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Book

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THE STRUCTURAL CHANGE AND LABOUR PRODUCTIVITY OF FIRMS: DO CHANGES IN THE AGE AND WAGE STRUCTURE OF EMPLOYEES MATTER?

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The structural change and labour productivity of firms: do changes in the age and wage structure of employees matter?

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Abstract

This paper aims to clarify how changes in the age and wage composition of the labour force are related to the productivity of firms over the business cycle. Based on a matched employer-employee database of Estonian firms from 2006–2014, we decompose changes in the labour force and distinguish between hired, separated and staying workers. Considering the age and wage of workers, we link changes in the labour force to changes in productivity. Using fixed effect panel data analysis we indicate that among high-waged employees middle-aged are the most productive, the productivity decreases with age but remains higher for old compared to young. the increase in labour productivity is supported by the decreasing share of employees with the lowest productivity. The share of high-income employees was reduced in the crisis and later mostly low-income employees were hired. In addition, structural changes have accelerated the process of ageing. There are, however, sector-specific differences because in knowledge intensive services, ageing is not as prevalent as in industry. We also show that labour productivity is higher in the youngest quartile than in the oldest quartile of enterprises in all four periods.

JEL Classification: J23, J24, J31, J63, M51

Keywords: productivity, labour productivity, ageing, Estonia

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1. INTRODUCTION

In an ageing world, insuring the acceptable dynamics of productivity is going to be a major challenge. How do firms adjust to the ageing of the population as a global trend? The global demographic trends in industrialised countries lead toward the reduction and ageing of the labour supply. The share of the prime-working-age population, in other words, people aged between 25 and 54 years is declining and a 19 per cent decrease in per capita income growth is projected over the next 50 years as a result (Manyika et al., 2015). To retain the standard of living, firms should be able to adjust to the process of the ageing labour force and find ways to increase labour productivity.

Productivity as a measure of the efficiency of production has been widely investigated. The productivity differences across firms have motivated researchers to identify different factors affecting productivity (Bartelsman, Doms, 2000; Del Gatto et al., 2011, Syverson, 2011). The most common measure of single factor productivity is labour productivity (Syverson, 2011). The increase of labour productivity under demographic pressure requires efficiency gains that reduce inputs for a given output, which could be increased through innovations that improve the performance, quality, or value of goods and services (Manyika et al., 2015). Consequently, through innovations and technological change, the increase in labour productivity is related to structural change. Structural change is associated with changes that affect disaggregate units; for example, firms or industries, and the different magnitude of the change in each single unit creates the change of the composition of the aggregate (Krüger, 2008).

In order to understand the relationships between the structural change and productivity growth, different methods of decomposing productivity growth have been developed. At the beginning, the research concentrated on the change in the relative share of output in each industry. Then, researchers started to consider firm entry and exit to and from an industry. The most notable contributions on decomposition methods that also consider firm entries and exits include Baily, Hulten, and Campbell (1992), Griliches and Regev (1992), Foster, Haltiwanger and Krizan (2001), and Baldwin and Gu (2006). Melitz and Polanec (2015) extended the productivity decomposition method developed by Olley and Pakes (1996). When export data became available, the researchers could analyse changes in productivity at the firm level. Resulting from the availability of firm-level data on employees Ilmakunnas and Maliranta (2007 and 2016) have shown that it is possible to decompose labour productivity based on changes in the employment of each firm. Their method involves entries and exits, but the entry and exit (hiring and separation) of employees of different age groups are analysed at the firm level. As a result, the decomposition of labour productivity is related to structural changes of labour in the firms. The method also shows the relative difference of productivity of employees of different age groups.

Links between ageing and productivity have been studied extensively because there is a combination of factors affecting these links and a number of empirical results do not always confirm the conventional shape of the age-productivity curve. While Lallemand and Rycx (2009), for example, have found that the productivity of workers indeed declines with age, Göbel and Zwick (2009) did not find the same pattern in their data. The controversial results are partly caused by the use of different methodologies. For example, longitudinal studies tend to overestimate the productivity levels of employees due to non-random attrition as well as test

practice[1] (Skirbekk, 2004), while the managers' assessments are subjectively biased based on their contact with older employees (Henkens, 2005). Therefore, the empirical work also lacks consensus on the peak age of productivity for employees.

Some surveys show occupational differences in the age-productivity curve. Veen (2008), for example, defines lawyers, professors, managers, medical doctors and engineers as workers in occupations that might have a higher productivity when the employees are old. Van Ours (2009) confirms that in economics the productivity of professors does not decline in older age. Avolio et al. (1990) only look at non-managerial workers, but also find declining productivity in only one group of five. At the same time, without considering age Kampelmann and Rycx (2012) conclude that occupations at the top of the wage hierarchy are overpaid with respect to their marginal productivity and occupations at the bottom underpaid. However, the research on this matter is not extensive. Maliranta et al. (2009) decompose both the hiring and separation rates by age (young/old), education (low/high), tenure (short/long), previous job (R&D/other), and current job (R&D/other) and include these rates as explanatory variables in models for productivity and profitability growth. Nevertheless, to our knowledge no survey has examined the ageing-productivity curve in two wage groups.

The current paper aims to clarify how structural change in the age and wage composition of the labour force is related to the productivity of firms over the business cycle. Data from Estonian employee payroll taxes for 2006–2014 has been matched with financial data from annual reports of all firms in Estonia. We decompose the changes in the labour force and distinguish between hired, separated and staying workers using methodology initiated by Ilmakunnas and Maliranta (2007 and 2016). Additionally, we divide the workers into three age groups and two wage groups while linking changes in the labour force to changes in productivity. The decomposition method allows us to identify the link between within-firm structural changes and productivity through the mobility of workers. A panel data model with fixed effects is estimated, where the parameters can be interpreted as the relative productivity levels of the different employee groups.

In doing so we add to the relatively small amount of literature of the linkages between within-firm structural changes and productivity. We make, in particular, two contributions: First, we further develop the decomposition of labour productivity at firm level. Unlike the prior study by Ilmakunnas and Maliranta (2007), we are able in addition to the age groups also figure out firm-level entries and exits (hiring and separation) of employees of different wage groups. (We have monthly data about wage of employees.) This provides some proxy for the skills and capabilities of employees and hence gives a better understanding of the age-wage preferences of firms in their restructuring process in order to improve their competitiveness. Our second contribution is that due to access to data, which cover the whole business cycle before and after the Great Recession we can demonstrate differences in the entries and exits (hiring and separation) of employees of different wage and age groups over the different stages of the business cycle.

Ilmakunnas and Maliranta (2007), in their study using the same method, investigated the Finnish economy in a period of stable economic growth, and in Ilmakunnas and Maliranta (2001) they conducted a flow rate analysis of workers in Finland during the economic recession.

[1] Test practice means that people who take the same test for the second, third or fourth time may perform better than the people who take the test for the first time, only because the test is familiar to them. People who have already taken the test may intentionally practice before the next test, because they know what to practice. (Kulik et al. 1984)

We use both methods to analyse structural change in deep economic recession in Estonia. Estonia is a particularly interesting case for such an analysis because it is one of the EU countries where labour productivity improved after the 2008–2009 global financial crisis. At the same time, the GDP decline in Estonia during the recession in 2009 was one of the largest in the EU -14.6% (Masso and Krillo, 2011). Due to a flexible labour market the recovery mostly took place through a reduction in the number of workers instead of the number of working hours for each worker (Meriküll, 2011, Roosaar, et al., 2014). Moreover, Estonia's older labour market is relatively active (Sinclair et al., 2013); therefore, older employees in our data are more frequent than in other countries, where older employees have less incentives to work. In Estonia for example the working old-age pensionaries can receive wage and national pension at the same time. In 2011, in Estonia the employment rate among 65- to 69-year-olds was 19.5 percent, while in the EU27 the respective number was 10.5 (Dubois and Anderson, 2012). In 2015, the median age in Estonia (41.6 years) was similar to median age in more developed countries in United Nations (41.1 years) (United Nations, 2017). Another interesting feature of the Estonian labour market is that while Estonian employees are relatively free to leave Estonia and there are no restrictions on mobility of EU citizens, annual immigration quotas are set on the mobility from the third countries. The quotas are quite restrictive and related with the salary thresholds, which vary according to a skill-scheme and profession (Smidova and Yashiro, 2017). The rest of the paper is organised as follows. A literature review is given in the next section. In the section 3 the data and methodology are presented. In section 4 the results of the econometric models are described and the last section summarises and concludes.

2. LITERATURE REVIEW

The decomposition of firms' productivity by age and wage indicates the relative productivity of each group of employees. Therefore, the literature review below mostly concentrates on what can cause of the differences in productivity of these groups of employees. Although the conventional age-productivity curve has the shape of an inverse U, the empirical evidence is mixed (e.g. Skirbekk, 2004 for an overview). Skirbekk (2004) indicates that age influences labour productivity through four factors – education, physical abilities, job experience, and mental abilities. Based on the data from 111 countries, Lee and Lee (2016) have shown that over the past two centuries there has been remarkable growth in average educational attainment and human capital stock. Additionally, in 2017 Eurostat announced that the share of people aged 30 to 34 in the European Union (EU), who have completed tertiary education had increased from 23.6% in 2002 to 39.1% in 2016. Therefore, younger employees have relatively higher education. As a result, considering education level alone, the young should be the most productive of all age groups.

Considering the greater physical capacities of younger workers, their productivity should be relatively high compared to older age groups. It has been indicated that physical abilities start declining after the age of 30 years, although regular physical exercise can indeed help people remain in relatively good physical condition (Ilmarinen, 2001). Another study shows that cognitive decline is already evident in middle age (age 45–49) (Singh-Manoux et al., 2012). However, the relative advantage of the better physical ability of younger workers may somewhat decrease in time given that in the USA, the amount of highly physically demanding jobs in the economy has shown a diminishing trend from 1970 (Johnson et al., 2011). This trend is very likely to be similar in all the developed countries.

The greatest difference between young employees and older workers is related to job experience. Long experience on the job can improve the productivity of older workers relative to that of younger workers (Skirbekk, 2008b). Maranto and Rogers already suggested in 1984 that the productivity of investigators[2] improved significantly during the first six years of job experience. Dependent on occupation, achieving expert competence has been shown to take ten years if strategic and analytical competence is important (Skirbekk, 2008a). Work experience can compensate for the decline of some basic cognitive processes – it improves tacit knowledge, professional competence, and cooperation skills while it also increases structural awareness about the organisation and expands customer networks (Ilmarinen, 2012).

The exact effect of job experience is highly related to mental abilities that have complex links with age. There are two kinds of mental abilities – fluid abilities that involve on-the-spot reasoning ability independent of past experience, and crystallised abilities that rely on accumulated knowledge (Skirbekk, 2004; Johnson *et al.*, 2011). Such a distinction of cognitive abilities is based on dividing intelligence into crystallised and fluid intelligence and intelligence in the theory is conceptualised as a major, largely genetically fixed source of individual differences in IQ (Kan et al., 2013). Strategic thinking, sharp-wittedness, consideration, wisdom, ability to deliberate and to rationalise, control of life, holistic perception and language skills improve with age and are some of the examples of crystallised abilities (Ilmarinen, 2012). Procedural knowledge and verbal ability for example are usually found to remain stable as well as interactive skills (Lallemand and Rycx, 2009).

Although young are more educated and physically more fit and old are experienced and have higher level of crystallized abilities, the productivity is dependent on whether the employee also uses the skills while working. Van Ours (2009) concludes that the net effect of the age-specific productivity determinants depends on the use of individual skills in the work process, but also on work organisation, interactions with other workers, and firm-level factors (e.g. technology). Therefore, the type of skill required in the workplace in different occupations may induce differences in the age-productivity relation across occupations. Avolio et al. (1990) explain their result of a non-linear age-productivity curve in non-managerial occupations with the fact that better performers get promoted out of lower-level jobs. In the following analysis, we also consider the wage of employees. Therefore, we may expect the old low-waged employees to be poorer performers who remain in lower-level jobs. The young have not had time to prove their performance and make a career; therefore, the explanation is not true for young workers. However, in a similar manner we may expect the performance of young low-waged workers to be relatively poor. Most good performers among the young may not be found in the labour market when they are in their early twenties because they have the abilities required to study and acquire higher education. Among middle-aged employees we expect to find slightly smaller differences. Consequently, higher productivity may be related to non-observable aptitude.

We are not able to analyse what kind of skills and abilities the employees use at work or which factors lead to higher or lower productivity in each group of employees in our data. Also, we cannot analyse individual productivity of each employee with our method. The assumption of equal individual productivity in each age group is a major simplification in this research. It has indeed been found that productivity variations between individuals (caused by schooling, genetics, and family influences) tend to be greater than variations across age groups (Skirbekk, 2008b). From the aspect of aging Deary et al. (2000) show that individual differences remain stable over the life cycle. We can nevertheless analyse differences between productivity of

[2] They do not consider police investigators but field investigators whose principal job task is the recovery of unpaid wages that employers allegedly owe to employees.

groups of employees in different sectors. High shares of older adults in manufacturing plants for example have been found to increase labour productivity compared to large shares of younger adults (Malmberg et al., 2008). The positive effect of ageing may be larger in innovative enterprises compared with those involved in routine tasks (as shown more recently by Backes-Gellner and Veen, 2013). Working in teams of mixed ages may influence the results of empirical studies as the team members affect each other's productivity (Börsch-Supan and Weiss, 2010). Therefore, it may affect the productivity of groups of employees in the sectors where teamwork is more important. Göbel and Zwick (2009) have confirmed considerable variation in the age-productivity profile amongst establishments in the economy, but they (2012) find no significant differences in age-productivity profiles between sectors. Mahlberg et al. (2013b) reveal that age effects at the industry level are of a higher magnitude than at the regional level. The empirical results have thus been contradictory.

It is necessary to analyse the relationship between age and productivity in different phases of the business cycle, because Skirbekk (2008b) claims that the relationship is found to vary over time according to market needs. Firstly, the variation in the age-productivity relationship may result from labour hoarding. Labour hoarding means that if adjusting the labour force is costly in the short run, firms may smooth labour input over the cycle and "hoard" labour in downturns; using the labour force variably over the cycle creates the illusion of increasing returns (Bernanke and Parkinson, 1991). The ability and need to hoard employees may differ in different economic sectors. In addition, firms may be more willing to hoard the group of employees who are the most productive.

Secondly, the minimum ability requirement is also affected by changes in the labour market that result from changes in business cycle phases. In a boom period of the economy, the minimum ability requirement is less important due to the general scarcity of workers in the economy (as in Estonia before 2008). Conversely, during a recession, the minimum ability requirement can be raised because there are more unemployed workers available. However, the impact should be relatively equal to all the age groups as the vacancies usually should not discriminate people of any age. For each vacancy a certain level of skills is nevertheless required. Therefore, the scarcity or abundance of employees with certain skills on the labour market should influence the minimum ability requirements for the employees of respective wage groups.

