countries and the USA between 1950 and 2050. Figure 10.1 shows that the US level of ageing is far below the EU-15 level. What is most noticeable is that, in the period between roughly 2000 and 2025, the Dutch level of ageing will move from the ‘low’ US level to the ‘high’ EU-15 level. This is a very interesting phenomenon and one wonders if there is a specific reason for this? Perhaps, there are regional differences within the Netherlands behind this rise in ageing. If so, are there any differences in regional productivity growth that might counteract or stimulate this rise in ageing?

The threat of ageing to a country, in terms of a lower level of wealth, can easily be assessed using the definitional equation below:

$$\frac{Y}{P} = \frac{Y}{H} \cdot \frac{H}{E} \cdot \frac{E}{P_{15-64}} \cdot \frac{P_{15-64}}{P}, \tag{10.1a}$$

where Y is the real value added, H is the total hours worked, E the employed labour force, $P_{15\text{–}64}$ the population of working age (between 15 and 64), and P the total population. To consider the growth in wealth rather than the absolute level, Eq. (10.1a) can be rewritten as:

$$\Delta\log\left(\frac{Y}{P}\right) = \Delta\log\left(\frac{Y}{H}\right) + \Delta\log\left(\frac{H}{E}\right) + \Delta\log\left(\frac{E}{P_{15-64}}\right) + \Delta\log\left(\frac{P_{15-64}}{P}\right), \tag{10.1b}$$

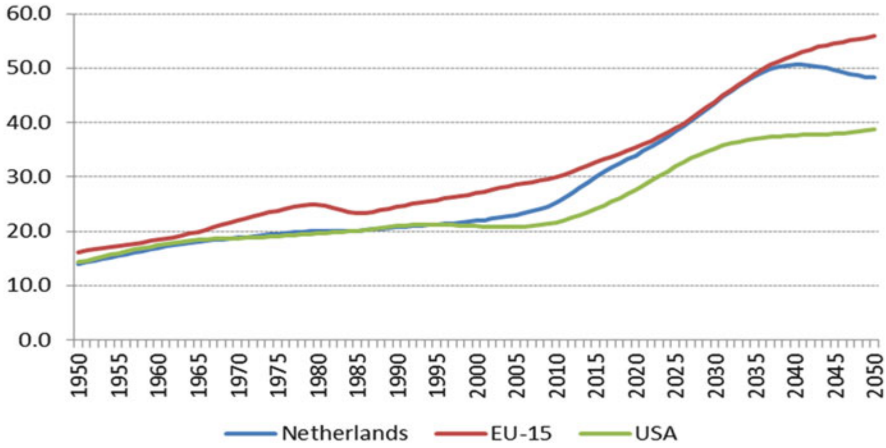

Fig. 10.1 Ageing: people aged 65+ as a percentage of 20–64 year olds (1950–2050), in the Netherlands, the EU-15 countries and the USA. *Source*: OECD, Pensions at a Glance 2011: Retirement-income Systems in OECD and G20 Countries—© OECD 2011

Essentially this states that the growth rate in real wealth, i.e. the log change in per capita real GDP, $\Delta\log(Y/P)$, can be decomposed into four factors: (i) change in real labour productivity, in terms of growth in constant-prices GDP per hour worked, $\Delta\log(Y/H)$, plus (ii) the change in the number of hours worked per employed person, $\Delta\log(H/E)$, plus (iii) the change in net labour participation, $\Delta\log(E/P_{15\text{–}64})$ plus (iv) the change in the population share of working age, $\Delta\log(P_{15\text{–}64}/P)$. Any increase in immigration is likely to affect the latter two factors via rising P and $P_{15\text{–}64}$.

If the retirement age were to rise from 65 to say 67 years, the working-age population rises from $P_{15\text{–}64}$ to $P_{15\text{–}66}$. With a constant P, in the final term of (Eq. 10.1b), the growth rate of the working-age population will then rise, i.e., $\Delta(P_{15\text{–}6.}/P) = (P_{15\text{–}66}/P) - (P_{15\text{–}64}/P) > 0$. Provided all the other terms in (Eq. 10.1b) remain the same, then wealth will also increase, i.e. $\Delta(Y/P) > 0$. Clearly, these other terms are also likely to change but it is not certain in which direction. A rise in the working-age population ($\Delta P_{15\text{–}6.} > 0$) will likely lead to more employment ($\Delta E > 0$). The question is then whether $\Delta P_{15\text{–}6.} >$ or $< \Delta E$. The same holds for the other variables in Eq. (10.1b).

Figure 10.2 shows the 5-year average percentage productivity growth in the Netherlands, the EU-15 and the USA. The 5-year average was taken to avoid large year-to-year fluctuations. In the 1970s and 1980s, productivity growth in both the Netherlands and the EU-15 countries was high, but on a declining path, while in the US productivity growth was much lower at a fairly stable rate between 1 and 2%. After 2000, the 5-year US productivity growth rose to more than 2%, while in the EU-15 and the Netherlands it reached an all-time low in the period 2005–2010. The higher US productivity growth after 2000 is usually linked to the use of ICT throughout the US economy, but particularly in services such as wholesale and retail trade and financial services (Van Ark et al. 2003).

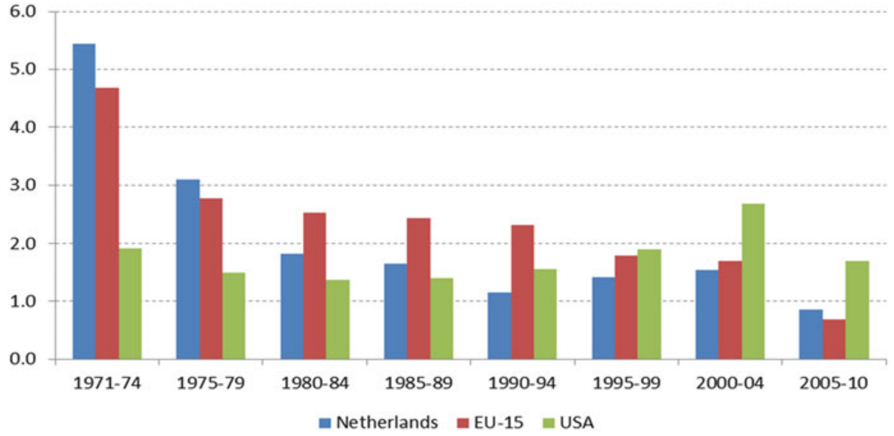

Fig. 10.2 Five-year average growths in real labour productivity in the Netherlands, EU-15 and the USA between 1970 and 2010 (%). *Source*: EUKLEMS database (at www.euklems.org) for growth of hours work in all three countries; Statistics Netherlands for Dutch real labour productivity growth, and likewise for all EU-15 countries from Eurostat and for the USA from the US Bureau of Labor Statistics

Another noteworthy phenomenon is the spatial shift in regional productivity growth rates, particularly in northwest European countries. Traditionally, the economic core regions of such countries have been the major contributors to national productivity growth. However, since 2000, the leading role in national productivity growth has shifted towards the peripheral regions. In other words, these peripheral regions have had a much more positive effect on national productivity growth than the economic core regions. This was shown for regional productivity growth in the Netherlands by Broersma and Van Dijk (2008) and was linked to growing congestion in the urban economic core. More recently, this finding has been backed by the OECD (2011) and Dijkstra et al. (2013, Fig. 4) who have shown that this shift towards falling productivity growth in core urban regions and rising productivity growth in peripheral rural regions was present throughout the EU-15 and particularly in northwest European counties. Further, this trend could indeed be linked to the effects of traffic congestion in the core regions and also to the widespread use of ICT in both core and periphery areas.

In these data, we can observe three aspects related to ageing in the Netherlands: (i) a substantial rise in national ageing from the low level of the US growth path to the higher EU growth path starting from 2000, (ii) more rapid ‘ageing’ in peripheral regions, which will rise by 27 percentage-points between 2012 and 2040 compared with a projected 20 percentage-point rise in the economic core regions and (iii) the regional motor of national productivity growth shifting, since around 2000, from the core to the periphery. It seems as if this latter shift (iii) coincided with the relative rise in national ageing (i) and with the growing weight of the peripheral regions in national ageing (ii). These trends justify the focus of the current paper. What possibilities does the Netherlands have, in terms of increasing productivity growth rates, to boost wealth in order to counteract the negative impacts of ageing? This issue will be investigated using an employer-employee matched micro-level dataset for the Netherlands covering the period 1999–2005. For employers, this database provides information about value added, various production costs, employment and their location. In terms of the employees working for these firms, we can distinguish their gender, age and level of skill.