Thirdly, none of the participants in the labour market has perfect information about the qualities of the other party, but the expectations of the employee and the employer must match for hiring to take place. Matching theories explain the relationship of economic cycle to quit propensity. Cornelißen et al. (2007) show that in recessions, workers accept a worse match quality to avoid unemployment. The quit propensity of these workers remains high because they continue on-the-job search to leave for a better job. Due to the larger number of vacancies in periods of economic growth, the propensity to quit increases with the growth of economy. Therefore, considering the different probability of match quality among employees from different age and wage groups, it is reasonable to expect the high-waged employees in each age group to have the better match in general than low-waged employees. In addition, the match of younger employees should also be of lower quality than for older employees as the young may not have enough experience to apply for their dream jobs, younger employees may also not know yet what is the most suitable job for their needs.

3. DATA AND METHODOLOGY

3.1. Data

We analyse the Estonian data for the period 2006–2014. This is an exceptional period when the high economic growth rate of 8.4 in 2007 was replaced by economic decline of -5.1 percent in 2008 and -14,2 percent in 2009. In Estonia in 2008–2009, the extent of the decline in output can be compared to the Great Depression articulate per cent from their peak levels, and so Estonia, Latvia and Lithuania were more severely affected by the recession than any other region in the world (Purfield and Rosenberg, 2010). In other countries in Europe, the cumulative negative impact of recession was smaller or appeared over a longer period of time (e.g. in Southern Europe). Therefore, in the whole world in general the effect of the recession was less severe.

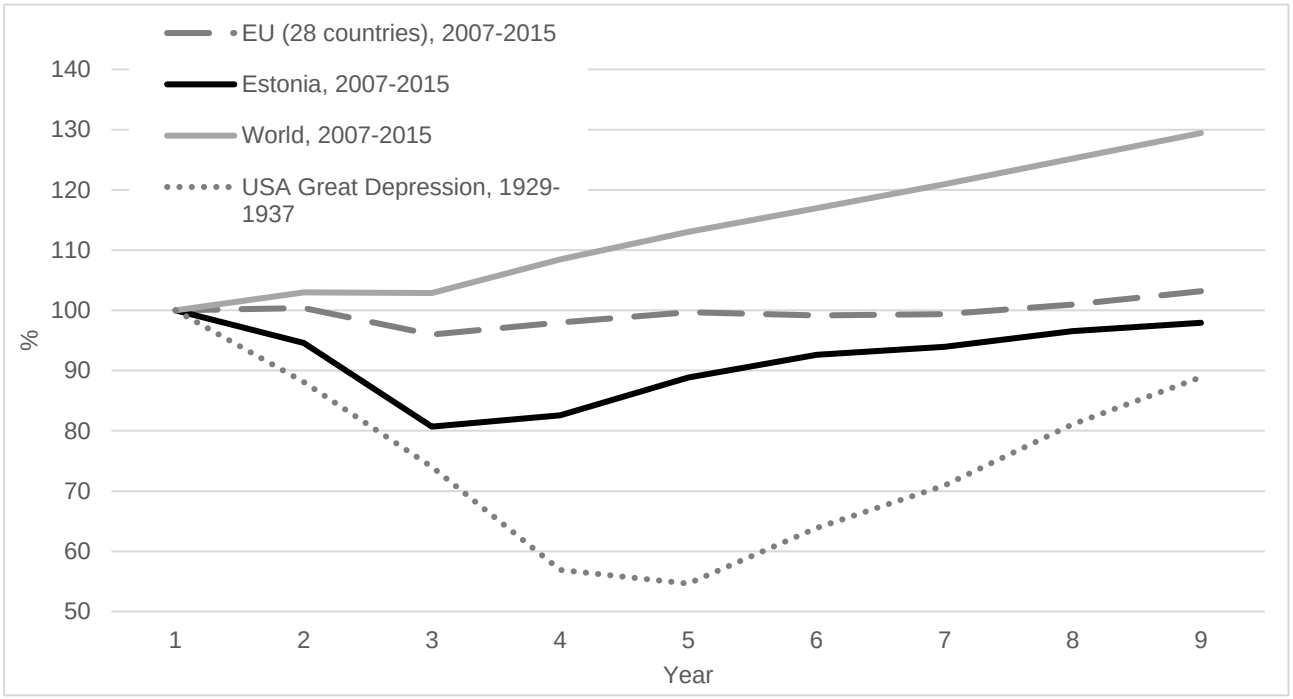

Figure 1. GDP as percentage of GDP at the beginning of the crisis
Source: Eurostat, International monetary Fund, Bureau of Economic Analysis.

We use the records of employee payroll taxes from the Estonian Tax and Customs Board that have been matched with firms' records from the Commercial Register of Estonia (dataset of annual reports). Therefore, firms in Estonia are included in our initial sample for the period 2006–2014. Estonian enterprises used mostly three strategies to cut labour costs during the crisis – wage cuts and reductions of hours as well as reducing the number of employees, but the latter was by far the most prevalent of the strategies (Masso and Krillo, 2011; Meriküll, 2011). The sample has been aggregated to one unique observation for each firm-employee-year combination. This means that although we have data for each month every year, we have included the data from January and eliminated all the data for the other months of each year. January is the most logical choice because for most firms the end of the business year is the end of the calendar year. Therefore, we look at the changes in the firms' workforce from January of some year to January of the next year and only consider the situation of each enterprise (and

each employee) once per year. In addition, each year we only include every employee with his or her main job – the job where the wage was the largest.

We use two-year periods to define the labour flows and changes in productivity. Therefore, the flows and changes are defined for four periods: 2006–2008, 2008–2010, 2010–2012 and 2012–2014. Two-year periods follow our interest in the impact of the crisis that requires separating the years 2008–2009 as the years with the lowest GDP-growth. Usually, in productivity decompositions three and five-year periods have also been used (e.g. Masso et al., 2004). Our observation unit as in Ilmakunnas and Maliranta (2007) is a firm. All the enterprises are from the industrial and service sectors, and so agricultural, real estate and financial intermediation enterprises are excluded. The industrial sector comprises mining, manufacturing and public utilities. In the largest sector, services, we separate knowledge intensive services (as defined by Eurostat[3]) and compare these results with other services. We conduct a separate analysis on enterprises in construction, as that sector is exceptional in the period 2006–2014 due to the housing bubble in the Baltic states (Masso and Krillo, 2011), and the decline in employment was considerable during the recession. The service sector consists of retail and wholesale trade, business services and personal services. The analysis as a whole has one major limitation, namely that we cannot include micro enterprises. Removing all the enterprises with less than 10 employees reduces the sample size, but if an employee leaves such a firm that has only two workers, we would record the reduction of workforce by 50%. If there are a lot of small firms in one economic sector, the result is different from the result in other sectors mainly because of the size of the enterprises and not anything else. In the first period, we include 4,101 enterprises, in the second period 3,976 enterprises and in the third and fourth 3,041 and 3,272 enterprises respectively.

For comparability reasons, our definition of young, middle-aged and older workers coincides with that of others (e.g. Ilmakunnas and Maliranta 2007; Mahlberg et al. 2013 a, b; Vanderberghe 2011). Young are less than 30 years old, middle-aged are considered to be 31–50 years old and older employees are over 50 years old. We use the methodology proposed by Ilmakunnas and Maliranta (2007 and 2016), which is based on the decomposition of industry-level productivity changes used for instance by Diewert and Fox (2005). Firm-level productivity is decomposed into the effects of hired and separated, and also into the share of staying employees. While Ilmakunnas and Maliranta analyse only young, middle-aged and old workers, we add another dimension with two wage groups. The non-observable aptitude and skills of employees are proxied with their wage.[4] Based on 2-digit level NACE codes we calculated the average wage for each industry. Then, all the employees of the firms were divided into the high-earners group (if the wage was higher than the average wage in the industry) and the low-earners group (if the wage was equal to the average or less). Altogether we have six groups – young high-earners, middle-aged high-earners, and old high-earners, young low-earners, middle-aged low-earners, and old low-earners. Kampelmann and Rycx (2012) affirm that there is an upward-sloping and significant occupational wage profile. We do not have data on occupations in our matched data of employees and employers. The Labour Force Survey

[3] Knowledge intensive services include high-tech knowledge-intensive services (NACE rev 2: 59; 60; 61; 62; 63; 72), knowledge-intensive market services (excluding financial intermediation and high-tech services) (NACE rev 2: 50; 51; 70; 71; 73; 74; 78; 80), knowledge-intensive financial services (NACE rev 2: 64; 65; 66; excluded in our analysis), other knowledge-intensive services (NACE rev 2: 58; 75; 84; 85; 86; 87; 88; 90; 91; 92; 93).

[4] According to the theory of human capital, investment in education and training increases worker productivity, consequently demand for those workers raises and as a result their wages also improve. Although wage may partly reflect how much a job is valued or how strong are unions, evidence from across the world concerning the human capital and wages is consistent with the theory (see e.g. Holmes 2017).

data for Estonia from 2010 nevertheless indicate that 69 per cent of high skilled white-collar workers (legislators, senior officials and managers, professionals and technicians and associate professionals) earn more than the average. At the same time, 65 per cent of low skilled blue-collar workers (plant and machine operators and assemblers and elementary occupations) earned less than the average. Therefore, to some extent the wage level as defined here also reflects occupational distribution; we can expect the blue-collar workers to earn mainly less than average and the white-collar workers to earn rather more than average. Wage level is also a proxy for skill level. The authors of the method have used the same method to analyse knowledge spillovers from workers mobility (Maliranta et al., 2009) as well as the impact of ageing on employee productivity in Finland (Ilmakunnas and Maliranta, 2007; Maliranta and Ilmakunnas, 2005). They did not incorporate any other characteristics of workers into the analysis, although they additionally divided separated employees based on where they went – to another firm or retirement.

The dynamics of worker flows is shown in Figure 2 below and in Appendix 1. The figures provide the number of high-waged and low-waged (also old, young and middle-aged) from the flow analysis. The employees can stay, separate or be hired only during a period that has a beginning and an end, and the firm also has to be active at the beginning as well as at the end of the period. The employees who are hired in one firm are considered separated in another firm during the same period, unless the employee enters the labour market from inactivity. The figure indicates that there was a sharp decline in hirings for low-waged as well as high-waged employees in the second period and the hirings in the last period did not reach back to the initial level. Comparing the first and last period, the number of hired low-waged employees declined by 27.4% (from 183,011 to 132,736), and the number of hired high-waged employees decreased by 33.4% (from 113,357 to 75,511).

While there were significantly more low-waged employees hired among the stayers, the numbers were rather similar for low-waged and high-waged employees in all periods (around 180,000 to 200,000 and the number of stayers increased after the recession in both groups by less than 10 per cent). The number of separations was larger during the first two periods compared to the two last periods. Supposedly, during the first period, there were rather more workers who left for better pay or positions because it was the period of economic boom and a lot of vacancies were available. During the second period (in 2008–2009), the number of involuntary separations was relatively larger than in the other three periods.[5] The number of separations in the third and the fourth period should reflect the average number of separations in Estonia during slower economic growth (near 32,000 for high-waged employees and 44,000 for low-waged employees). More statistical information can be found in Appendix 1.

In Appendix 1 Figure 2, the difference between hired and separated employees shows that compared to high-waged employees, more low-waged employees were hired in 2006–2008 (before the crisis) and also after the crisis. In the last period (2012–2014), hirings and separations were nearly equal in both wage groups. During 2008–2010, there were significantly more separations than hirings – the difference was about 50,000 jobs for low-waged employees and 30,000 jobs for high-waged employees. Comparing separations and hirings in three age groups indicates that before the crisis significantly more (by about 40,000) young employees were hired than separated in the first period; the differences in other age groups were smaller.

[5] Based on Estonian Labour Force Survey data, Masso and Krillo (2011) also documented an increase in personnel cuts (194% in 2009 compared to the total number in 2008), enterprise closures (300%) and termination of self-employment (190%).

While in 2008–2009, the number of separations was larger than that of hirings in all age groups, after the crisis the separations outnumbered hirings in the older age group and in 2012–2014 also among middle-aged employees. Separations in the oldest group of employees are influenced by employees taking retirement. The numbers of hirings and separations are high for the young because in this age group the number of staying workers is very low compared to other age groups. This illustrates the fact that the young are more open to new opportunities (see also section 2).

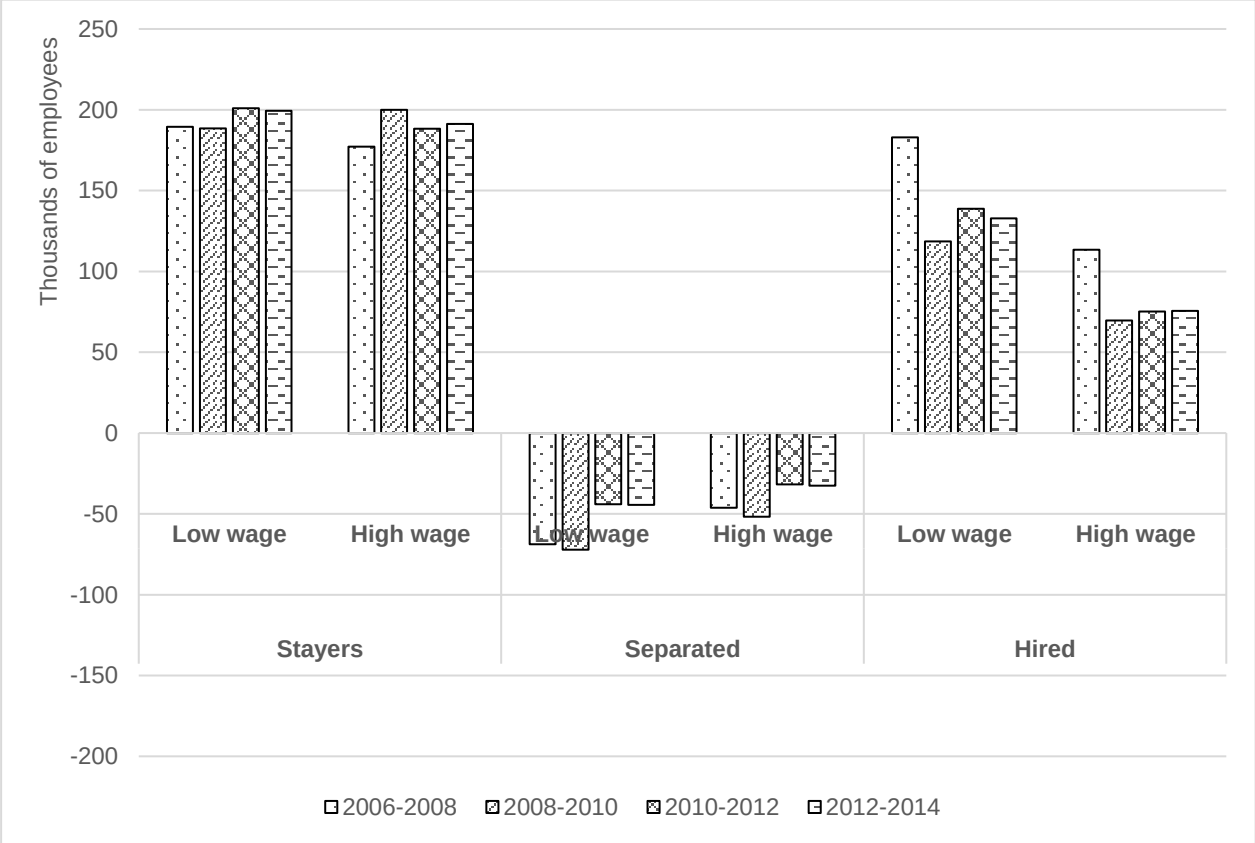

Figure 2. Number of employees of different categories in the sample in four periods

Note: Low-waged stayers, high-waged stayers and low-waged hired and high-waged hired employees form 100% of employees at the end of each period. Low-waged stayers, high-waged stayers and low-waged separated and high-waged separated employees form 100% of employees at the beginning of each period.