10.3 Related Studies

Some studies have related the *level* of labour productivity to the *level* of ageing. Aubert and Crépon (2006) studied productivity using a matched employer-employee dataset for France covering 1994–2000. They found that productivity rises with age until the age of 40 after which it no longer rises. This relationship appears to be stable over industries. The age-productivity profile of firms appears to be similar to the age-labour costs profile and hence productivity rises with age but also with labour costs. The productivity-wage relationship was also studied by Van Ours and Stoeldraijer (2010) using matched employer-employee data for Dutch manufacturing companies between 2000 and 2005. They, however, found little evidence of productivity and labour costs being age-related.

Malmberg et al. (2008) observed that the age composition of the working-age population affects productivity in a complex way and, in their view, two hypotheses are relevant. The first is based on productivity at the individual level. Given that most studies indicate that labour productivity peaks somewhere between 30 and 50 years of age, firms with a relative young or old workforce tend to have a lower productivity *level* than firms with a workforce aged between 30 and 50. The second hypothesis is based on the experience of the Horndal steel plant in central Sweden. Between 1927 and 1952, this plant had a mean annual productivity growth rate of 2.5% despite a lack of major investments and the proportion of workers aged over 50 increasing from one-third in 1930 to almost a half in 1950 (Genberg 1992). This so-called Horndal experience suggests that workforce ageing is not a barrier to productivity growth. On the contrary, an ageing workforce appeared compatible with rapid increases in labour productivity, attributed to a learning-by-doing effect. Later, this formed an important part of Kenneth Arrow's learning-by-doing argument (Arrow 1962). Malmberg et al. (2008) argue that although the two hypotheses are competing (older workers have a lower level of productivity but a faster growth rate), both can be true, and drawing conclusions regarding the productivity of an ageing workforce is not as straightforward as it may appear because the aggregate effect is not necessarily a simple sum of the productivity of the various age groups. These authors further analysed a panel of employer-employee matched micro-data for Sweden covering 1985–1996 and found not a negative but a positive effect of ageing on plant-level productivity growth.

Next, we move to recent studies on the effect of increasing ageing on productivity *growth*. Such studies have only recently gained momentum. Bloom et al.

(2011) found that, between 1965 and 2005, the average legal retirement age in most developed, countries rose by about 6 months, while average male life expectancy rose by 9 years during the same period. They also studied the implications of ageing on economic growth. Their key premise is that labour supply, productivity and savings vary with age. Analysis of the effects of expected population ageing on (per capita) economic growth represents new territory due to the unprecedented size and nature of the current demographic shift. Gonzales-Eirpas and Niepelt (2012) show that taxation and the retirement age in OECD economies will need to increase in response to demographic ageing and, as a result, per capita growth will accelerate. In other words, as in (Eq. 10.1b), a rise in retirement age will increase wealth defined as per capita GDP. Studies have not as yet considered the effect a rise in retirement age will have on productivity growth at the firm level, and this is the aim of this paper. Beach (2008) shows that an ageing population is likely to have a noticeable direct and negative effect on wealth. Productivity growth, rather than growth in employment, will dominate changes in wealth because, due to ageing, the growth in participation will fall. However, a rise in the investment in skills and human capital on the supply side, combined with capital deepening and an increased rate of technological change on the demand side, of the labour market will raise labour productivity growth and mitigate the otherwise substantial fall in wealth over the coming decades.

Taking all this into consideration, we feel justified in specifying a single equation model for labour productivity growth in which both labour and capital are entered as lagged variables. In this way, problems of simultaneity can be avoided while, at the same time, interpretation of the estimation results remains straightforward. The aim of our analysis is to detect if, in addition to the effects of lagged growth of capital-labour ratios, there is also an effect of the gender, skills and age distributions of workers on productivity growth. We will use an employer-employee matched dataset of Dutch establishments, distinguished by industry, establishment size and region. The model we employ is set out in the next section, after which the data will be discussed and the estimation results presented.

10.4 Model Specification

The core of our specification is based on a simple production function of an individual business unit or establishment (which for ease will also be referred to as a firm):

$$y_i = f_i(n_i, k_i) = \Omega_i \left[\left(\left(\sum\nolimits_j e_{j,i}^{\mu} \right)^{1/\mu} \left(\sum\nolimits_j n_{j,i}^{\sigma} \right)^{1/\sigma} \right)^{\alpha} \left(\prod\nolimits_l k_{l,i}^{\beta_l} \right) \right] \qquad (10.2)$$

where y_i is firm-level output in terms of value added, Ω is a multifactor productivity (mfp) term in which labour input is measured in efficiency units of a variety of different, heterogeneous types of workers (see Hansen 1993). For different types of labour n_j, each with its own efficiency e_j, the overall input of labour in efficiency units in firm i can be represented by $e_i n_i = \left(\sum_j e_{j,i}^{\mu}\right)^{1/\mu}\left(\sum_j n_{j,i}^{\sigma}\right)^{1/\sigma}$, where σ (>1) is the substitution parameter for different types of labour and μ likewise for efficiency. In general, the higher the σ the less one type of labour can substitute for another. The larger the variety of workers j, the more detailed a choice a firm can make, thereby providing a better match of workers to jobs and thus a higher output. The parameter α reflects the elasticity of output with respect to labour inputs. Likewise, the amount of capital the firm uses in its production process is a multiplicative function of capital assets, k_l. The parameters β_l reflect the elasticity of output with respect to these various capital assets l.

We now assume that labour efficiency, e_i, depends multiplicatively on worker characteristics $x_{m,i}$, where $x_{m,i}$ refers to the gender, age and skill of workers in firm i.[1] Consequently, $e_i = \prod_m x_{m,i}^{\eta_m}$, where η_m are the elasticities of gender, age and skill respectively. The effect of these worker characteristics x_m on firm-level output depends not only on the values of η_m but also on the variety of efficiency units e_j of labour since $x_{m,i} = \left(\sum_j e_{j,i}^{\mu}\right)^{1/\left[\mu\,\left(\sum_m \eta_m\right)\right]}$. In addition, we take k_l to refer to capital in IT equipment and in non-IT equipment. Removing the firm index i, the assumptions above enable the production function defined in (10.2) to be rewritten as:

$$y = \Omega\left(\prod_m x_m^{\eta_m} n\right)^{\alpha} k_{IT}^{\beta} k_{non-IT}^{\gamma} \tag{10.3}$$

In turn, (Eq. 10.3) can be rewritten to represent firm-level labour productivity as follows:

$$\frac{y}{n} = \Omega\prod_m x_m^{\alpha\eta_m} n^{\alpha-1} k_{IT}^{\beta} k_{non-IT}^{\gamma} = \Omega\prod_m x_m^{\alpha\eta_m}\left(\frac{k_{IT}}{n}\right)^{\beta}\left(\frac{k_{non-IT}}{n}\right)^{\gamma} n^{\alpha+\beta+\gamma-1} \tag{10.4}$$

As such, firm-level labour productivity depends on multi-factor productivity (Ω), worker characteristics (x_m), capital-labour ratios for IT and non-IT capital and finally a scale term that vanishes in a situation of constant returns to scale.

Equation (10.4) can be rewritten in natural logarithms as an additive expression:

$$\log\left(\frac{y}{n}\right) = \omega + \sum_m \alpha\eta_m \log x_m + \beta\log\left(\frac{k_{IT}}{n}\right) + \gamma\log\left(\frac{k_{non-IT}}{n}\right) + \xi\log n \tag{10.5}$$

where $\omega = \log\Omega$ and $\xi = \alpha+\beta+\gamma-1$.

[1]The type of labour, n_j, depends on job characteristics, such as manual, servicing or managerial work. Note that we do not explore these type of characteristics further because the data available do not distinguish between different job characteristics.

Equation (10.5) can next be rewritten in growth terms as:

$$\Delta\log\left(\frac{y}{n}\right) = \Delta\omega + \sum\nolimits_m \alpha\eta_m \Delta\log x_m + \beta\Delta\log\left(\frac{k_{IT}}{n}\right) + \gamma\Delta\log\left(\frac{k_{non-IT}}{n}\right) + \xi\Delta\log n \qquad (10.6)$$

Equation (10.6) is the core of our model specification and shows how the growth in labour productivity changes when there are changes in

– mfp growth, also referred to as innovation, $\Delta\omega$
– worker characteristics (gender, age, skill), $\Delta\log x_m$
– capital intensity (both in IT and non-IT capital), $\Delta\log(k_{IT}/n)$ and $\Delta\log(k_{non-IT}/n)$
– scale, $\Delta \log n$[2]

Our analysis of labour productivity growth will be based on this core specification which, in its operational form formulated in growth rates ($\Delta \log \cdot$), becomes:

$$\begin{aligned}\Delta\log\left(\frac{y}{h_{-1}}\right) = \; & \beta_0 + \beta_1\Delta\log\left(\frac{k_{IT,-1}}{h_{-1}}\right) + \beta_2\Delta\log\left(\frac{k_{non-IT,-1}}{h_{-1}}\right) \\ & + \beta_3\Delta\log h_{-1} + \beta_4\Delta\log\left|S_m - S_f\right| + \beta_5\Delta\log S_{age1} \\ & + \beta_6\Delta\log S_{age2} + \beta_7\Delta\log S_{age3} + \beta_8\Delta\log S_{age4} \\ & + \beta_9\Delta\log S_{age5} + \beta_{10}\Delta\log S_{skill} + controls\end{aligned} \qquad (10.7)$$

where y is the firm-level value added, k is the capital stock of IT and non-IT capital, respectively, and h is hours worked. To avoid possible simultaneity between growth of value added and capital/labour growth, the latter two variables are entered into (10.7) with a lag. This enables Eq. (10.7) to be estimated as a single model, avoiding the need to specify a simultaneous model of productivity growth together with models for growth in hours worked and growth in capital. The employee controls in (10.7) are made up of industry dummies, firm size dummies, regional dummies and year dummies (the latter are not reported here for convenience). The variables y and k_{-1} refer to different years, and will be defined in constant prices to identify quantity effects.

In Eq. (10.7), S_m and S_f are the shares of male and female employees, respectively. The variables $S_{\text{age}i}$ are the shares of employees in age groups $i = 1$ through 5 (1 = 15–24 years of age, 2 = 25–34, 3 = 35–44, 4 = 45–54, 5 = 55 and above) with the last of these as the reference category, and S_{skill} refers to the share of highly skilled employees. This skill index will be discussed in more detail in the next section. Finally, firm-level controls in our model refer to two-digit industry levels, establishment size, regional location of the firm and time dummies. The gender-effect is operationalised by considering the absolute difference in the share of male to female employees. The hypothesis is that the more equal the spread of employees

[2]It is valid to remove this scale variable when estimating the level version (10.5). These results are not reported here for convenience.

by gender within a firm, the higher the growth in productivity. The model distinguishes five age classes and the hypothesis is that firms with a higher share of prime-aged employees will have higher productivity growth. With regard to the share of highly skilled workers, the hypothesis is that having more highly skilled workers in a firm than the industry average will increase productivity growth.

10.5 Data Description

For the purpose of this chapter, a matched employer-employee database for the Netherlands was compiled by linking a number of micro-level databases provided by Statistics Netherlands. Section 10.3 shows the database structure. At its heart is the so-called Social Statistical Jobs database (SSB-Jobs), which contains information on all the jobs of all Dutch employees at the business unit in which they work, the dates they started or finished their jobs and the business unit's main activity (NACE). We have obtained information on all employees in the Netherlands for the period 1999–2005. Some indicators in this database, such as wages, are however not available for all employees but for a large sample of firms.

From the employer perspective. it includes all business units with personnel between 1999 and 2005.[3] As such, the SSB-Jobs database forms the core of a matched employer-employee census. In principal, SSB-Jobs was established as a longitudinal database containing details of all employment spells of all employees at all business units in the Netherlands. In practice, there are about 10 million job-employee combinations in each year, including jobs that start and end within that same year. At any point in time during the period under consideration, there were about 7 million employee jobs in the Netherlands. Hence, roughly 3 million jobs appear and vanish within 1 year. These data, based on the number of jobs at any point in time, is labelled the cross-section database. A fixed point in time is set for September 30 of each year.[4]

10.5.1 Employer Side

On the employer side, business-unit survey information is only available on balance sheet information and wage costs from Production Statistics (PS), and on investments in fixed assets from Investment Statistics (IS). Other datasets, containing aggregated data, provide additional information such as prices at the two-digit

[3]Statistics Netherlands breaks companies down into business units. A business unit is the lowest level on which data on any given economic activity are collected by Statistics Netherlands.

[4]We selected this date because Statistics Netherland use this as the reference date in its employer surveys to which the SSB will be linked.

industry level (Sect. 10.3). Typically, these surveys include about 60,000 business units, covering all business units with 50 or more employees and a sample of smaller ones. This boils down to about 8% of all Dutch business units. However, some industries are not included, and business unit information is not available for agriculture, transport, financial and public sectors (government, education, healthcare) for the period 2000–2005. Consequently, the PS and IS used in this study are limited to business units in the manufacturing, construction, trade, hotels and business services industries.[5] For these five industries, a sufficient period of data is available, covering 1999–2005. These industries contribute about 50% of total Dutch value added (based on 2005 and 2012 data).

10.5.2 Employee Side

On the employee side, the SSB-Jobs database can be linked to personal information from the Municipality Base Register (MBR) that includes the gender, age, marital status and children of all 16 million inhabitants of all Dutch municipalities. Since the MBR includes characteristics of all employees, linking it to SSB-Jobs maintains the matched employer-employee census (see Fig. 10.3).

For our purposes, the key pieces of information that the MBR does not cover are the level of education and the level of skill of Dutch citizens. This brings us back to the one major flaw in this matched employer-employee database: the lack of education and skill information for each of the workers in the SSB. The only publicly available source of data on the education and skills of workers in the Netherlands is the Labour Force Survey (LFS). This LFS is a rolling panel, but only a small fraction of the people questioned are followed over time and the majority are randomly reselected each year. The LFS covers about 1% of the employees in the SSB. Given the large cross-sectional component of the LFS, linking the LFS to SSB-Jobs would not find any business unit with employees that would be covered in every year, and so the database would be empty.

10.5.3 Construction of Capital and Skill Indicator

The database for 1999–2005 used in our empirical analysis lacks information on the capital stock of firms and the skill levels of their individual workers Consequently, these variables (capital stock and worker skill level) are approximated using variables that are present in our dataset.

[5]Manufacturing is covered by NACE codes 15–37; construction is NACE 45, trade NACE 50–52, hotels NACE 55 and business services NACE 70–74 (plus NACE 93 which formally comprises other services).

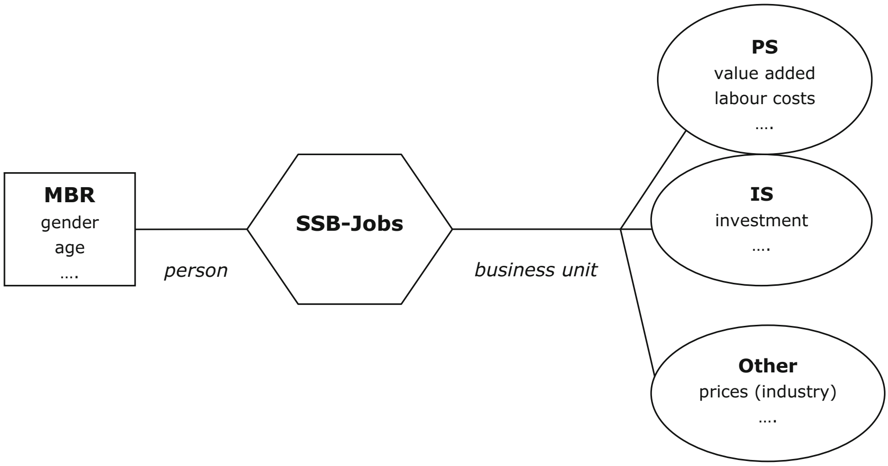

Fig. 10.3 Structure of the Dutch matched employer-employee database. Note: The *hexagon* represents the key database linking persons to business units, the *rectangular shape* represents a census, and *ovals* are surveys

It is widely accepted that productive capital stock is the best measure of capital input for productivity analysis (OECD 2001). However, due to a lack of data, most studies use proxies for productive capital stock. For example, Licht and Moch (1999) use the number of computers as a proxy for the computer capital stock. The book values of capital were used in Brynjolffson and Hitt (1996) and in Lichtenberg (1995), while Lehr and Lichtenberg (1999) used investment flows. Book values are imperfect measures of productive capital stocks as they are based on historic, rather than replacement, costs and on accounting rules rather than on economic depreciation. Investment flows as a proxy suffer from noise when investment growth rates are not constant, which is typically the case with computer investment. Although our dataset has some limitations, it is possible to calculate a set of useful variables for our analysis. The Appendix shows how we approximated the capital stocks of each individual business unit. These capital stocks are used in estimating productivity growth through Eq. (10.7).