3.2. Method

Our method is based on a decomposition technique proposed by Ilmakunnas and Maliranta in 2007. The dependent variable in our analysis is labour productivity growth, which is measured as a two-year (*t* and *t-2*) rate of change in value added per employee in deflated terms. Ilmakunnas and Maliranta (2007) begin with the assumption that the labour of an enterprise consists of *M* different age groups and the added value at year t=1 (Y_1) can be defined as the sum of all the added values generated by *M* age groups

$$Y_1 = \sum_j^M Y_{1j} \quad . \qquad (1)$$

Note that in the current study, differently from Ilmakunnas and Maliranta (2007), we divide age groups into two subgroups based on wage. Therefore, in our case *M* is not equal to 3 but it is equal to 6. For the labour productivity of the enterprise, we divide both sides of equation (1) with the sum of the total of the labour groups L_1 and use the average of the labour productivities of *M* age groups weighted with their employment shares:

$$\frac{Y_1}{L_1} = \sum_j^M \frac{L_{1j}}{L_1}\frac{Y_{1j}}{L_{1j}} \quad (2)$$

where $L_1 = \sum_j^M L_{1j}$.

We can divide each of these *M* age groups into newly hired workers (*hire*) and stayers (*stay*) based on whether they work in the enterprise at the beginning of the period (t=0) or at the end of the period (t=1). Stayers are present in the firm at the beginning and at the end of the period. Newly hired workers can only be found in the data at the end of the period as they have been hired during the time between the beginning (t=0) and the end (t=1) of the period. As another addition to the method from Ilmakunnas and Maliranta (2007), we claim that the weight for the number of hired employees cannot be 1 as for the number of stayers because the newly hired employees have been into the firm only part of the time. The real weight for each hired employee could be computed by tracking the exact time that he or she has been in the firm by the end of the period and dividing it with the length of the whole period. To avoid time-consuming tracking, we assume that the new employees are hired with constant intervals during the whole period and 0.5 could be used as the average weight for all the hired employees. Later, we similarly weight separated employees with 0.5 instead of 1.

Therefore, the firm's labour productivity can alternatively be presented as follows:

$$\frac{Y_1}{L_1} = \sum_j^M \frac{L_{1j,stay}}{L_1}\frac{Y_{1j,stay}}{L_{1j,stay}} + \sum_j^M \frac{0.5L_{1j,hire}}{L_1}\frac{Y_{1j,hire}}{0.5L_{1j,hire}} + \varepsilon_{Y/L,1} \quad (3)$$

where $L_1 = \sum_j^M L_{1j,stay} + 0.5\sum_j^M L_{1j,hire}$

Using the fact that the shares of hired workers and stayers add up to one,

$$\sum_j^M \frac{L_{1j,stay}}{L_1} + \sum_j^M \frac{0.5L_{1j,hire}}{L_1} = 1$$

equation (3) can be rewritten as:

$$\frac{Y_1}{L_1} = \sum_j^M \frac{L_{1j,stay}}{\sum_{1j} L_{1j,stay}}\frac{Y_{1j,stay}}{L_{1j,stay}}\frac{\sum_{1j} L_{1j,stay}}{L_1} + \sum_j^M \frac{0.5L_{1j,hire}}{L_1}\frac{Y_{1j,hire}}{0.5L_{1j,hire}} =$$

$$= \sum_j^M \frac{L_{1j,stay}}{L_{1,stay}}\frac{Y_{1j,stay}}{L_{1j,stay}}\left(1 - \frac{\sum_{1j} 0.5L_{1j,hire}}{L_1}\right) + \sum_j^M \frac{0.5L_{1j,hire}}{L_1}\frac{Y_{1j,hire}}{0.5L_{1j,hire}} =$$

$$= \sum_j^M \frac{L_{1j,stay}}{L_{1,stay}}\frac{Y_{1j,stay}}{L_{1j,stay}} - \frac{\sum_{1j} 0.5L_{1j,hire}}{L_1}\sum_j^M \frac{L_{1j,stay}}{L_{1,stay}}\frac{Y_{1j,stay}}{L_{1j,stay}} + \sum_j^M \frac{0.5L_{1j,hire}}{L_1}\frac{Y_{1j,hire}}{0.5L_{1j,hire}} =$$

$$= \sum_j^M \frac{L_{1j,stay}}{L_{1,stay}} \frac{Y_{1j,stay}}{L_{1j,stay}} + \sum_j^M \frac{0.5L_{1j,hire}}{L_1} \left(\frac{Y_{1j,hire}}{0.5L_{1j,hire}} - \sum_j^M \frac{L_{1j,stay}}{L_{1,stay}} \frac{Y_{1j,stay}}{L_{1j,stay}} \right) = \quad (4)$$

$$= \sum_j^M \frac{L_{1j,stay}}{L_{1,stay}} \frac{Y_{1j,stay}}{L_{1j,stay}} + \sum_j^M \frac{0.5L_{1j,hire}}{L_1} \left(\frac{Y_{1j,hire}}{0.5L_{1j,hire}} - \sum_j^M \frac{L_{1j,stay}}{L_{1,stay}} \frac{Y_{1j,stay}}{L_{1j,stay}} \right) =$$

$$= \sum_j^M \frac{L_{1j,stay}}{L_{1,stay}} \frac{Y_{1j,stay}}{L_{1j,stay}} + \sum_j^M \frac{0.5L_{1j,hire}}{L_1} \left(\frac{Y_{1j,hire}}{0.5L_{1j,hire}} - \frac{Y_{1,stay}}{L_{1,stay}} \right)$$

For labour productivity at the beginning of the period, there are no newly hired employees, as by definition these are the workers who come to the firm by the end of the period. Therefore, the group of separated workers (*sepa*) is defined – those who are present in the firm at the beginning of the period and have separated before the end of the period. Here, the separated employees have not been in the firm for the whole period and their weight is 0.5 instead of 1. Analogously to (4) labour productivity at the beginning of the period can be defined as:

$$\frac{Y_0}{L_0} = \sum_j^M \frac{L_{0j,stay}}{\sum_{0j} L_{0j,stay}} \frac{Y_{0j,stay}}{L_{0j,stay}} + \sum_j^M \frac{0.5L_{0j,sepa}}{L_0} \left(\frac{Y_{0j,sepa}}{0.5L_{0j,sepa}} - \sum_j^M \frac{L_{0j,stay}}{\sum_{0j} L_{0j,stay}} \frac{Y_{0j,stay}}{L_{0j,stay}} \right) =$$

$$= \sum_j^M \frac{L_{0j,stay}}{\sum_{0j} L_{0j,stay}} \frac{Y_{0j,stay}}{L_{0j,stay}} + \sum_j^M \frac{0.5L_{0j,sepa}}{L_0} \left(\frac{Y_{0j,sepa}}{0.5L_{0j,sepa}} - \frac{Y_{0,stay}}{L_{0,stay}} \right), \quad (5)$$

where $L_0 = \sum_j^M L_{0j,stay} + 0.5 \sum_j^M L_{0j,sepa}$.

It holds by definition that the total number of stayers at the beginning of the period equals the number of stayers at the end of the period:

$$\sum_j^M L_{0j,stay} = \sum_j^M L_{1j,stay} \ .$$

The variable of interest is the change in labour productivity,

$$\frac{Y_1}{L_1} - \frac{Y_0}{L_0} = \Delta \frac{Y}{L} \quad (6)$$

The changes in the composition of staying age groups between the beginning and the end of the period are not taken into account even if they occur in the data, thus the assumption is

$$L_{0j,stay} = L_{1j,stay}.$$

The following is obtained:

$$\frac{Y_1}{L_1} - \frac{Y_0}{L_0} = \left(\sum_j^M \frac{L_{1j,stay}}{L_{1,stay}} \frac{Y_{1j,stay}}{L_{1j,stay}} + \sum_j^M \frac{0.5L_{1j,hire}}{L_1} \left(\frac{Y_{1j,hire}}{0.5L_{1j,hire}} - \frac{Y_{1,stay}}{L_{1,stay}} \right) \right) -$$

$$- \left(\sum_j^M \frac{L_{0j,stay}}{\sum_{0j} L_{0j,stay}} \frac{Y_{0j,stay}}{L_{0j,stay}} + \sum_j^M \frac{0.5L_{0j,sepa}}{L_0} \left(\frac{Y_{0j,sepa}}{0.5L_{0j,sepa}} - \frac{Y_{0,stay}}{L_{0,stay}} \right) \right) =$$

$$= \sum_{j}^{M} \frac{L_{0j,stay}}{\sum_j L_{0j,stay}} \left(\frac{Y_{1j,stay}}{L_{1j,stay}} - \frac{Y_{0j,stay}}{L_{0j,stay}} \right) + \tag{7}$$

$$+ \sum_{j}^{M} \frac{0.5L_{1j,hire}}{L_1} \left(\frac{Y_{1j,hire}}{0.5L_{1j,hire}} - \frac{Y_{1,stay}}{L_{1,stay}} \right) +$$

$$+ \sum_{j}^{M} \frac{0.5L_{0j,sepa}}{L_0} \left(\frac{Y_{0,stay}}{L_{0,stay}} - \frac{Y_{0j,sepa}}{0.5L_{0j,sepa}} \right) .$$

The first set of terms on the right-hand side of equation (7) indicates the productivity growth accumulating over time for workers who stay in the firm. This term is positive if the average productivity growth of the stayers is positive. As growth may vary across the age groups, the total effect is a labour share weighted average of productivity changes in the different groups. The second set of terms shows the productivity effects of hiring workers in different age groups. The productivity level of the hired type *j* workers have to be higher than the average of staying workers for the impact of the hiring on the productivity change to be positive. Note that adjustment costs are implicit and the relative productivity of the hired workers is net of adjustment costs.[6] The third set of terms shows analogously the separation of type *j* workers and the effect of separations is positive if this group of *j* workers has a lower productivity level than the average current worker in year 0. The impact on productivity is again net of adjustment costs.

The terms of (7) are divided by the average productivity level in years 0 and 1, thus growth rates are obtained as follows:

$$\frac{{}^{Y_1}/_{L_1} - {}^{Y_0}/_{L_0}}{0.5\,({}^{Y_1}/_{L_1} + {}^{Y_0}/_{L_0})} \approx \ln \frac{{}^{Y_1}/_{L_1}}{{}^{Y_0}/_{L_0}} = d\ln(Y/L) \tag{8}$$

Based on equations (7) and (8), productivity gaps between age groups can be estimated.

$$\frac{\Delta({}^{Y}/_{L})}{({}^{Y}/_{L})} = \alpha + \sum_j^M \beta_{LP,i,t,j,hire} HR_j + \sum_j^M \beta_{LP,i,t,j,sepa} SR_j + \sum_j^{M-1} \chi_{LP,j,stay} STAYSH_j + \delta' \boldsymbol{Z} + \varepsilon \tag{9}$$

where $\overline{(Y/L)} = 0.5[(Y_0/L_0) + (Y_1/L_1)]$ is the average of the productivity of the two periods, hiring rate $HR_j = \frac{L_{1j,hire}}{L_1}$ and separation rate $SR_j = \frac{L_{0j,sepa}}{L_0}$ are the shares of hired workers and separated workers and $STAYSH_j = \frac{L_{0j,stay}}{L_{0,stay}} = \frac{L_{1j,stay}}{L_{1,stay}}$ represents the share of employees who stay in the enterprise. The control variables Z are added to describe other exogenous factors that affect the productivity of enterprises, wages and profits. Panel data is used, and so in equation (9) indexes for enterprise (i) and period (t) are added. We interpret the coefficients as:

$$\beta_{LP,i,t,j,hire} = \beta_{LP,i,t,j,hire} = \frac{(Y/0.5L)_{1,i,t,j,hire} - (Y/L)_{1,i,t,stay}}{\overline{({}^{Y}/_{L})}}, \tag{10}$$

[6] Labour adjustment costs include recruiting costs, costs of screening and training new employees, layoff notice periods, and mandatory severance pay. To a large extent the labour adjustment costs are related to labour market regulation. One of the consequences of the high costs is hindered reallocation of labor resources from less to more productive firms, and therefore, also slower economic growth in general (Trapeznikova, 2017)

that measure relative productivity and relative wage of newly hired employees and we also interpret another set of coefficients:

$$\beta_{LP,i,t,j,sepa} = \frac{(Y/L)_{0,i,t,stay} - (Y/0.5L)_{0,i,t,j,sepa}}{\overline{(Y/L)}} \quad (11)$$

that measure the relative productivity of the separated employees before they leave.

For the labour flows, we compare employees in firms separately at the end (*t*) and at the beginning (*t-2*) of the period in each age group. In each period, age is calculated according to the actual age of the employee at the end of year *t*. For example, those who were 49 years old in t-2, are 51 years old in t and included among the "old". Those who were 30 already in year *t-2*, are 32 in *t*, and hence included in the middle-aged group. Similarly, we determine the wage group for an employee in year *t-2* and assume that in year *t* his or her wage group has not changed. However, for hired employees who cannot have a wage in the data for year *t-2* we have used their wage from the year *t*. Some additional variables are added to the equation as controls – log of capital per employee in difference form, the initial levels of the log of value added per worker and the log of the average wage (both in *t-2*). Instead of the fifteen counties in Estonia, we use the more general division of five areas in Estonia – Northern Estonia, Western Estonia, Central Estonia, North-Eastern Estonia and Southern Estonia (corresponding to the NUTS III regions of Estonia). In 2007, Ilmakunnas and Maliranta used the ordinary least squares method and instrumental variables in their analysis. They also included interactions of industry and period in their model, omitting the straight effect of industry and period variables alone. We argue that a fixed effect panel data model is more appropriate for this kind of productivity analysis because in pooled ordinary least squares equations, ignoring the object-specific term (characterizing e.g. the quality of management) leads to errors that are highly autocorrelated.

Instrumental variables for Ilmakunnas and Maliranta (2007) include among others the share of home-owners in each age group as an instrument for separation rates. We could have defined the same variable based on the Estonian Population and Housing Census conducted in 2011. Even if the share of home-owners can be rather stable among the older employees, supposing that people in the younger age groups do not buy a home or sell it during the period under investigation, is not reasonable. Therefore, the share of home-owners in 2011 would not have described the whole period of analysis, and could not have worked as an instrument in the current analysis.

4. EMPIRICAL RESULTS

4.1. Average age, wage and productivity and the dynamics of hiring, separation and staying in firms

In the following analysis, we first take a look at the ageing process in firms for the period 2006–2014. Next, we show productivity differences related to the average age and wage of employees in firms. We also check the dynamics of the hiring and separation rates and share of stayers through the four periods of the business cycle.

Table 1 in Appendix 2 shows that the average age in our sample has increased by about two years, from 41.5 to 43.4 through 2006–2014. In the industrial sector, the employees are

relatively older; the average age in industry has increased from 42.5 to 44.4. The employees in services are the youngest, the average age in services increased from 40.8 to 42.8 over eight years. In 2014, the share of employees younger than 31 years is the smallest in industry (17.9%) and the highest in services (24.3%). In general, in all sectors, the share of young employees has decreased and the share of old employees has increased.

Dividing the firms into four quartiles based on the average age of their employees indicates that in general in the youngest quartile, the average labour productivity is higher than in the older quartiles (see Table 1 below). The crisis reduced the differences between the highest and lowest average productivities, but in 2006 as well as in 2014 the labour productivity is higher in the two younger quartiles compared to the two older quartiles. In 2006, the average labour productivity of all the firms in the youngest 1st quartile in industry, services or construction was 39,978 euros; by 2014, the productivity has not yet recovered being only 36,236 euros. The decline in labour productivity is mostly related to services, where it decreased in all four quartiles from 1.7% to 17.3% compared to the level in 2006. The labour productivity in all four quartiles in industry has increased (varying from 2% to 15% from its initial level).

Table 1. The average productivity per employee in four quartiles*

	Year	1st quartile	2nd quartile	3rd quartile	4th quartile
Industry, services and construction	2006	39977.81	36059.04	27902.16	23816.17
	2008	34422.83	33195.97	25713.41	22075.25
	2010	33487.87	33087.11	26704.09	20612.66
	2012	35268.65	36017.40	28198.47	21790.64
	2014	36236.46	36133.55	29417.06	22408.10
Industry	2006	32933.64	27705.02	23231.25	24492.51
	2008	31378.47	24912.91	21942.33	21988.31
	2010	35808.89	29091.14	23862.98	22381.23
	2012	33518.55	29328.94	22979.15	24181.34
	2014	35929.48	31824.71	25310.53	25037.71
Services	2006	43640.58	44661.64	35383.26	24427.23
	2008	35666.68	40176.71	31472.31	23269.96
	2010	33522.82	35624.25	31027.11	20651.11
	2012	35482.55	38224.15	33512.75	21555.00
	2014	36076.19	40858.74	34791.28	22213.48

*Quartiles are determined based on the average age of employees in the firm (firms employing at least 10 employees).

A more detailed comparison of the first and fourth quartile in the whole sample indicates that there are also noticeable productivity differences dependent on how large a proportion of the employees earn a wage higher than the average in each industry (Table 2 below). The productivity increased by 2014 in both quartiles only in firms where less than 30% of the employees earn more than the average wage (by 2.5% in the fourth quartile and only 0.2% in the first). In both quartiles, the difference in labour productivities has grown over time – by the end of the period in 2014 in the first quartile the productivity of firms with less high-waged employees forms 56.6% of the other group and in the fourth quartile this figure has grown to 61%. In 2014, in the fourth quartile, the labour productivity of the firms with a lower proportion of high-waged employees only forms about 43% of the labour productivity of firms with a larger proportion of high-waged employees.

Table 2. The average labour productivity in the first and fourth quartile*

Year	1. quartile		4. quartile	
	high-waged >30%	high-waged <30%	high-waged >30%	high-waged <30%
2006	47234.7	23269.5	30127.0	17242.1
2008	40696.9	19836.0	27649.6	16526.5
2010	39760.7	21644.9	26414.8	17030.1
2012	40739.6	22354.5	28652.8	17975.3
2014	41213.0	23314.0	28978.8	17665.7

*Quartiles are determined on the basis of the average age of employees in the firm (firms employing at least 10 employees). Separate figures for firms where the proportion of high-waged workers is less than 30% and for firms where the proportion of high-waged workers is more than or equal to 30% (firms employing at least 10 employees)

Comparing the average changes in labour productivity (see Appendix 2, Table 2) shows that during the first two periods, the change was usually negative and during the last two periods the average change was positive. There are again differences between sectors. In industry and construction, for instance, the average change was positive already during the period of the recession in 2008–2010. At the same time, the change was large and negative in services during the recession. During the last period, industry was the most successful sector again with an average productivity change over the 2-year period of 6%. Enterprises in knowledge intensive services have, as in non-knowledge intensive services, increased their labour productivity in the last two periods, but in knowledge intensive services the positive change is greater (9.8% versus 5.1% in 2010–2012 and 3.9% versus 0.6% in 2012–2014). The highest productivity change in the table above is in construction in 2010–2012; however, this may result mainly from the great decrease in the number of firms in this sector, mainly firms with less productive employees may have left. In addition, in the fourth period (2012–2014), the average change in labour productivity in construction is negative as opposed to the firms in other sectors. This result may be related to new firms entering the market, or large increases in the number of employees in construction firms (we only analyse firms with 10 employees or more).

Kernel density estimates (Appendix 2, Figure 1) show that in 2004–2006 the change in labour productivity in enterprises of the youngest quartile had different densities. In the crisis, in 2008–2010, as less productive enterprises left the market, the densities of the first and last quartile became more similar. In 2012–2014, the differences between the labour productivity in different quartiles increased again. A Kolmogorov-Smirnov test gives values D=0.170 with p=0.000 for the years 2006–2008, D=0.059 with p=0.053 for the years 2008–2010, D=0.0662 with p=0.043 for the years 2010–2012 and D=0.070 with p=0.026 for the years 2012–2014. Therefore, at the 90% confidence level, in all periods, the distribution functions of the labour productivity change in two quartiles are not equal. In the first period, this is also true at the 99% confidence level and in the two last periods at the 95% confidence level.

Therefore, the average age of employees has increased the most in industry. The average age of employees in firms seems to be related to firm's labour productivity as the firms in the youngest quartile have higher labour productivity than firms in the oldest quartile independent of sector. After the crisis, in 2010-2012 and 2012-2014 the distribution of productivity changes in oldest and youngest quartiles are more similar than before the crisis, but still statistically significantly different at lower confidence level.

The changes in the average of the share of stayers (Figure 3 below, numerical data in Appendix 3) that help us understand the restructuring process during phases of the business cycle depend on the sector, but there are some notable similarities. In general, the share of old stayers has increased in both, low and high wage groups. The average share of older high-waged employees among all stayers increased between 2006 and 2014 from 11.6% to 14.2%. First, this may reflect the fact that high-waged senior workers have important roles in enterprises – their

experience was valued and needed in the restructuring processes during the economic recession. Second, this may imply that it was relatively more costly to fire older employees during the crisis. The second argument is not supported by the comparison of the separation rates of different age and wage groups. The separation rate of older high-waged employees increased the most during the recession in 2008–2010. The initial separation rate for older high-waged employees was the smallest and remained lower than the rates for other age and wage groups. Nevertheless, this indicates that older high-waged employees also separated during the recession and the stayers' share of older workers did not increase only because they did not separate from enterprises.[7]

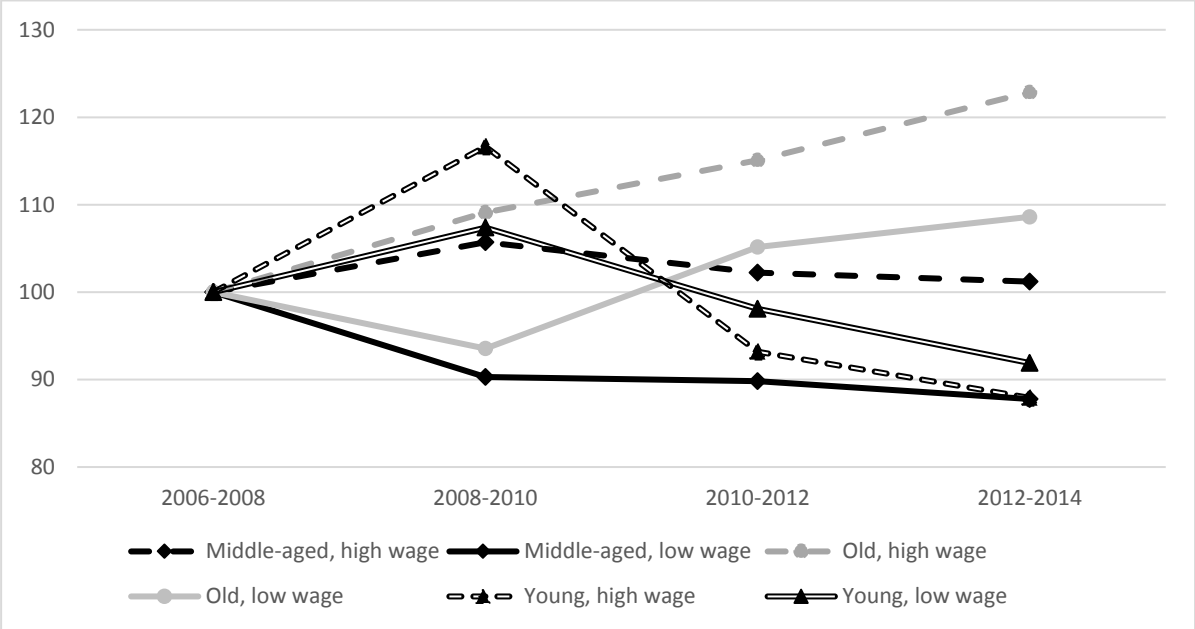

Figure 3. The relative dynamics of the share of stayers in the whole sample (compared to 100% for 2006–2008)

There is also a clear trend of an increasing share of old stayers among older low-waged employees in all sectors except knowledge intensive services. In the latter, the share of high-waged older employees increases compared to its initial level, while the share of low-waged older employees conversely decreases. There may be a smaller need for older low-waged employees in knowledge intensive services because there is a greater demand for skills in knowledge intensive services. Assuming that wage is a proxy for skill level and using the explanation from Avolio et al. (1990) that better performers get promoted out of lower-level jobs, the firms of knowledge intensive services as a group of highly innovative service industries indeed require more workers of higher skill level for an increase in labour productivity.

In absolute numbers, in all four periods, the average share of young staying workers was less than 10% in all sectors and it declined further by 2014. There were only marginal differences between the average shares of high-waged young and low-waged young. In all sectors, during

[7] The new Employment Contracts Act entered into force on 01.07.2009 in Estonia and reduced the costs associated with terminating employment relationships (Malk, 2015). The research has indicated that the reform has increased the flexibility of the Estonian labour market by making workforce adjustments more flexible for employers and increasing the reallocation of workers (Malk, 2014). Therefore, it was also relatively simple to fire older employees. Although employment protection legislation was fairly strict in Estonia until the introduction of the new Labour Code in 2009, the numerical flexibility was facilitated via its poor enforcement (Masso, Eamets 2007).

the recession there was a temporary increase of the average share of stayers among the young, but in the last period, their share was below the initial level in both age groups. Again, differently from other sectors, the share of low-waged young in knowledge intensive services remained near its initial value by the end of the fourth period. In knowledge intensive services the higher average share of young low-waged stayers seems to be related to their higher labour productivity. This may be related to the higher education level of young employees (Lee, Lee, 2016 as discussed in section 2), their relatively better computer skills and eagerness to study compared to older employees of the same wage group.

In general, the average share of all middle-aged stayers is over 20 per cent. Services stand out as an exception, where the average share of high-waged middle-aged stayers is 4.7 percentage points higher than among low-waged middle-aged stayers in the period 2012–2014. This difference is related to knowledge intensive services, where the average share of low-waged middle-aged stayers was 19.3% while the share of high-waged middle-aged stayers was 30.1% in the fourth period. The average share of high-waged middle-aged stayers remains near its initial level for the first period in all sectors without exception by the end of the fourth period. Therefore, it can be assumed to be the most productive group of workers that employers want to keep in the firm. While the average share of low-waged middle-aged stayers decreases in all other periods compared to the first, in construction the share remained near its initial level.

Hiring rates in all sectors remained below 10% and there was a significant drop in all hiring rates in all sectors during the recession period. In the whole sample, the average rates of all age and wage groups increased after the recession in 2008 and reached higher levels compared to the first period. The hiring rate and separation rate in the construction sector are depicted in Figure 4 below as the changes in both rates were the largest in construction. Based on the theoretical age-productivity curve (Skirbekk, 2008a, 2008b) and the greater volatility of employment for the young, we expected the hiring rates and separation rates of young workers to be larger than for middle-aged workers. However, contrary to these predictions, we cannot find notable differences between young and middle-aged workers. All the hiring rates for 2012–2014 remained below the initial level in all sectors except construction. In the latter, hiring rates for high-waged and low-waged old employees reached 110% of its initial level for 2010–2012, although for 2012–2014 both rates were below 100% again. This result may be related to the fact that the construction sector was hit the worst during the recession as also stated in Masso and Krillo (2011). In construction, the separation rates are also higher for all age and wage groups during the recession. Moreover, a considerable number of employees from the construction sector have left Estonia to work in Finland, where the wages are higher and the economic crisis did not affect the construction sector as severely as in Estonia. Data from Statistics Estonia shows that in 2009, 2,733 people went to Finland, but the number gradually increased to 187% of the initial level by 2014, when 5,120 individuals moved to Finland. All of these were not from the construction sector, but Krusell (2013) shows that 40% of all the Estonian workers abroad work in construction (in Estonia, only 10% of employees work in construction). As in general, young employees have moved away from Estonia, the construction sector in Estonia was left with older and middle-aged employees.