We have also constructed an approximation for the skill level of every business unit in the SSB where wage information was available. Our approach was motivated by the literature on human capital externalities that, in essence, claims a positive relationship between skill level and wages. A rise in the skill level will raise the wage rate by $x\%$.[6] In our approach, we reversed this reasoning and applied

[6]Such analyses are usually based on a so-called Mincerian wage equation. Rauch (1993) found x to be $\approx 3\%$, Acemoglu and Angrist (2000) $\approx$ around 1%, Moretti (2004) ≈ 0.5–0.7% and Winter-Ebmer (1994) ≈ 4–9%. As such the levels of the return on human capital vary by country, the sample selected, human capital definition, the type of model and data (cross-sectional, time series, panel). Nevertheless, a significant positive effect is generally found.

it to all employees in a business unit. This then yields the average skill level in a business unit. That is, the higher the average wage rate in a business unit, the higher the average skill level of employees in that business unit.

The dataset we use also contains information on the average hourly wage a firm pays to its employees. Wage rates differ by industry due to industry-specific characteristics. That is, the average hourly wages in manufacturing differ from those in business services and in healthcare. We therefore determined, for each year and for each two-digit industry, the distribution of wage rates of firms in that particular industry. We assume that when a firm in a specific industry pays more than another firm within that same industry, that the former has a larger proportion of highly skilled employees. In other words, when a firm is paying above the industry average, it implies that its share of highly skilled workers is above that of firms with a lower average wage. As such, the relative wage rate a business unit is willing to pay is an indication of its relative share of highly skilled employees. In this way, we calculated individual firm skill level for every year available (1999–2005) and in every two-digit industry. In other words, the difference between the firm wage rate, W_i, and its industry wage rate, $W_{industry}$, is a measure of the skill level of that firm. Hence,

$$S_{skill} = 1 + \left(W_i / W_{industry}\right) \tag{10.8}$$

where S_{skill} is the share of skilled employees in firm i. In this way, we end up with an approximation for the share of skilled workers in each firm in each year. This skill level for each firm can then be used as an explanatory variable in Eq. (10.7) to represent the impact of a change in skill level on productivity growth. Equation (10.8) is defined in such a way that $S_{skill} > 0$, and so a logarithm can be calculated and applied in our model (10.7).

10.5.4 Regional Classification

The data with which our model will be estimated allow us to include a number of control variables. Apart from the gender, age and skill of the employees of a firm, we can also distinguish between different characteristics of the firm. We can distinguish the industry of a firm in terms of its NACE classification, the size class of a firm in terms of the number of employees and we can distinguish its location. A common way to incorporate locational demarcation is based on the so-called NUTS levels of Eurostat. For the Netherlands, the most detailed regional demarcation is the municipality level. On a note of caution, neither the NUTS, nor the municipal, demarcations have a truly economic interpretation as they are based more on a historical or political interpretation than an economic one. Given that we have information on the municipality in which a firm is located, we have simply aggregated these municipalities into areas that reflect a more economic

Fig. 10.4 Economic core, intermediate zone and periphery of the Netherlands. *Source*: own calculations from data of Statistics Netherlands

demarcation. These relate to the concept of functional urban areas (FUAs) as discussed by the OECD (2014a). Figure 10.4 shows how this classification has been applied to create three economic regions based on a grouping of municipalities.[7]

The economic core of the Netherlands is located in the western part of the country, includes the four largest cities (Amsterdam, Rotterdam, The Hague and Utrecht), and is where employment is most concentrated and most activities take place. The area includes neighbouring municipalities to these four cities, and we have set the boundary at about an hour's car journey from one end of the region to the other. The next group of municipalities is the called intermediate zone, which is

[7]We also estimated model specifications using the more common standard regional classification into NUTS-1 and NUTS-2 areas, but this did not significantly alter any of the conclusions.

also based on a similar journey time. The idea is that this intermediate region benefits from its proximity to the economic core, and also benefits from specificities of being outside the core, such as more space and higher quality residential areas. The remainder of the country is labelled the periphery (see Fig. 10.4).

10.5.5 Additional Labour Market Variables

Although Eq. (10.1b) is based on a decomposition of labour productivity growth by country or region, it is likely that a firm's labour productivity growth also depends on the following additional variables: (i) the change in the number of hours worked per employee, $\Delta(H/E)$; (ii) the change in (net) labour participation, $\Delta(E/P_{15-64})$, and depending on the level at which P_{15-64} is aggregated; and (iii) the change in the population share of working age, $\Delta(P_{15-64}/P)$. However, as neither P_{15-64} nor P can be observed at the firm level, we have to aggregate these to a higher level. The most obvious choice is to link this to the regional classification into the three economic core, intermediate zone and periphery regions shown in Fig. 10.4.[8]

As a consequence, there is only one variable that can be drawn from (10.1b) and added to (10.7). This is the change in hours worked per employee $\Delta\log(H/E)$, which is the only variable in (10.1b) that is actually monitored on the firm level. The other two variables are only observable on the regional level and these are included as control dummies in our model (10.7) based on the three economic regions of Fig. 10.4. To avoid simultaneity, this additional variable (H/E) is entered with a lag.

10.6 Model Specification and Empirical Results

Taking the additional variable of working hours per employee into account and including variables for regional worker and job characteristics in the Netherlands, Eq. (10.9) provides the model specification for the real *growth* rate in firm level productivity:

[8] We could have chosen a different kind of regional classification, such as NUTS-1, NUTS-2 or municipalities. However, this would have meant that we had to specify and estimate our model as a multilevel specification. We instead opted for a simple regional classification, which means that our model can be estimated using micro-level data, with the higher-level regional variables becoming regional dummy variables for the three regions distinguished.

$$\begin{aligned}\Delta\log\left(\frac{y}{h_{-1}}\right) = \; & \beta_0 + \beta_1\Delta\log\left(\frac{k_{IT,-1}}{h_{-1}}\right) + \beta_2\Delta\log\left(\frac{k_{non-IT,-1}}{h_{-1}}\right) + \beta_3\Delta\log h_{-1} \\ & +\beta_4\log\left|S_m - S_f\right| + \beta_5\log S_{age1} + \beta_6\log S_{age2} + \beta_7\log S_{age3} \\ & +\beta_8\log S_{age4} + \beta_9\log S_{age5} + \beta_{11}\log S_{skill} \\ & +\beta_{12}\Delta\log\left(\frac{h_{-1}}{e_{-1}}\right) + controls\ (\text{industry, firm size and region})\end{aligned} \tag{10.9}$$

The model shown in Eq. (10.9) will be estimated and tested using SPSS. The estimation results that explain the real productivity growth of Dutch firms are shown in Table 10.1. This productivity growth constitutes the source of the welfare growth that is being considered in this chapter [see Eq. (10.1b)]. Other potential sources of welfare growth including a growth in working hours, in the number of workers and in the working-age population are addressed in other studies. Since our study is on real productivity growth, the explanatory variables of model (10.9) are also in the form of first differences and may need to be lagged to avoid simultaneity. Real labour productivity growth depends on the lagged growth rates of the ratios of IT-capital to hours worked and of non-IT capital to hours worked. It will also depend on the lagged growth rate of our additional variable of (lagged) growth of hours worked per employee. An important question when it comes to the specification of our growth model is whether the variables reflecting worker characteristics (gender, age, skill) should also be in terms of growth rates or can remain as levels because these characteristics change over time very gradually. For example, changes in age class occur only when workers move from one age class (each spanning 10 years) to the next. The fact that changes in these variables are small argues against using growth rates because these will be close to zero. However, the actual levels of these worker characteristics may indeed affect real productivity growth: workers in a certain age group may well demonstrate higher labour productivity growth rates than workers in another age group. For example, younger workers may learn faster. This leads us to conclude that, in our model, the real labour productivity growth of a firm is best related to the level of the workers' gender, age and skill characteristics. Similarly, the other control dummies related to firm characteristics (region, industry and size) are also applied as levels as they are generally constant over time and incorporating zero growth rates would not provide useful information.