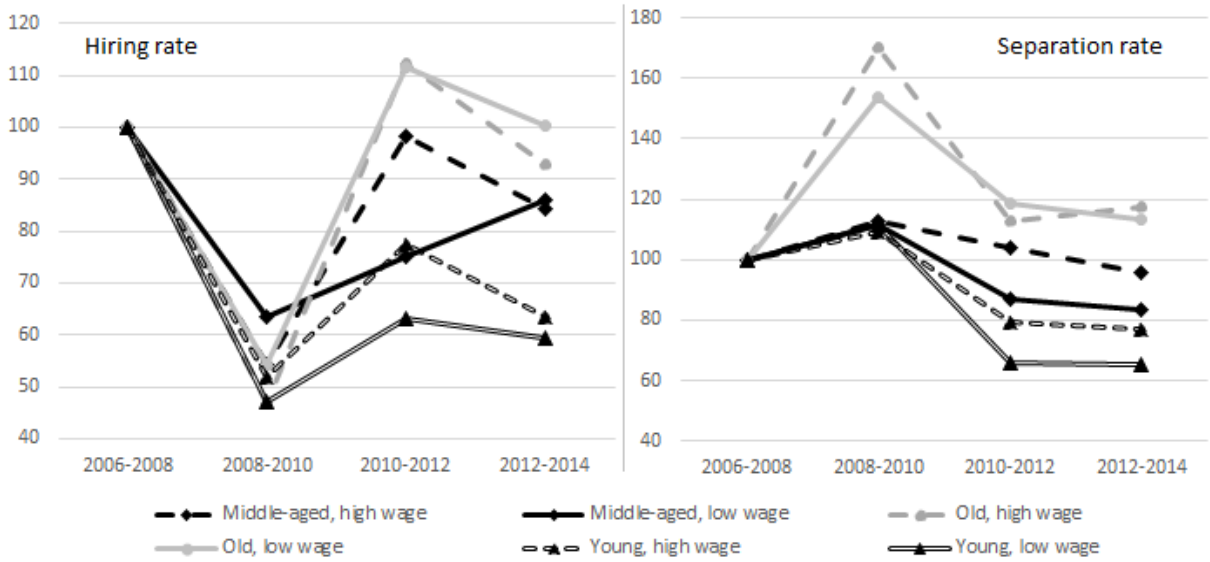

Figure 4. Hiring and separation rates in construction sector (compared to 100% for 2006-2008)

All the separation rates, as with the hiring rates, remained near 10% or below. The recession in general resulted in a temporary increase in all separation rates. In industry, as opposed to other sectors, the average separation rates of none of the age groups or wage groups increased by 2012–2014 compared to their initial level. Older employees stand out among others because their separation rate increased the most in all sectors during the recession. As discussed above, the initial average separation rate of older employees was also rather low compared to other age groups. Similar to high-waged old workers, the separation rate for high-waged young employees was very low and even decreased. As discussed at the end of section 2, and using the explanation based on Avolio et al. (1990), older high-waged employees may be as valuable as young employees for firms, and the difference between the change in the two rates must be related to older employees taking retirement, a choice that the young high-waged employees do not have.

As the average separation rate of old high-waged employees increased and the average share of high-waged old stayers also increased, the general hiring rate of old high-waged employees increased relatively more than the hiring rate of high-waged young employees. The trend was not similar in knowledge intensive services, where the hiring rate of middle-aged high-waged workers increased the most. The separation rate in knowledge intensive services was the highest for old high-waged employees, but the hiring rates of older employees remained also among the lowest during the last period. Therefore, the large positive changes in labour productivity in knowledge intensive services seem to be related to differences in hiring and separation rates compared to other sectors. One explanation here is related to the education differences between older and younger employees. The employees knowledge base and skills composition of older employees does not match to the needs of the knowledge intensive services sector.

4.1. Decomposition of labour productivity

The results from the fixed effects panel data regression are presented in the Table 3 below. All the statistically significant positive coefficients for hired employees show that these hired workers have higher productivity than the average staying worker. All the positive coefficients describe high-waged employees and thus hiring high-waged employees is related to increase in labour productivity. Among hired employees in the general model, the age-productivity relation

follows the theoretical prediction of an inverse U (as explained in Skirbekk 2008a and 2008b) among high-waged workers. We see that the middle-aged are the most productive – they are 61% more productive than average staying workers, older are 38% more productive and young are 25% more productive than average staying workers. In the context of different skills discussed in section 2 this result indicates that experience and crystallised abilities may be more important for high-waged employees than physical fitness or higher education level. This result contradicts Kampelmann and Rycx (2012), who cannot reject the hypothesis of a flat productivity-profile, but they did not include age in a similar manner into their analysis. Interestingly, old high-waged employees in industry are only 4 percentage points less productive than middle-aged high-waged employees. Although previous research has indicated that for some occupations the productivity does not decline with age and these occupations are in general highly paid – lawyers, professors, managers (Veen, 2008); we cannot generalise based on our research that the productivity of all the high-waged employees does not decline with age.

In most cases the productivity of hired low-waged employees is not statistically significantly different from the productivity of stayers, but in traditional services, young low-waged employees are 22.5% less productive than average stayers. Also in knowledge intensive services low-waged older employees are 88% less productive than average stayers in this sector. These results are related to the specific sectors. In traditional services there are many low-waged young employees employed as waiters, waitresses and cashiers. Maybe there is a need to train them and also the new workers need some practice to become as fast and effective as staying employees. Services also depend on whether clients find the service, right after opening new units may not be very productive until the clientele has developed the habit to come to the new unit. In traditional services, the average productivity level is very high, therefore the low-wage old cannot be very productive compared to stayers as they most likely are not involved in the knowledge intensive activities. In services the productivity of middle-aged high-waged employees is lower than in industry by nearly 30 percentage points. Therefore, we find sectoral differences also in hiring high-waged employees from different age groups.

Table 3. Fixed effects panel data regression results, dependent variable productivity change in the firm (firms employing at least 10 employees)

Variables	Industry, services or construction (2+3+6)	Industry (2)	Services (3=4+5)	Knowledge intensive services (4)	Traditional services (5)	Construction (6)
Hired, young, high wage	0.246*	0.358	0.164	0.344	0.161	-0.092
	(0.112)	(0.266)	(0.125)	(0.240)	(0.143)	(0.388)
Hired, young, low wage	-0.097	0.023	-0.225*	-0.329	-0.164	0.283
	(0.081)	(0.179)	(0.092)	(0.175)	(0.108)	(0.308)
Hired, middle-aged, high wage	0.612***	0.770***	0.457***	0.623*	0.405**	1.079**
	(0.103)	(0.211)	(0.123)	(0.261)	(0.137)	(0.332)
Hired, middle-aged, low wage	0.051	-0.120	0.070	0.065	0.084	0.374
	(0.081)	(0.147)	(0.100)	(0.252)	(0.109)	(0.276)
Hired, old, high wage	0.375*	0.735*	0.107	0.470	0.053	0.648
	(0.190)	(0.353)	(0.232)	(0.460)	(0.265)	(0.641)
Hired, old, low wage	-0.127	-0.148	-0.184	-0.887**	-0.011	0.377
	(0.106)	(0.185)	(0.131)	(0.290)	(0.147)	(0.382)
Separated, young, high wage	0.465***	0.733*	0.330*	0.758**	0.281	0.498
	(0.127)	(0.311)	(0.142)	(0.282)	(0.163)	(0.430)
Separated, young, low wage	0.286**	0.404*	0.335***	0.260	0.350**	0.437
	(0.088)	(0.206)	(0.102)	(0.201)	(0.117)	(0.298)

Separated, middle-aged, high wage	0.670***	0.548**	0.516***	0.373	0.541***	1.040***
	(0.089)	(0.193)	(0.108)	(0.211)	(0.123)	(0.256)
Separated, middle-aged, low wage	0.784***	1.072***	0.639***	0.230	0.700***	0.633**
	(0.074)	(0.139)	(0.092)	(0.240)	(0.100)	(0.231)
Separated, old, high wage	0.292*	0.464	0.323	0.498	0.320	0.470
	(0.141)	(0.276)	(0.174)	(0.320)	(0.205)	(0.416)
Separated, old, low wage	0.679***	0.727***	0.576***	0.567*	0.550***	0.769**
	(0.079)	(0.128)	(0.103)	(0.239)	(0.115)	(0.271)
Stayers, young, high wage	0.168*	0.329*	-0.002	0.186	-0.016	0.405
	(0.067)	(0.138)	(0.078)	(0.160)	(0.089)	(0.238)
Stayers, young, low wage	0.038	0.191	-0.042	-0.049	-0.014	0.163
	(0.060)	(0.120)	(0.071)	(0.144)	(0.082)	(0.200)
Stayers, middle-aged, high wage	0.249***	0.314***	0.124*	0.196	0.123	0.413*
	(0.048)	(0.090)	(0.058)	(0.122)	(0.066)	(0.162)
Stayers, middle-aged, low wage	0.068	0.137	0.005	0.168	-0.019	0.148
	(0.045)	(0.085)	(0.054)	(0.125)	(0.060)	(0.151)
Stayers, old, high wage	0.174***	0.264**	0.146*	0.322**	0.095	0.026
	(0.049)	(0.087)	(0.063)	(0.123)	(0.073)	(0.158)
Stayers, old, low wage (reference)						
Constant	8.979***	9.105***	7.842***	8.110***	7.827***	11.907***
	(0.225)	(0.421)	(0.285)	(0.531)	(0.332)	(0.734)
Number of obs.	14390	4247	8190	1916	6389	1953
F-test statistic	249.052	75.654	133.654	41.304	100.934	48.688
R^2	0.450	0.446	0.436	0.482	0.428	0.578

Note: Standard errors in parenthesis, * p<0.1, ** p<0.05, ***p<0.01, all groups of workers are weighted with the number of employees in the firm, other variables include log change in capital per labour, log of initial productivity and wage level, also 5 area dummies and 4 period dummies. Additional dummies in the general model (column 1) include industry, services and construction.

Coefficients for separation show a positive effect on productivity change if the workers of the respective group have a lower productivity level than the average staying worker. The coefficients concerning separation are all positive in Table 3. This may show that in the flexible labour market in Estonia it was possible to fire workers who were less productive. In an economy with strong labour unions, productivity increase may not be achieved as fast or as effectively.

Among separated workers in the whole sample, the positive coefficients are higher for low-waged workers in two older age groups compared to high-waged workers in the same groups. For young it is the other way around, separated high-waged employees are nearly 18 percentage points less productive than low-waged young. Among separations of young there are relatively more voluntary separations than in the group of middle-aged employees. Young may still be trying to find the right job and firm for themselves. Old may have the option to move from employment to retirement. Therefore, the similar productivity level of middle-aged high-waged employees (67%) and old low-waged employees (67.9%) is not surprising. Among high-waged middle-aged employees there are relatively less voluntary quits while among low-waged old there are relatively more voluntary quits. Voluntary quits raise the productivity of the whole group because some very productive employees may quit voluntarily.

Again, there are sectoral differences in the coefficients. In industry the separated employees were more productive than the employees from the respective group of separators in services. While in case of hiring it is clear that only the most suitable candidates are hired, the coefficients for separated employees are more ambiguous and cannot be interpreted as the real difference between the productivities of different age and wage groups.

Nevertheless, our results concerning the productivity may be highly dependent on our method. There is an important difference in the hiring and separation processes for firms. Hiring a good (in this context productive) candidate is possible only if the pool of applicants is large enough. The firm's good image, location and relatively higher wage than in other sectors, may have an important role in increasing the number of candidates. Therefore, some firms can select the most productive of the candidates in terms of qualification as well as age. Some firms cannot choose the age of their new workers because there are not enough suitable candidates or they even have to lower their minimum ability requirement. So, the sectoral differences among hired workers partly reflect whether the firm (or sector in general) is appreciated among potential workers. Separation processes may be initiated by the worker (voluntary separations) or by the employer (firings). As we cannot decide based on our data if the separation is voluntary, we can only assume that due to the recession we have more involuntary separations in the sample than usual. Again, the sectoral differences in the effect of separation rates partly depend on the number of voluntary separations, the more there are voluntary separations in the sector, the smaller the positive effect of leaving on the productivity change. In a similar manner, the differences in the productivity of high-waged workers compared to low-waged workers may result from such factors in the current analysis.

The positive coefficient in section 3 of Table 3 for a staying group of workers shows productivity growth due to the accumulation of human capital through experience, and this is calculated in reference to the group of old low-waged employees. In the whole sample, the statistically significant positive coefficient is calculated for old, young and middle-aged high-waged stayers. The values of the coefficients for young and old differ only by less than 1 percentage point (16.8% *vs.* 17.4%). Considering only age groups, this result is not in line with the literature because the young are supposed to be more eager to study and increase their human capital, older employees are less eager to change and the enterprises do not like investing in their training as they will leave the firm sooner than young employees (Grund and Westergård-Nielsen, 2005). Looking at wage groups next to age shows that older high-wage employees are more valuable for employers and they might undergo training because in knowledge intensive services they may need it. The coefficients do not show necessarily the differences in the training of employees. There are no statistically significant coefficients in traditional services, but it may just indicate that the employees are trained and their productivity increases in a similar manner despite the age or wage group. In services the high-waged stayers gain less experience/are less trained relative to old low-waged employees in industry.

Next to training, firms have other possibilities to generate changes in productivity of certain groups pf workers. Statistically significant coefficients may imply that firms had a chance to implement organisational innovations that resulted in reducing high-waged jobs (especially in services) without considerable changes in productivity. Also, firms could have outsourced some functions. As a result, the productivity growth of high-waged employees could be larger than the growth among older low-waged employees. The productivity growth of low-waged employees appeared to be similar in all age three age groups.

We have conducted a robustness check of our analysis by including the firms with 5 employees into our sample (see Appendix 4). The number of statistically significant coefficients becomes larger, but the results are not too different, and our main conclusions do not change. The results of the robustness check are less reliable because in small firms there are not enough employees in each age- and wage group. Additionally, the test that we conducted indicated that the fixed effects model should be preferred to the ordinary least squares model (F-test that all u_i=0, Prob> F=0.000). The result of Breusch-Pagan Lagrange multiplier test (Prob>chibar2=0.000) indicates that random effects model should be preferred to the simple ordinary least squares

model. Hausman test indicated that fixed effects model should be preferred to random effects model (Prob>chi2 = 0.0000). We also tested whether period dummies should be included into our model and the test indicated that (Prob > chi2 =0.0000) that the coefficients for each period are statistically significantly different from each other. Similar to Ilmakunnas and Maliranta (2007), not all the variables are statistically significantly related to labour productivity in our main analysis, but differently from their research, we do not interpret coefficients that are not statistically significant.

In the literature review in section 2, we argue that the changes in individual productivity may be dependent on the phase of the economic cycle because the economic cycle affects minimum ability requirement, quality match and because employers can hoard labour. To analyse the data from this angle, we generated four simple OLS regressions, one for each period. The results in Appendix 5 show that there are changes in the productivity of different age and wage groups if we compare different periods. We know that in 2008–2010 only a small number of employees were hired, and a relatively large number of employees separated from their employer. Therefore, the pool of unemployed employees increased, and firms could employ more productive high-waged young and middle-aged employees.