Table 10.1 presents the estimation results for the productivity growth model (Eq. 10.9) in which the worker characteristics of gender, age and skills are thus in the form of levels. This shows that the growth rates of both the IT and non-IT capital-labour ratios have a strong positive effect on productivity growth. Further, the hours worked per employee has a positive and strongly significant effect on real productivity growth, indicating that an increase in the number of hours worked by existing employees does indeed have a positive effect on labour productivity growth.

Table 10.1 Estimation results explaining the *growth* of firm labour productivity for the Netherlands, 2001–2005

Variable name	Symbol in Eq. (10.9)	Estimation and (test Results) of (10.9)
Intercept	β_0	−0.190 (−7.105)
Lagged growth rate of IT-capital—labour ratio	$\Delta\log\left(\frac{k_{IT,-1}}{h_{-1}}\right)$	0.740 (70.31)
Lagged growth rate of non-IT-capital—labour ratio	$\Delta\log\left(\frac{k_{non-IT,-1}}{h_{-1}}\right)$	0.703 (47.83)
Lagged growth rate of hours worked per employee	$\Delta\log\left(\frac{h_{-1}}{e_{-1}}\right)$	0.012 (6.036)
Level of worker characteristics		
Gender		
Absolute difference in share of male and female workers	$\log\lvert S_m - S_f\rvert$	−0.000 (−0.113)
Age group		
Share age group 15–24	$\log S_{age1}$	0.044 (11.57)
Share age group 25–34	$\log S_{age2}$	−0.020 (−3.188)
Share age group 35–44	$\log S_{age3}$	−0.014 (−1.807)
Share age group 45–54	$\log S_{age4}$	−0.011 (−1.996)
Share of age group 55+	Reference category	–
Skill		
Share skilled workers	$\log S_{skill}$	0.399 (25.77)
Establishment characteristics		
Region		
Core	Reference category	–
Intermediate zone		0.021 (3.639)
Periphery		0.028 (4.368)
Industry	NACE	
Wholesale	Reference category	–
Food and tobacco	15–16	−0.035 (−3.170)
Textiles etc.	17–19	−0.033 (−1.681)
Paper and graphics	21–22	−0.048 (−4.371)
Petroleum, chemicals	23–25	0.035 (3.054)
Machinery	27	−0.038 (−3.807)
Machinery products	28–29	−0.048 (−4.488)
Electronics	30–33	0.014 (0.908)
Transport equipment	34–35	−0.037 (−2.165)
Other manufacturing	20, 26, 36, 37	−0.067 (−5.774)
Construction	45	−0.046 (−4.459)
Automotive trade	50	−0.087 (−5.162)
Retail trade	52	−0.056 (−4.510)
Hotels etc.	55	−0.160 (−9.092)
Real estate services	70	−0.088 (−3.142)
ICT business services	72	0.038 (1.818)
High skilled business services	741–744	−0.031 (−2.625)

(continued)

Table 10.1 (continued)

Variable name	Symbol in Eq. (10.9)	Estimation and (test Results) of (10.9)
Low skilled business services	745–748	0.019 (1.494)
Other services	90–93	−0.089 (−1.947)
Firm size	employees	
	1–4	−0.438 (−2.169)
	5–9	0.008 (0.081)
	10–19	−0.095 (−4.492)
	20–49 Reference category	–
	50–99	0.011 (1.665)
	100–149	0.021 (2.605)
	150–199	0.035 (3.446)
	200–249	0.015 (1.141)
	250–499	0.012 (1.224)
	500–999	0.019 (1.374)
	1000–1999	0.019 (0.978)
	>2000	0.016 (0.759)
Adjusted R^2		0.180
Observations		28,818

Note: The categories for age group '55 and above', for region 'Core', for industry 'wholesale trade' and for firm size '20–49 employees' all act as reference categories for which coefficients cannot be estimated and therefore have the value zero in the table. We also included year dummies, but they are not reported here for convenience

The coefficient for gender is not significant, implying that the male–female distribution of employees within a firm has no effect on productivity growth. Of particular interest for this chapter is the relationship between ageing and productivity growth. The results show that compared to the reference group of older workers (55+), all the other age groups between 25 and 54 have negative coefficients implying younger workers' productivity growth is below that of the older reference age group. The largest and most significant negative effect is for the 25–34 age group. However, the youngest group (15–24) has a positive coefficient indicating that the productivity growth of this age group does outstrip that of older workers. This large effect of young people on productivity growth can be explained by the fact that young people have a steep learning curve. What is perhaps more surprising is that the older workers show higher productivity growth rates than the so-called prime-age workers. However, this finding is in line with the Horndal effect (Genberg 1992) and with results reported by Malmberg et al. (2008) that suggest that ageing does not have a negative effect on productivity growth because the positive effects of learning-by-doing experiences outweigh the negative effect of the lower flexibility of more elderly workers. As expected, the 'share of skilled workers' coefficient is highly significant implying that having more skilled workers boosts productivity growth.

The results for the three distinguished economic regions (economic core, intermediate zone and periphery) show very interesting differences and point towards the following characteristics: productivity growth is higher outside the core region and is slightly larger in the periphery than in the intermediate zone. That is, firms outside the economic core have higher productivity growth than firms located inside this core region. This finding is in line with results found by Broersma and Van Dijk (2008) using regional industry data. In an EU-wide study of regional labour productivity, Dijkstra et al. (2013), despite not making distinctions based on worker characteristics, such as age and skill, nor on firm characteristics such as industry or size, nevertheless also found lower productivity growths in the economic core regions of countries in northwest Europe. They related this to the high costs associated with traffic congestion in economic core regions. The regional differences that we have identified are also in line with the most recent report on the Netherlands by the OECD (2014a, pp. 81–82) which makes clear that Functional Urban Areas with over 500,000 inhabitants show slower labour productivity growths than the national average.

We have also controlled for differences in the productivity of different sectors. The highest real growth rates in firm labour productivity are seen in the manufacturing of petroleum and chemical products and in ICT business services. Productivity growth is also relatively high in low skilled business services compared to wholesale trade (our reference category). The chemical industry, which showed the highest growth in productivity, is particularly present in the periphery, such as in the municipalities of Delfzijl and Emmen (both in the north) and Terneuzen and Geleen (both in the south). Nevertheless, the analysis shows that even after taking account of both industry and regional effects, the effects of real productivity growth is still significantly higher outside the core regions.

Finally, Table 10.1 also suggests a link between establishment size, in terms of numbers of employees, and the real growth rate of a firm's labour productivity. We observe that firms with about 100–200 employees show significantly higher productivity growths. Although the coefficients are not always significant, the general picture is that intermediate-sized firms do slightly better than both smaller and larger firms. The most striking result is the significantly lower growth rates we find for small firms with less than 20 employees. Given that the spatial distribution of firms by size differs substantially by region (Edzes et al. 2013), it is important to control for firm size and industrial sector when attempting to draw conclusions. Even after this, the finding of higher productivity growth in the peripheral parts of the country remains a very robust result.

10.7 Concluding Remarks

Ageing is a phenomenon that attracts ever-increasing attention because it has many implications for society and is therefore an important topic for policymakers. In this chapter, we focus mainly on the consequences for welfare and labour supply.

Ageing may also lead to higher labour costs (or lower net wages) if the working generation has to finance pension payments for an increasing number of retired people. We focus here on the effect of a decreasing labour supply and how this can be compensated for to maintain the same welfare level. In principle, there are a number of ways to resolve this issue:

1. increase the retirement age, so that people stay longer in the labour force;
2. increase the number of working hours, especially for part-time workers;
3. increase the size of the working population (such as through immigration);
4. increase labour productivity, such that the same number of working hours delivers more production;
5. optimise the spatial allocation of production activities and the work force to maximise efficiency and minimise congestion and pollution cost.

In addition, one should take account of possible interactions between these variables. For instance, if older workers continue working to an older age, or employees work more hours, this might also have positive effects on labour productivity, causing that the overall effect of working more years and/or more hours to be less negative than expected.

In this chapter, we have tried to shed light on this issue through an empirical analysis using data for the Netherlands. The Netherlands still has a moderate ageing population compared to some countries such as Italy, Spain and Japan, but the rise in ageing is relatively strong, with the country expected to move from the relatively low US level to the higher EU level. Another feature of the Netherlands is its very low average number of working hours due to the high proportion of part-time workers (particularly females). Labour productivity is high, but has only been growing slowly, particularly since 2000. Productivity growth appears to be particularly low in the more-densely populated, economic core region of the Netherlands. The negative effects of congestion and pollution seem to outweigh any positive agglomeration effect. This raises questions as to how, among other aspects, ageing, the number of working hours and the spatial distribution of production influences labour productivity growth at the firm level.

These general observations have been investigated in several elementary studies. In this chapter, a more thorough multivariate model is used to explain the real growth rate in labour productivity of firms in the Netherlands using an entirely new and unique dataset for the Netherlands, with firm and worker micro-level data for the period from 2000 to 2005.

The results show that real productivity growth depends primarily on the real lagged capital-labour ratios for both IT and non-IT capitals. An increase in the real growth rates of these two capital-labour ratios raises the growth in real labour productivity. The results indicate that increasing the skill level of the workforce will also have a positive effect on a firm's labour productivity growth. As such, investing in education and training is a good investment. An increase in the working hours of existing employees will raise their productivity, especially since employees in the Netherlands have a relatively low level of working hours to start with. That is, an increase in the working hours of current employees will increase the growth in real labour productivity. Our results also show that the gendered distribution of workers does not have much influence over productivity growth.

With regard to the age distribution of workers we found that, compared to the reference group of older workers (55+), all the age groups covering workers aged between 25 and 54 have lower productivity growth. The poorest performance in terms of productivity growth was, perhaps surprisingly, associated with the 25–34 age group. Only the 15–24 age group outperformed our oldest category in terms of productivity growth. The counterintuitive finding that older workers achieve higher productivity growth than those often viewed as in the prime age-group for workers is in line and with results reported by Malmberg et al. (2008) who similarly concluded that ageing does not have a negative effect on productivity growth. This can perhaps be explained by the so-called Horndal effect, where the accumulated work experience and firm-specific knowledge of older workers compensates for possible negative ageing effects such as lower flexibility and a reluctance and inability to learn new things (Genberg 1992).

Further, we found that the type of firm, in terms of its main activity (i.e. its industry), has an influence on productivity growth. Capital-intensive industries, such as the petroleum and chemical branches, have relatively high productivity growth rates. It is also significant that the ICT service industry has a strong productivity growth. This might be promising for the future given that the surge in US productivity growth in the late-1990s appears to be driven by the growth witnessed in ICT-using service industries (van Ark et al. 2003). We also assessed the influence of firm size, and found that medium-sized firms have seen slightly higher productivity growth rates than both smaller and larger companies.

Finally, having taken account of the influence of industry, firm size and differences in workers' characteristics, we are still able to show that the periphery outperforms the core region in terms of productivity growth, although the absolute level of productivity is still higher in the core region. The latter could be related to a higher skill level and a younger population composition. As such, it is likely that factors absent from our analysis are also driving this difference. For example, these might be phenomena linked to regional differences with respect to (i) adaptability to new situations, (ii) integrity, (iii) being able to work as a team, (iv) communicative skills and (v) showing initiative and leadership. Nevertheless, our conclusion that productivity growth is relatively high in the periphery compared to the economic core of the Netherlands remains valid. Broersma and Van Dijk (2008) studied regional labour productivity based on Dutch NUTS-2 regions and also found that, apart from a number of explanatory variables, multifactor productivity (mfp) growth is the largest contributor to labour productivity growth, particularly in peripheral regions. Here, mfp growth can be seen as the residual in a production function, which itself can be related to a multitude of explanatory variables, including those mentioned above (i)–(v). Overall, one can conclude that the regional differences in productivity are narrowing.

The explanations for the growth of labour productivity lead to several policy recommendations with regard to the problem of ageing. Given that we find that having a higher proportion of older workers may well have a positive effect on productivity growth, stimulating a further increase in the participation rate of older workers may increase labour productivity growth and, as a result, raise wealth. Increasing the retirement age to increase the labour supply will also contribute to productivity growth and thus help to maintain the high level of welfare in the Netherlands despite the ongoing ageing. Our results also show that increasing the number of working hours per employee, by reducing the high proportion of part-time working for which the Netherlands is famous, may also lead to an increase in productivity growth and hence further growth in welfare. A practical problem is that Dutch workers have indicated that they are very satisfied with their working hours and reluctant to increase them (Noback et al. 2014).

The results for the three economic regions (economic core, intermediate zone and periphery) convincingly show that firms outside the economic core have higher productivity growth rates than firms that are located inside this core region. This corroborates results found by Broersma and Van Dijk (2008), the OECD (2011) and Dijkstra et al. (2013), and suggests that positive agglomeration effects are outweighed by other aspects such as higher traffic congestion and pollution costs. Given that it is especially the large cities in the core Randstad region that show labour productivity growth rates below the national average, a more equal spread of economic activities to include the intermediate and peripheral areas may increase the overall national labour productivity growth and reduce regional differences. This might also help to mitigate the effects of ageing and population decline in the peripheral areas.

Appendix 1: Characteristics of the Data

The number of data points for all the firm variables, for each year between 1999 and 2005, is over 45,000. A summary of these data is provided in Tables 10.2 and 10.3. Table 10.2 provides an overview of the control variables in the database that are used when estimating Eq. (10.7), while Table 10.3 provides some descriptive statistics for the other variables used in the model. Table 10.2 reflects that each of the control variables (by industry, firm size and region) has sufficient observations for our analysis. Here, the ‘other services’ industry is the smallest with only 119 observations, which should be sufficient for estimation purposes.

Table 10.2 Distribution of data observations, 1999–2005

Variable	Detail	Frequency	%
Industry	NACE (1993)		
Manufacturing: Food and tobacco	15–16	2876	6.3
Textile, cloths, leather	17–19	790	1.7
Paper, graphics	21–22	3065	6.7
Petroleum, chemicals, rubber	23–25	2890	6.3
Metal, metal products	27–28	4178	9.2
Machinery	29	3268	7.2
Electronics	30–33	1238	2.7
Transport	34–35	1028	2.3
Other	20, 26, 36–37	2680	5.9
Construction: Construction	45	3619	7.9
Trade: Car sales	50	1036	2.3
Wholesale trade	51	9177	20.1
Retail trade	52	2919	6.4
Hotels: Hotels, restaurants, etc.	55	1043	2.3
Business services: Renting of equipment	71	364	0.8
Computer services	72	742	1.6
High skilled business services	741–744	2354	5.1
Low skilled business services	745–748	2226	4.9
Other services: Other services	93	119	0.3
All industries		45,612	100
Region	Number of municipalities		
Economic core	139	18,382	40.3
Intermediary	169	16,394	35.9
Periphery	150	10,836	23.8
All regions		45,612	100
Firm size			
Number of employees			
Less than 20		1138	2.5
20–50		12,674	27.8
50–100		14,291	31.3
100–200		9746	21.3
200–500		5072	11.1
More than 500		2691	6.0
All sizes		45,612	100

Source: Derived from firm-level database of Statistics Netherlands

Table 10.3 Mean values of some plant-level variables, 1999–2005

Variable	Unit	Frequency	Mean	SD
Value added (current prices)	1000 euro	45,612	10,274.4	59,270.6
Labour costs (current prices)	1000 euro	45,612	5451.7	23,755.1
Depreciation (current prices)	1000 euro	45,612	1259.5	8535.4
Total investments (current prices)	1000 euro	45,612	1269.5	8260.9
IT investments (current prices)	1000 euro	45,612	99.9	687.5
Total capital stock (current prices)	1000 euro	45,612	20,763.0	147,903
IT capital stock (current prices)	1000 euro	45,612	720.8	4188.7
Number of employees	1	45,612	225	1330.2
Percentage males	%	45,611	74.6	21.6
Average age	Years	45,612	37.9	4.8
Percentage 15–24 years of age	%	45,612	13.1	14.1
Percentage 25–34 years of age	%	45,612	27.8	11.6
Percentage 35–44 years of age	%	45,612	28.4	9.7
Percentage 45–54 years of age	%	45,612	20.0	9.6
Percentage 55 years and above	%	45,612	10.6	8.0
Index of skilled workers per firm relative to those per industry	1 + (firm wage)/(industry wage)	45,364	2.0	313.1

Source: Statistics Netherlands, various sources from www.cbs.nl

Appendix 2: Calculation of Firm-Level Capital Stock

The database for 1999–2005 that we use in our empirical analysis of the level and growth of labour productivity lacks information about the capital stock of each firm and about the education or skill level of the individual workers. This means that the capital stock and worker skill level variables have to be approximated using variables that are available in our dataset.