We see that the productivity of hired employees increased in 2008–2010 compared to the first period (in the groups of high-wage young and high-wage middle-aged). On the one hand, it could be expected due to the firms' chance to raise the minimum ability requirement. On the other hand, due to the larger pool of unemployed people the match between the firm and each newly hired employee may also be better. Comparison of coefficients in boom (2006-2008) and stabilisation (2012-2014) periods indicates that among low-wage young the productivity decreased. It is unexpected and may result from the fact that the unemployment among young increased the most and many low-wage young migrated to foreign countries to work there. If the more productive low-wage young left the Estonian labour market, the group of low-waged young may be less productive during stabilisation compared to boom period. For low-income old we can see the gradual decrease in their productivity in recession, recovery and stabilisation periods. The result is logically related to the decrease of the unemployment rate in Estonia in the period of 2010-2014. In the stabilisation period in 2012-2014 we can compare the productivity of low-income employees in different age-groups and conclude that the most productive age for low-income employees is middle-aged, young are slightly less productive and old are the least productive employees. This result confirms the hypothesis presented in the section 2 that the more productive employees in the low-wage group of old have been promoted out of this group and the group of young low-waged employees must be more productive because their group is more heterogenous.

In terms of separations, the relatively smaller numbers (and even a negative one) in the first column show that under the scarcity of workforce in the boom period there were more voluntary separations in the labour market and the labour productivity of the separated employees was relatively higher compared to other periods. Where comparison is possible, we can document a decrease in productivity of separated employees in the recession period 2008–2010 as there are many involuntary separations in the economy. The employees who are less productive are forced to leave the firms. Also, restructuring processes caused by the recession may result in closures of entire less productive units and the decrease in productivity of separating groups of workers is logical. The process of labour hoarding may be shown in the coefficients of stayers. If the stayers are less productive in recession than in boom or recovery phase, it may refer to labour hoarding. In our data (where comparison is possible), the stayers seem to be rather more productive in recession. Also, we could document increase of separations rate in recession. Moreover, the relative comparison of different groups of stayers cannot show the process of

labour hoarding properly. If all the groups become less or more productive at the same time, it is not shown anywhere in the table. The exact reasons for all the described developments in productivity need to be analysed with proper methods and probably additional data, but our initial check shows that there are differences in the level of productivity in the different phases of the economic cycle. Moreover, the differences seem to depend on the age and wage of employees.

5. CONCLUSION

The links between restructuring in firms and productivity have been investigated from different angles, but the aspect of restructuring related to employee age and skills has not yet been widely analysed. At the same time, restructuring at firm level may be an important source of change in productivity. Our paper presents fixed effects panel data regression results that decompose the productivity change of firms through the hiring and separation of workers who are differentiated on the basis of age and wage. We used matched employer-employee data for the period 2006–2014 in Estonia, and therefore had a chance to look at some of the restructuring processes in firms during the crisis.

The crisis in a way accelerated the process of ageing; it is more noticeable in industry and less in knowledge intensive services. This may hinder raising knowledge intensiveness in the more affected sector; for example, due to the lower education level of older employees among other factors (Skirbekk 2004, 2008a, 2008b). We could document the increase in the share of high-wage older employees as well as in the share of low-wage older employees in addition to the natural ageing of employees. First, this result may be related to layoffs because it is relatively easier and cheaper to fire younger workers with less working experience in the firm. Secondly, this illustrates how the combination of strict immigration policies and relatively lenient emigration policies in Estonia can influence the ageing of the workforce. Many young from construction sector left to work in Finland, but by law the quota on immigration may not exceed 0.1% of the number of people who live permanently in Estonia.

There are sectoral differences in the ageing process. We found that in knowledge intensive services the share of young stayers is higher and the average increase in productivity in the third sector was rather large. As the migration quota does not apply to experts or consultants who have specific education in the field, in knowledge intensive services firms may have had a chance to hire young educated migrants from non-EU countries despite the quota. It may also indicate that in knowledge intensive services innovative processes have been conducted differently from other sectors. If these enterprises were innovative before the crisis, there is a high chance that they continued to be innovative during the crisis as was found by Archibugi et al. (2013). However, we cannot check for this with our data. Future research could include checking whether the positive effect of ageing is larger in innovative enterprises as stated by Backes-Gellner and Veen (2013). For this purpose, data from Community Innovative Surveys (CIS) could be matched with our dataset. As CIS also includes information on the type of innovation conducted in the enterprise, the matched data of employers, employees and CIS would make it possible to show whether the changes in the structure of employees are related to process innovation and whether the innovations are related to higher productivity in the firms.

In industry as well as services, there appears to be an inverse relation between the productivity of labour and the average age of firm's employee in the firm. The analysis of labour productivity in quartiles illustrated that the older the average age of the employees in the firm, the lower the labour productivity in the firm. The relation was the clearest in industry. At country level, the

increase of the share of older workers have been shown to be negatively associated to labour productivity (e.g. Tang and MacLeod, 2006; Grönqvist, 2009). Therefore, the share analysis in the current research tends to confirm the results of other share analysis, although we cannot control for other influential factors that these authors could include in their analysis. During the recovery years low-waged jobs were recreated faster than high-waged jobs. As a result, the ratio of low-waged employees to high-waged employees increased.

Based on hiring data our decomposition confirms the inverse U shape among high-waged employees. We can quantify the differences and show that middle-aged employees are 61% more productive than average stayers. High-waged old are nearly 38% more productive and young are nearly 25% more productive than average staying employee. This may be explained by the nature of the hiring process, as firms may choose the most suitable workers based on the personality of the candidates or some other factors. Assumedly, the firm chooses appropriate candidates mainly based on skills and the choice between different ages can be rather random. Unfortunately, the relationship between low-waged employees and the change in labour productivity is not statistically significant in most cases and we cannot make any conclusions based on these numbers. We only know that the low-waged hired employees are on average slightly more productive than low-waged employees already in the firm because the not statistically significant difference is calculated in relation to the average employee (both wage groups together). Thus, the productivity of high-waged employees is in general higher than that of low-waged employees. This is an expected result and contradicts Kampelmann and Rycx (2012) who cannot reject the flat productivity-profile. We use different methods and also Kampelmann and Rycx do not separate the employees based on differences in age.

We conclude from our analysis that there may be sectoral differences to the ageing productivity curve among high-waged employees. In the general model for all the sectors we see regular inverse U shape pattern, but in industry the productivity difference for old and middle-aged high-waged employees is only 4 percentage points. Despite the different methods we confirm the result of Malmberg et al., 2008 and contradict Göbel and Zwick 2009 (see also section 2). Our result may be related to Estonian context. In the deep crisis period, sectors may be forced to act differently to tackle the crisis. This may also imply that firms conducted several organisational innovations which made it possible to reduce the number of high-waged employees in a way that the productivity level remained the same. Some functions may have been moved outside the firms. These steps may have resulted in higher productivity among older high-waged employees compared to middle-aged employees in industry. Among the stayers, the increase in low-waged employee productivity does not appear to depend on the age level.

During the recession, there was an active separation of workers in firms. The separated were less productive than the average incumbent worker at the beginning of the period. This may indicate that the restructuring processes in the recession years included the separation of workers with lower productivity. Among staying workers; in most cases there were only high-waged workers with faster growth of labour productivity than the reference group of low-waged older employees. Therefore, the increase in labour productivity in firms may be partly related to the hiring of more productive employees and separation of less productive employees as well as other restructuring processes in firms. Hired low-waged workers were only slightly more productive than low-waged employees already in the firm. The newly hired workers do not yet have firm-specific human capital. New employees usually need training and time to get used to the new environment. Skills of high-waged employees seem to be more universal as in our model, the already were more productive than stayers and also gained productivity while staying in the firm.

Separate OLS models for each period did not show any evidence of labour hoarding, but our method is not the most appropriate to analyse labour hoarding. We could document the increase of minimum ability requirement in recession period in 2008-2010, as the productivity of hired employees increased compared to the boom period and the productivity decreased again in the recovery and stabilisation period. At the same time, the decrease in productivity of separated employees in the recession period 2008–2010 indicated that the number of involuntary separations in the economy increased. Individual match quality could not be analysed with our method, but the increase of involuntary separations matches the argument that in crisis the quit propensity of all employees is low. To what extent the productivity of (hired, separated and staying) employees changes remains to be clarified in future studies.

The limitations of the current study are mainly related to our data. Comparing the age-related productivity of blue-collar workers with the productivity of white-collar workers may give slightly different results, and occupations may be more exact as a proxy for employee skill level than our high-wage and low-wage approach. Furthermore, the differences between productivity in wage and age groups would be clearer if we could separate voluntary separations from involuntary firings, because we expect the voluntary separations to be more prevalent among workers with high productivity and involuntary firings among workers with lower productivity. It would be interesting to compare the current results with the more exact calculations which take into account how many hours per day (to separate part-time employees from full-time employees) and for how many months of the whole period each single employee has worked in firm (to generate a more exact scale for the number of separations and hirings).

All in all, the structural change has increased the speed of ageing of employees. Also, our analysis indicates that higher average age of employees is related to lower productivity per employee. We nevertheless do not find evidence that older low-waged employees are less productive than low-waged employees in other wage groups. Older high-waged employees are in general less productive than middle-aged high-waged employees, but they are more productive than high-waged young employees. The analysis on the differences of productivity related to economic cycle indicated that from the larger pool of unemployed people in recession firms can hire more productive young and middle-aged employees than in other periods. Thus, we confirm that the productivity of hired employees depends also on the economic cycle. The managers have to continuously take into account that working conditions need to be appropriate for older employees. However, based on our analysis the managers do not need to avoid hiring employees who are older than 50 years. Among high-waged the older employees are more productive than young and among low-waged employees, we could not show any statistically significant differences in productivity of different age groups.

The overall policy implication is the need to improve the system of providing upskilling opportunities in Estonia, in terms of technical skills and knowledge but also attitudes. On the one hand, firm managers can pay attention to increasing productivity of low-waged employees who do not seem to become more productive due to accumulating experience based on the current research. On the other hand, the Estonian government can facilitate the process. Around 30% of adult Estonians do not have a professional qualification. The average number of hours of training per participant is among the lowest in the OECD and training of low-skilled workers remains below the average. (Smidova and Yashiro, 2017) The ambitious targets in Estonian lifelong learning strategy foresee reduction of the share of adults without professional qualification to 25%, but it requires widespread career counselling service by Estonian Unemployment Insurance Fund to be provided not only for unemployed but also to those who are currently in employment.

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APPENDICES

Appendix 1. Statistical information of the sample of employees and enterprises

Table 1. Descriptive statistics, whole sample of employer-employee data without outliers

Variable name and definition	Mean	Standard deviation
Change of labour productivity	-0.017	0.520
Number of employees by enterprise	42.973	124.523
Mean age of employees by enterprise	42.586	6.655
Median age of employees by enterprise	42.351	8.226
Hiring rate, young (<31), high wage	0.041	0.074
Hiring rate, young (<31), low wage	0.085	0.112
Hiring rate, middle-aged (31-50), high wage	0.053	0.079
Hiring rate, middle-aged (31-50), low wage	0.085	0.101
Hiring rate, old (>50), high wage	0.016	0.037
Hiring rate, old (>50), low wage	0.049	0.078
Hiring rate, all age and wage groups	0.331	0.209
Separation rate, young (<31), high wage	0.035	0.067
Separation rate, young (<31), low wage	0.077	0.106
Separation rate, middle-aged (31-50), high wage	0.066	0.089
Separation rate, middle-aged (31-50), low wage	0.102	0.111
Separation rate, old (>50), high wage	0.026	0.049
Separation rate, old (>50), low wage	0.079	0.098
Separation rate, all age and wage groups	0.339	0.201
Stayers' share, young (<31), high wage	0.062	0.112
Stayers' share, young (<31), low wage	0.081	0.127
Stayers' share, middle-aged (31-50), high wage	0.254	0.231
Stayers' share, middle-aged (31-50), low wage	0.256	0.225
Stayers' share, old (>50), high wage	0.128	0.153
Stayers' share, old (>50), low wage	0.219	0.213
Log of initial wage level in the company	7.396	0.519
Log of initial productivity level in the company	9.959	0.830
Log of capital level at the beginning of the period minus log of capital level at the end of the period	0.133	1.109
Industry (dummy, 1 if firm belongs to industry sector)	0.292	0.455
Services (dummy, 1 if firm belongs to services sector)	0.574	0.494
Construction (dummy, 1 if construction firm)	0.134	0.341
Knowledge intensive services (dummy, 1 if belongs to knowledge intensive services)	0.131	0.338
Traditional services (dummy, 1 if belongs to traditional services)	0.443	0.497
Northern Estonia	0.552	0.497
Central Estonia	0.074	0.262
North-Eastern Estonia	0.068	0.252
Western Estonia	0.104	0.305
Southern Estonia	0.202	0.402

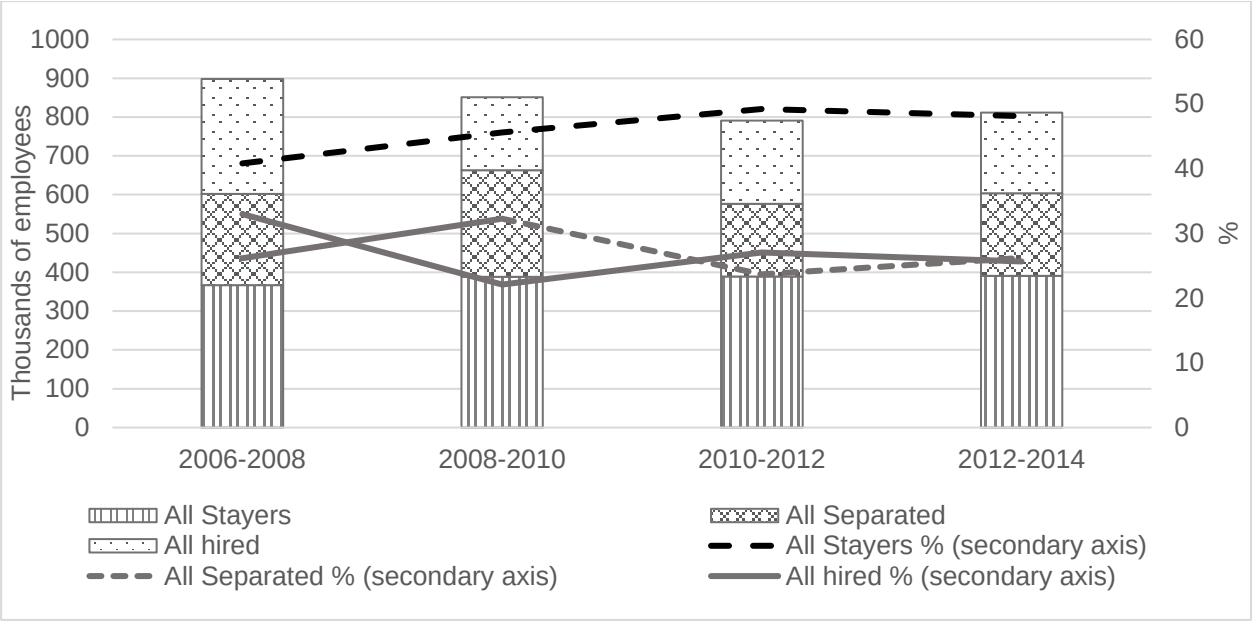

Figure 1. The absolute number and percentage of hired, separated and staying workers in all periods