It is generally accepted that, for productivity analyses, the productive capital stock of a firm is the best measure of capital input (OECD 2001). However, due to a lack of data, most studies use a proxy for productive capital stock. For example, Licht and Moch (1999) use the number of computers as a proxy for the computer capital stock. Book values of capital stock were used in Brynjolffson and Hitt (1996) and in Lichtenberg (1995), while Lehr and Lichtenberg (1999) used investment flows. Book values are imperfect measures of productive capital stocks as they are based on historic, rather than replacement, cost and on accounting rules rather than economic depreciation. Investment flows, as a proxy, are prone to be misleading if the investment growth rate is not constant, which is typically the case for computer investments.

An alternative approach is to derive productive capital stock using the Perpetual Inventory Method (PIM), which essentially sums past investment flows, correcting for reduction in productive capacity due to ageing. Assuming a geometric withdrawal pattern (see e.g. Jorgenson and Stiroh 2000), the capital stock is derived as follows:

$$K_t = K_{t-1}(1 - \delta) + I_t \tag{10.10}$$

where K_t is the capital stock at year t, I_t the investment flow during year t, and δ the rate of economic depreciation.

The main problem with using this approach, especially in micro-level studies, is the lack of long series of investment flow data. Typically, micro-level data on investments are only available for a short time period. Standard methods to circumvent this problem in macro-analyses, such as the Harberger method, are nor appropriate and cannot be used. In the Harberger method, the initial year's capital stock is estimated by dividing investment in the initial year by the sum of the growth rate of investment and the depreciation rate. This method is based on a steady-state assumption: and so investment flows must be smooth and grow at a constant rate. This might be an acceptable assumption for the total economy or the sectoral level, but it is not realistic at the firm level. Firm-level investment patterns are volatile: investments often occur in spikes. Here, we propose a new method to deal with this problem that uses information on depreciation reported by firms.

Most micro-production surveys that include investment variables also include depreciation recorded in the firms' books. This reported (firm-level) depreciation, which is determined by accounting rules rather than technical factors, contains information on past firm-level investments. This information can be retrieved when the accounting practices of a firm is known using the so-called "booked depreciation method" (see Broersma et al. 2003). Linear depreciation is a standard accounting rule that is often used in practice. With this approach, an investment made in year t is written off in equal parts during the anticipated lifetime of the asset. If the lifetime L of an asset is say 15 year, each year one-fifteenth of the original investment value is recorded as depreciation. Hence, the booked depreciation in year t (*i.e.*, D_t) is the summation of investments made in the period t–L to t, multiplied by 1/L:

$$D_t = \sum_{k=1}^{L} \frac{1}{L} \cdot I_{t-k} \tag{10.11}$$

From this, one can deduce that:

$$D_{t+1} - D_t = \frac{1}{L} I_t - \frac{1}{L} I_{t-L} \tag{10.12}$$

Rewriting gives:

$$I_{t-L} = I_t - L(D_{t+1} - D_t). \tag{10.13}$$

This equation shows that past investment flows (made before time t) can be derived on the basis of investment and depreciation data at time t and later.

This "booked depreciation method" has been used to derive constant price investment flows for total capital before 1999 (see below for the formal derivation). For computer equipment, separate firm-level depreciation figures are not available. Therefore, we assumed that, prior to our first observation (1999), the capital stock of computer hardware for each firm was equal to its two-digit industry's average proportion of computer capital in 1999 multiplied by the firm's total capital stock in 1999, derived using the booked depreciation method.

Constant price investment flows were estimated by deflating firm-level investment flows by the price deflators (for the relevant two-digit industry) for total investment in fixed assets and in computing equipment, drawn from the EUKLEMS database (www.euklems.net). This deflator is also used to calculate firm-level constant price depreciations.

When using investment series in (10.10), stocks are derived using a depreciation rate for non-computer equipment of 0.067, based on an average lifespan of 15 years ($\delta = 1/L$). The lifespan of buildings is much longer but we are only considering productive capital stocks and do not see buildings as falling within this category. When it comes to computer capital, we assume a lifetime of 5 years, and hence $\delta = 0.2$. Finally, we estimate the real stock of non-computer capital simply by subtracting the computer stock from the total capital stock.

The specific application of the depreciation method outlined above to the current analysis requires further assumptions as depreciation and investment data are only available for the period 1999–2005. First, we split the 15-year period from 1984 to 1998 into two: 1984–1989 and 1990–1998 for reasons that will become apparent below. Based on a linear depreciation rule, and with K_{1999} the real capital stock in 1999, we can state that:

$$\begin{aligned} K_{1999} &= \sum_{t=1984}^{1998} \frac{(t-1984+1)}{15} I_t \\ &= \sum_{t=1984}^{1989} \frac{(t-1984+1)}{15} I_t + \sum_{t=1990}^{1998} \frac{(t-1984+1)}{15} I_t \end{aligned} \tag{10.14}$$

where I and D refer to the investment and depreciation flows in constant prices. The first term on the right hand can be derived using (10.13):

$$I_t = 15(D_{t+15} - D_{t+16}) + I_{t+15}, t = 1984\ldots 1989 \tag{10.15}$$

From which we get:

$$\sum_{t=1984}^{1989} I_t = \sum_{t=1984}^{1989} 15 \cdot (D_{t+15} - D_{t+16}) + I_{t+15}$$

Then, substituting this in (10.14), we get:

$$\sum_{t=1984}^{1989} \frac{(t-1984+1)}{15} I_t = \sum_{t=1984}^{1989} \left[(t-1984+1) \cdot (D_{t+15} - D_{t+16}) + \frac{(t-1984+1)}{15} I_{t+15} \right]$$
$$= \sum_{t=1999}^{2004} \left[(t-1999+1) \cdot (D_t - D_{t+1}) + \frac{(t-1999+1)}{15} I_t \right]$$

The second term on the right-hand side of (10.14) is unknown but can be approximated as follows:[9]

$$\sum_{t=1990}^{1998} \frac{(t-1984+1)}{15} I_t \approx \frac{11}{15} \sum_{t=1990}^{1998} I_t \tag{10.16}$$

Using (11), the total depreciation over the period equals:

$$\sum_{t=1999}^{2005} D_t = \frac{1}{15} \left(\sum_{t=1990}^{2004} I_t + \sum_{t=1989}^{2003} I_t + \ldots + \sum_{t=1985}^{1999} I_t + \sum_{t=1984}^{1998} I_t \right) \tag{10.17}$$

which can be rewritten as the following three terms:

$$\sum_{t=1999}^{2005} D_t = \frac{7}{15} \sum_{t=1990}^{1998} I_t + \sum_{t=1999}^{2004} \frac{(2004+1-t)}{15} I_t + \sum_{t=1984}^{1989} \frac{(t-1984+1)}{15} I_t. \tag{10.18}$$

Rearranging then gives:

$$\sum_{t=1990}^{1998} I_t = \frac{15}{7} \sum_{t=1999}^{2005} D_t - \sum_{t=1999}^{2004} \frac{(2004+1-t)}{7} I_t - \sum_{t=1984}^{1989} \frac{(t-1984+1)}{7} I_t \tag{10.19}$$

The first and second terms can be simply found from the available data, and the third term can be derived from (10.15), i.e. $I_t = 15(D_{t+15} - D_{t+16}) + I_{t+15}$, which yields $I_{1999-15} = I_{1984}$ and so on. The third term then becomes:

[9]This approximation is exact when I_t is constant over time.