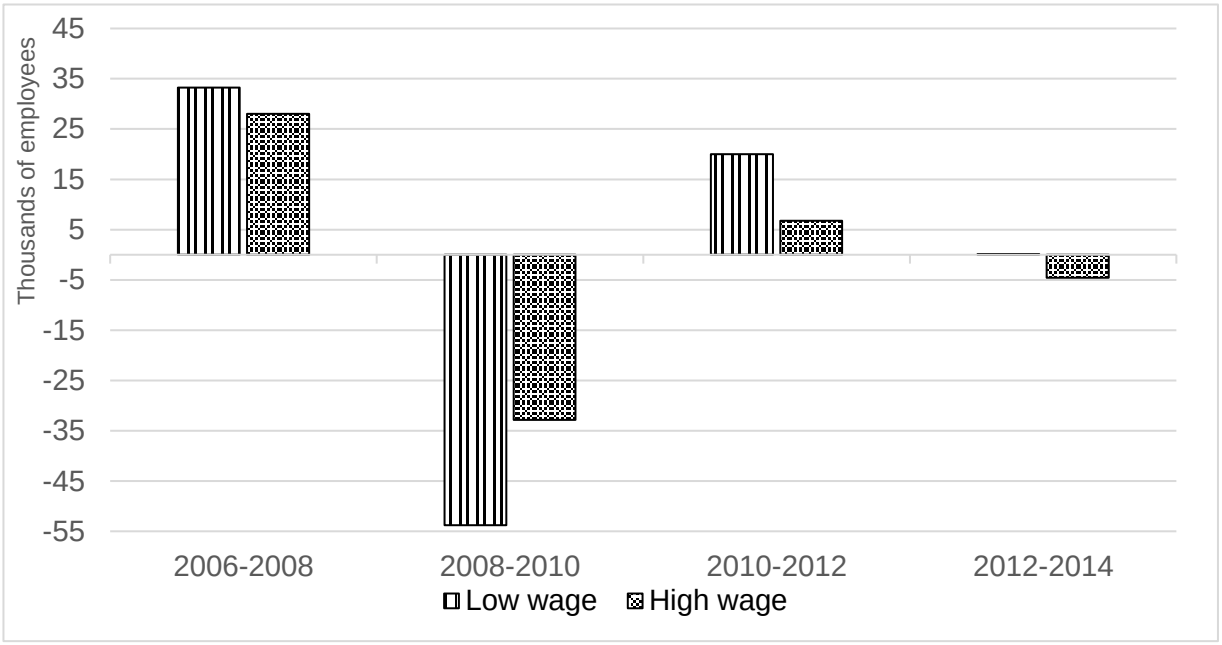

Figure 2. Differences between hired and separated employees across time periods on the basis of wage group (absolute numbers)

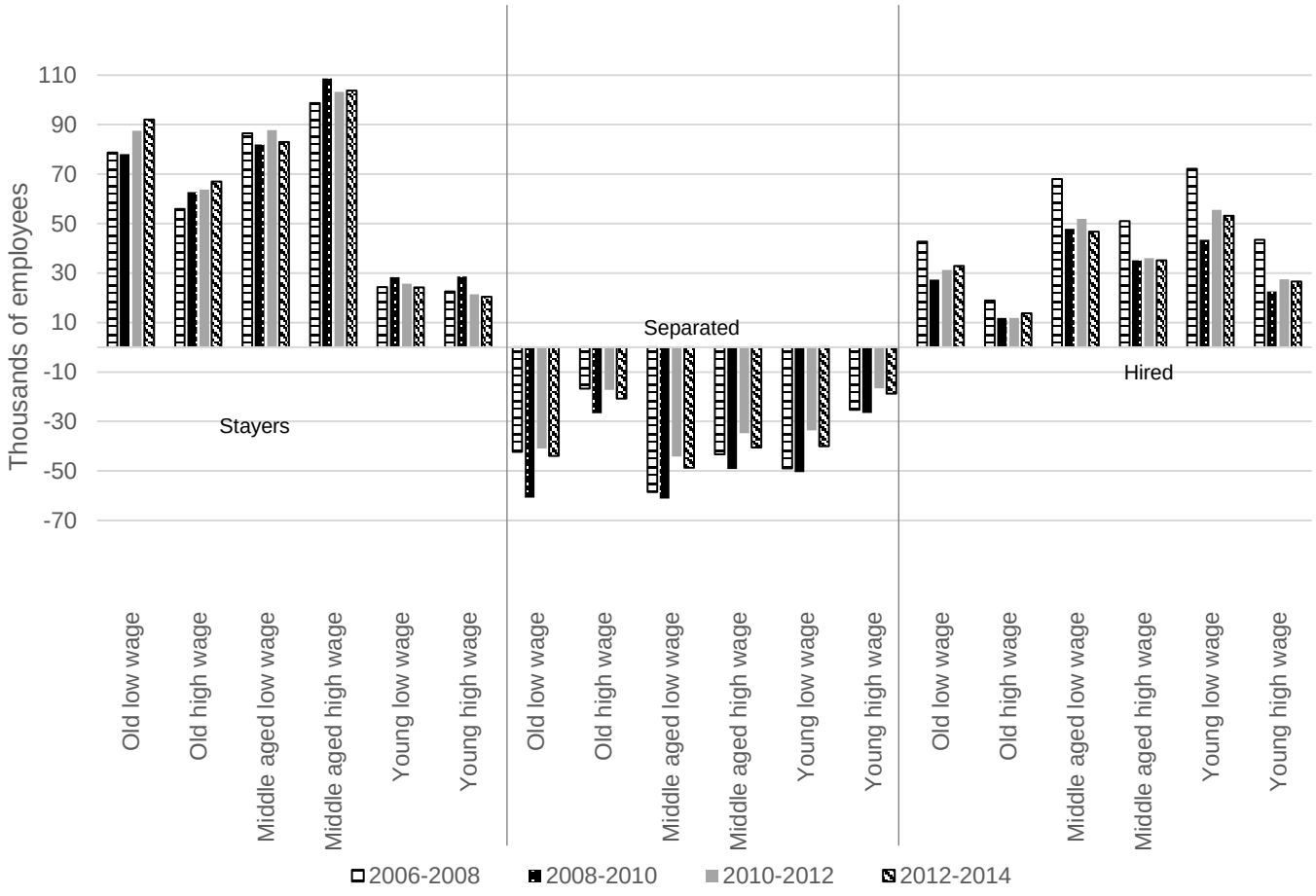

Figure 3. All age and wage groups in each period, in thousands

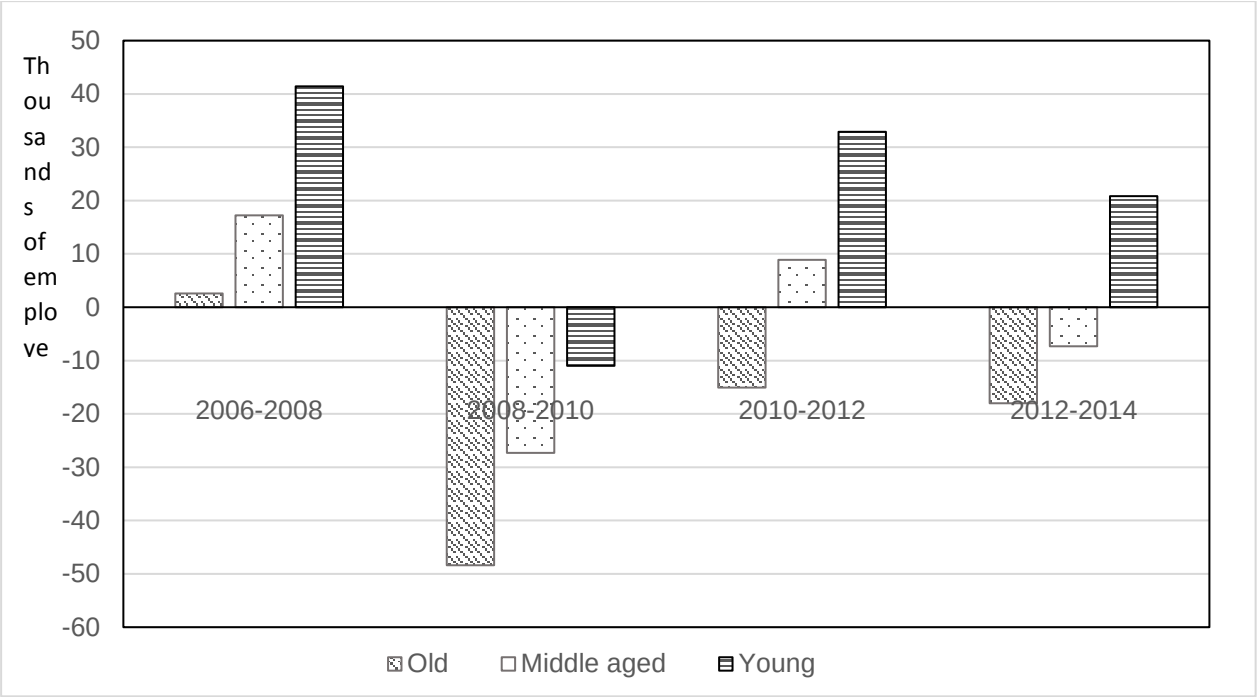

Figure 4. Differences between hired and separated employees across time periods on the basis of age group (absolute number of employees)

Appendix 2. Relations between age, wage and productivity in firms

Table 1. The average age in years and average proportion of young (less than 31 years old) and old (over 50 years old) in different sectors and in the whole sample (firms employing at least 10 employees)

Year	Industry, services and construction			Industry			Services			Construction		
	<31 (%)	>50 (%)	Average age	<31 (%)	>50 (%)	Average age	<31 (%)	>50 (%)	Average age	<31 (%)	>50 (%)	Average age
2006	24.8	27.6	41.5	21.4	29.9	42.53	27.4	25.8	40.75	26.5	26.7	41.03
2008	25.2	29.0	41.7	19.8	32.6	43.35	28.3	27.1	40.87	28.4	26.7	40.73
2010	22.0	30.8	42.7	17.0	34.1	44.11	25.1	28.6	41.82	21.9	31.4	42.87
2012	23.1	30.6	42.4	18.4	33.6	43.75	26.4	28.5	41.54	22.5	31.1	42.57
2014	21.7	33.6	43.4	17.9	35.6	44.36	24.3	32.4	42.75	21.0	32.7	43.16

Table 2. Productivity change and the number of firms in different sectors

	All firms		Industry		Services		Knowledge intensive services		Traditional services		Construction	
Period	Change (%)	No. of firms	Change (%)	No. of firms	Change (%)	No. of firms	Change (%)	No. of firms	Change (%)	No. of firms	Change (%)	No. of firms
Total	-0.017	15188	0.022	4431	-0.040	8718	-0.014	2114	-0.048	6725	-0.001	2039
2006-2008	-0.095	4212	-0.052	1225	-0.118	2322	-0.032	546	-0.144	1803	-0.093	665
2008-2010	-0.034	4080	0.077	1155	-0.101	2299	-0.153	543	-0.087	1784	0.007	626
2010-2012	0.071	3452	0.006	1003	0.065	2092	0.098	526	0.051	1602	0.289	357
2012-2014	0.013	3444	0.062	1048	0.013	2005	0.039	499	0.006	1536	-0.121	391

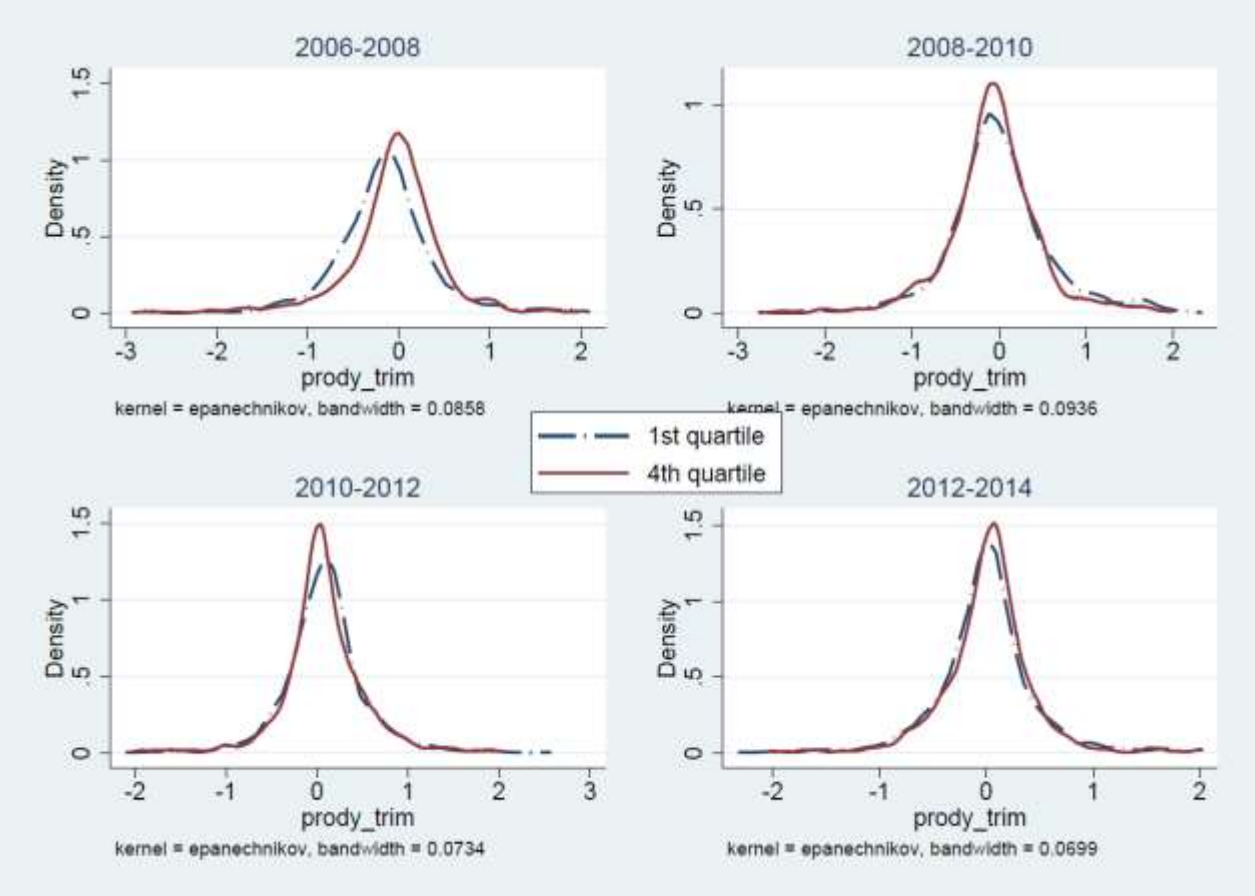

Figure 1. Kernel density estimates for the change of labour productivity in the youngest and oldest quartile of the whole sample of enterprises calculated based on the average age of employees in the firm