$$\sum_{t=1984}^{1989} \frac{(t-1984+1)}{7} I_t = \sum_{t=1984}^{1989} \left[\left(\frac{15 \cdot (t-1984+1)}{7} \right) \cdot (D_{t+15} - D_{t+16}) + \left(\frac{(t-1984+1)}{7} \right) \cdot I_{t+15} \right]$$
$$= \sum_{t=1999}^{2004} \left[\left(\frac{15 \cdot (t-1999+1)}{7} \right) \cdot (D_t - D_{t+1}) + \left(\frac{(t-1999+1)}{7} \right) \cdot I_t \right]$$

By combining information on $\sum_{t=1990}^{1998} I_t$ (from 10.19) with (10.16), we can obtain the second term in (10.14) as follows:

$$\sum_{t=1990}^{1998} \frac{(t-1984+1)}{15} I_t \approx \frac{11}{15} \sum_{t=1990}^{1998} I_t$$
$$= \left[\frac{11}{7} \sum_{t=1999}^{2005} D_t \right] - \left[\sum_{t=1999}^{2004} \frac{11 \cdot (2004+1-t)}{105} I_t \right]$$
$$- \sum_{t=1999}^{2004} \left[\left(\frac{11 \cdot (t-1999+1)}{7} \right) \cdot (D_t - D_{t+1}) + \left(\frac{11 \cdot (t-1999+1)}{105} \right) \cdot I_t \right]$$

As such, we now have an expression for the (constant price) capital stock in 1999. Using the perpetual inventory method (PIM), we can then easily construct the capital stocks for 2000 through 2005 as:

$$K_t = K_{t-1}(1-\delta) + I_t$$

where I_t is the investment (in constant prices) and δ the depreciation rate ($\delta = 1/L$). For total capital we use $L = 15$ years, so $\delta = 0.067$. The same methodology is applied to the computer capital stock, with the difference being that the depreciation period is now 5 years instead of 15 years, so $\delta = 0.2$. The starting value for computer capital is determined, as outlined above, by simply assuming that, in 1999, the share of computer capital in total capital for a firm is equal to the computer share in total capital for the relevant industry. These are reported in the table below (Table 10.4). Since each firm has different starting values for K_{1999}, each firm will also have different starting values for computer capital $K_{IT,\ 1999}$. Then, using PIM, for each firm we calculate the investment in computers in year t *as* $I_{IT,t}$, and, with $\delta = 0.2$, we can then calculate the computer capital stocks for the years 2000 through 2005 for each firm.

Table 10.4 Share of computer capital by industry in 1999

Industry	NACE-code	Proportion of computer capital in total capital (%)
Manufacturing of food, drinks and tobacco	15–16	0.82
Manufacturing of textiles, clothes and leather	17–19	1.18
Manufacturing of paper, publishing and printing	21–22	1.24
Manufacturing of refined petroleum and chemicals	23–25	0.57
Manufacturing of basic metals and fabricated metals	27–28	1.02
Manufacturing of machinery	29	2.87
Manufacturing of electrical and optical equipment	30–33	1.74
Manufacturing of transport equipment	34–35	0.91
Manufacturing of wood, cork, wood products, manufacturing of non-metallic minerals, manufacturing nec, and recycling	20, 26, 36–37	1.18
Construction	45	2.04
Sales, maintenance and repair of motor vehicles	50	1.36
Wholesale trade	51	3.50
Retail trade	52	1.37
Hotels, restaurants etc.	55	0.56
Renting machinery	71	0.71
Computer services	72	28.59
High skilled business services	741–744	6.23
Low skilled business services	745–748	4.93
Other services	93	3.20

Note: the values in the final column are the computer capital stock as a percentage of the total capital stock for 1999. Multiplying these percentages by the firm-level total capital stock for the year 1999 yields the firm-level capital stock of computing equipment in the same year. Using the price levels of total capital and of computers in 1999, one can calculate the share of computer capital in constant prices

Source: Statistics Netherlands, National Accounts (http://statline.cbs.nl/Statweb/selection/?DM=SLNL&PA=82640NED&VW=T)

References

Acemoglu D, Angrist JD (2000) How large are human-capital externalities? Evidence from compulsory schooling laws. NBER macroeconomics annuals, MIT Press, Cambridge, pp 9–59

Arrow KJ (1962) The economic implications of earning by doing. Rev Econ Stud 29(3):155–173

Aubert P, Crépon B (2006) Age, wage and productivity, unpublished manuscript INSEE Paris; published in French in Economie et Statistique, 363, pp 95–119

Auer P (2000) Employment revival in Europe. ILO, Geneva

Beach CM (2008) Canada's aging workforce: participation, productivity, and living standards. A Festschrift in honour of David Dodge, Bank of Canada. November 2008. http://www.bankofcanada.ca/wp-content/uploads/2010/09/beach.pdf

Bloom DE, Canning D, Fink G (2011) Implications of population aging for economic growth. NBER working paper, W16705

Broersma L, McGuckin RH, Timmer MP (2003) The impact of computers on productivity in the trade sector: explorations with Dutch microdata. De Economist 151(1):53–79

Broersma L, van Dijk J (2008) The effect of congestion and agglomeration on multifactor productivity growth in Dutch regions. J Econ Geogr 8(2):181–209

Brynjolffson E, Hitt L (1996) Paradox lost: firm-level evidence on the returns to information system spending. Manag Sci 42(4):541–558

Dijkstra L, Garilazo E, McCann P (2013) The performance of European cities and city-regions: myths and realities. Eur Plan Stud 21(3):334–354

Edzes AJE, Rijnks R, van Dijk J (2013) Spatial implications of using firm level quotas to employ low productive workers. Tijdschrift voor Sociale en Economische Geografie/J Econ Soc Geogr 104(5):621–629

Genberg M (1992) The Horndal effect: productivity growth without capital investment at Horndals verken between 1927 and 1952. Uppsala University, Uppsala

Gonzales-Eiras M, Niepelt D (2012) Ageing, government budgets, retirement, and growth. Eur Econ Rev 56(1):97–115

Hansen GD (1993) The cyclical and secular behaviour of the labour input: comparing efficiency units and hours worked. J Appl Econ 8(1):71–80

Jorgenson DW, Stiroh KJ (2000) Raising the speed limit: US economic growth in the information age. Brookings papers on economic activity, pp. 125–211

Lehr B, Lichtenberg F (1999) Information technology and its impact on firm-level productivity: evidence from government and private data sources, 1977–1993. Can J Econ 32(2):335–362

Licht G, Moch D (1999) Innovation and information technology in services. Can J Econ 83 (2):363–383

Lichtenberg FR (1995) The output contributions of computer equipment and personnel: a firm-level analysis. Econ Innov New Technol 3(3–4):201–218

Malmberg B, Lindh T, Halvarsson M (2008) Productivity consequences of workforce ageing: stagnation or Horndal effect? Population ageing, human capital accumulation, and productivity growth. Popul Dev Rev 34: 238–256

Moretti E (2004) Workers' education, spillovers, and productivity: evidence from plant-level production functions. Am Econ Rev 94(3):656–690

Noback I, Broersma L, van Dijk J (2014) Gender-specific dynamics in hours worked. Exploring the potential for increasing working hours in an ageing society. In: Karlsson C, Andersson M, Norman T (eds) Handbook of research methods and applications in economic geography. Edward Elgar, Cheltenham

OECD (2001) OECD productivity manual: a guide to the measurement of industry-level and aggregate productivity growth. OECD, Paris

OECD (2011) Regional outlook. OECD, Paris

OECD (2014a) Territorial reviews: Netherlands 2014. OECD, Paris

OECD (2014b) Ageing and employment policies Netherlands—Working better with age. OECD, Paris

Rauch JE (1993) Productivity gains from geographic concentration of human capital: evidence from the cities. J Urban Econ 34:380–400

Van Ark B, Inklaar R, McGuckin B (2003) ICT and productivity in Europe and the United States: where do the differences come from? CESifo Econ Stud 49(3):295–318

Van Ark B, Chen V, Gupta A, Levanon G, Therrien A (2010) The 2010 productivity brief: productivity, employment and growth in the World's economies, executive action series. The Conference Board, New York

Van Ours J, Stoeldraijer L (2010) Age, wage and productivity. CESIfo working paper no. 2965, CESIfo, Germany

Winter-Ebmer R (1994) Endogenous growth, human capital, and industry wages. Bull Econ Res 46(4):289–314