Appendix 3. The average hiring and separation rates and stayers' share in industry, services and a whole sample of industry, services and construction

		Industry, services and construction				Industry				Services			
		2006-2008	2008-2010	2010-2012	2012-2014	2006-2008	2008-2010	2010-2012	2012-2014	2006-2008	2008-2010	2010-2012	2012-2014
Hiring rate (%)	Middle-aged, high wage	0.265	0.275	0.271	0.276	0.054	0.034	0.047	0.044	0.064	0.049	0.057	0.059
	Middle-aged, low wage	0.277	0.247	0.241	0.229	0.105	0.066	0.093	0.083	0.099	0.075	0.078	0.078
	Old, high wage	0.108	0.117	0.128	0.138	0.019	0.010	0.017	0.014	0.018	0.012	0.016	0.017
	Old, low wage	0.196	0.183	0.203	0.215	0.071	0.037	0.054	0.051	0.056	0.037	0.045	0.050
	Young, high wage	0.070	0.081	0.068	0.062	0.036	0.019	0.029	0.025	0.062	0.035	0.044	0.049
	Young, low wage	0.083	0.097	0.089	0.080	0.074	0.050	0.068	0.067	0.111	0.082	0.096	0.094
Separation rate (%)	Middle-aged, high wage	0.070	0.071	0.060	0.063	0.057	0.057	0.044	0.046	0.076	0.074	0.066	0.070
	Middle-aged, low wage	0.120	0.108	0.086	0.088	0.119	0.108	0.075	0.084	0.118	0.098	0.088	0.087
	Old, high wage	0.023	0.031	0.024	0.026	0.025	0.031	0.021	0.023	0.022	0.027	0.025	0.027
	Old, low wage	0.078	0.093	0.072	0.070	0.091	0.114	0.077	0.079	0.073	0.078	0.067	0.064
	Young, high wage	0.040	0.038	0.029	0.030	0.027	0.024	0.015	0.017	0.048	0.044	0.035	0.036
	Young, low wage	0.088	0.083	0.067	0.068	0.072	0.057	0.039	0.048	0.094	0.088	0.080	0.080
Stayers' share (%)	Middle-aged, high wage	0.247	0.262	0.254	0.253	0.221	0.237	0.224	0.220	0.265	0.275	0.271	0.276
	Middle-aged, low wage	0.279	0.250	0.249	0.244	0.283	0.258	0.266	0.259	0.277	0.247	0.241	0.229
	Old, high wage	0.116	0.126	0.133	0.142	0.126	0.139	0.137	0.150	0.108	0.117	0.128	0.138
	Old, low wage	0.216	0.202	0.227	0.233	0.256	0.247	0.276	0.271	0.196	0.183	0.203	0.215
	Young, high wage	0.061	0.072	0.058	0.054	0.043	0.054	0.038	0.039	0.070	0.081	0.068	0.062
	Young, low wage	0.082	0.088	0.079	0.074	0.070	0.067	0.059	0.061	0.083	0.097	0.089	0.080

Appendix 4. Robustness check. Fixed effects panel data regression results with the sample including enterprises with at least 5 employees

Variables	Any firm with more than 4 employees (1+3+6)	Industry (2)	Services (3=4+5)	Knowledge intensive services (4)	Less knowledge intensive services (5)	Construction (6)
Hired, young, high wage	0.306***	0.524**	0.169*	0.169	0.199	0.522
	(0.076)	(0.199)	(0.084)	(0.133)	(0.105)	(0.272)
Hired, young, low wage	-0.069	0.117	-0.193**	-0.210*	-0.201**	0.197
	(0.052)	(0.126)	(0.059)	(0.104)	(0.070)	(0.191)
Hired, middle-aged, high wage	0.348***	0.694***	0.274***	0.479***	0.220*	0.177
	(0.067)	(0.156)	(0.078)	(0.139)	(0.092)	(0.212)
Hired, middle-aged, low wage	0.016	0.022	-0.042	-0.258	0.009	0.162
	(0.049)	(0.100)	(0.057)	(0.133)	(0.063)	(0.178)
Hired, old, high wage	0.221	0.487	0.038	0.447	-0.074	0.785
	(0.135)	(0.271)	(0.163)	(0.311)	(0.187)	(0.450)
Hired, old, low wage	-0.025	-0.066	-0.069	-0.369*	0.002	0.254
	(0.066)	(0.125)	(0.079)	(0.177)	(0.087)	(0.236)
Separated, young, high wage	0.595***	0.557*	0.549***	0.592***	0.561***	0.731*
	(0.087)	(0.238)	(0.097)	(0.160)	(0.117)	(0.301)
Separated, young, low wage	0.477***	0.694***	0.434***	0.409***	0.436***	0.674***
	(0.057)	(0.136)	(0.066)	(0.118)	(0.077)	(0.178)
Separated, middle-aged, high wage	0.709***	0.485**	0.621***	0.558***	0.628***	1.220***
	(0.061)	(0.149)	(0.070)	(0.122)	(0.083)	(0.187)
Separated, middle-aged, low wage	0.741***	0.857***	0.731***	0.774***	0.716***	0.633***
	(0.044)	(0.090)	(0.052)	(0.119)	(0.058)	(0.142)
Separated, old, high wage	0.473***	0.435*	0.497***	0.734***	0.434**	0.655*
	(0.100)	(0.219)	(0.119)	(0.210)	(0.141)	(0.300)
Separated, old, low wage	0.703***	0.693***	0.676***	0.452***	0.718***	0.881***
	(0.049)	(0.094)	(0.060)	(0.130)	(0.067)	(0.167)
Stayers, young, high wage	0.123**	0.209*	0.049	0.137	0.030	0.348*
	(0.043)	(0.100)	(0.049)	(0.088)	(0.059)	(0.151)
Stayers, young, low wage	-0.007	0.107	-0.022	-0.094	0.008	-0.051
	(0.037)	(0.084)	(0.042)	(0.080)	(0.049)	(0.120)
Stayers, middle-aged, high wage	0.150***	0.203**	0.084*	0.057	0.103*	0.301**
	(0.030)	(0.064)	(0.035)	(0.070)	(0.040)	(0.100)
Stayers, middle-aged, low wage	0.072**	0.101	0.080**	0.068	0.096**	-0.006
	(0.026)	(0.054)	(0.030)	(0.066)	(0.034)	(0.089)
Stayers, old, high wage	0.096**	0.167*	0.074	0.243***	0.016	0.069
	(0.033)	(0.066)	(0.039)	(0.071)	(0.046)	(0.108)
Stayers, old, low wage (reference)						
Constant	8.785***	8.945***	7.846***	7.881***	7.896***	11.692***
	(0.150)	(0.304)	(0.181)	(0.325)	(0.214)	(0.507)
Number of obs.	26480	6389	16601	4016	12862	3490
F-test statistic	489.945	127.882	290.104	84.375	221.989	84.018
R^2	0.467	0.474	0.451	0.481	0.448	0.575

Note: Standard errors in parenthesis, * p<0.1, ** p<0.05, ***p<0.01, all groups of workers are weighted with the number of employees in the firm, other variables include log change in capital per labour, log of initial productivity and wage level, also 5 area dummies.

Appendix 5. OLS in four periods, including enterprises with at least 10 employees. Dependent variable productivity change in the company

Variables	Period 1 2006-2008	Period 2 2008-2010	Period 3 2010-2012	Period 4 2012-2014
Hired, young, high wage	0.330*	1.114***	0.225	-0.254
	(0.160)	(0.221)	(0.191)	(0.170)
Hired, young, low wage	-0.342**	-0.240	-0.146	-0.478***
	(0.110)	(0.133)	(0.120)	(0.118)
Hired, middle-aged, high wage	0.511**	0.685***	0.011	0.114
	(0.159)	(0.189)	(0.169)	(0.151)
Hired, middle-aged, low wage	-0.199	-0.272	-0.199	-0.324**
	(0.117)	(0.142)	(0.128)	(0.118)
Hired, old, high wage	0.268	0.158	0.238	0.237
	(0.294)	(0.414)	(0.317)	(0.299)
Hired, old, low wage	-0.193	-0.491*	-0.508**	-0.732***
	(0.150)	(0.219)	(0.160)	(0.155)
Separated, young, high wage	0.104	-0.007	0.053	0.283
	(0.176)	(0.195)	(0.226)	(0.181)
Separated, young, low wage	0.202	0.523***	0.340*	0.370**
	(0.114)	(0.126)	(0.132)	(0.123)
Separated, middle-aged, high wage	0.265*	0.279	0.141	0.233
	(0.135)	(0.146)	(0.139)	(0.134)
Separated, middle-aged, low wage	0.490***	0.715***	0.668***	0.694***
	(0.104)	(0.106)	(0.117)	(0.113)
Separated, old, high wage	0.247	0.101	0.387	0.109
	(0.267)	(0.224)	(0.250)	(0.211)
Separated, old, low wage	-0.311*	0.286*	0.534***	0.519***
	(0.132)	(0.117)	(0.135)	(0.116)
Stayers, young, high wage	0.167	0.277**	0.201*	0.249**
	(0.092)	(0.091)	(0.096)	(0.086)
Stayers, young, low wage	0.150*	0.113	0.282***	0.118
	(0.075)	(0.075)	(0.077)	(0.072)
Stayers, middle-aged, high wage	0.128*	0.291***	0.181**	0.196***
	(0.060)	(0.063)	(0.065)	(0.055)
Stayers, middle-aged, low wage	-0.019	-0.018	0.054	0.105*
	(0.052)	(0.056)	(0.055)	(0.049)
Stayers, old, high wage	0.071	0.083	0.092	0.090
	(0.077)	(0.077)	(0.074)	(0.064)
Stayers, old, low wage (reference)				
Constant	1.963***	2.338***	1.621**	1.308**
	(0.282)	(0.584)	(0.500)	(0.467)
Number of obs.	4101.000	3976.000	3041.000	3272.000
F-test statistic	8.950	9.221	8.046	9.631
R^2	0.169	0.183	0.197	0.222

Note: Standard errors in parenthesis, * p<0.1, ** p<0.05, ***p<0.01, all groups of workers are weighted with the number of employees in the firm, other variables include log change in capital per labour, log of initial productivity and wage level, also 5 area dummies.

Struktuurimuutus ja tööjõu tootlikkus ettevõtetes: kui olulised on muutused ettevõtte töötajate vanuselises ja palgastruktuuris?

Tänapäeva maailmamajanduse oluline arengusuund on töötajaskonna juurdekasvu aeglustumine ja töötajate keskmise vanuse kasv. Nendes oludes muutub ettevõtetele üha olulisemaks küsimus, kuidas säilitada tööjõu tootlikkuse kasv ka vananeva töötajaskonnaga. Tööjõu tootlikkuse analüüsi kohta on ilmunud väga ulatuslikult kirjandust (nt. ülevaated Del Gatto et al, 2011, Syverson, 2011). Majanduse struktuurimuutuste ja tootlikkuse vaheliste seoste uurimiseks on pakutud välja mitmeid tootlikkuse dekomponeerimise meetodeid (Olley ja Pakes, 1996; Foster, Haltiwanger and Krizan, 2001; Melitz and Polanec, 2015), mis võtavad arvesse erinevatesse tööstusharudesse sisenevate ja sealt väljuvate ettevõtete tootlikkusi. Kuid erinevalt eelpool viidatud töödest Ilmakunnas ja Maliranta (2007, 2016) dekomponeerisid tootlikkust ettevõtte tasandil, vaadeldes ettevõtte poolt tööle võetud ja töölt lahkunud töötajaid erinevates vanuserühmades, mis võimaldas neil uurida seoseid tootlikkuse ja töötajate vanuselise struktuuri muutumise vahel.

Käesolev uurimistöö on motiveeritud eelmainitud ettevõtte tasandil tootlikkuse dekomponeerimise töödest, kuid lisaks töötajate vanuselisele jaotusele võetakse arvesse ka töötajate palgaerinevused. Artikliga selgitatakse välja, kuidas muutused ettevõtete töötajaskonna vanuselises ja palgaalases jaotuseson seotud ettevõtete tootlikkuse muutustega ühe majandustsükli sees. Kasutatakse Eesti Äriregistri andmeid aastatest 2006-2014, mis on ühendatud Eesti Maksuameti andmetega töötajate palkade kohta. Fikseeritud efektiga paneelandmete mudelis eristatakse neljal perioodil (2006-2008, 2008-2010, 2010-2012, 2012-2014) ettevõttesse juure palgatud, sellest lahkunud ning ettevõttesse alles jäänud töötajaid. Edasi jagatakse töötajad neis rühmades omakorda noorteks (kuni 30 aastasteks), keskealisteks (vanuses 31-50) ja vanemaealisteks (alates 51 eluaastast) ning samuti kõrge- ja madalapalgalisteks. Kõrgepalgaliste palk oli vastava aasta EMTAK kahenumbrilise tegevusala keskmisest suurem või sellega võrdne, madalapalgaliste palk oli madalam.

Töötajaskonna vananemine on vaatlusalusel perioodil muutunud kiiremaks. Nii töötlevas tööstuses kui ka teenustes avaldus pöördvõrdeline seos ettevõtete töötajate tootlikkuse ja töötajate keskmise vanuse vahel. Jaotades ettevõtted töötajaskonna vanuse alusel nelja rühma, selgus, et esimese kvartiili s.t. noorima töötajaskonnaga ettevõtetes on tootlikkus kõrgem kui neljanda kvartiili ehk kõige kõrgema keskmise vanusega töötajatega ettevõtetes. Eriti selgelt ilmnes see seos töötlevas tööstuses. Majanduskriisist väljumise käigus taastati kiiremini madalapalgalised töökohad nii noorte kui eakamate töötajate vanuserühmas. Selle tulemusena madalapalgaliste suhe kõrgepalgalistesse suurenes.

Tootlikkuse dekomponeerimine näitas, et töötajate palkamise puhul on kõrgepalgaliste töötajate tootlikkuse ja vanuse seos teooriatele vastavalt tagurpidi U kujuline. Madalapalgaliste töötajate tootlikkus üldjuhul ei erinenud ettevõttesse jäänud töötajate keskmisest tootlikkusest. Sõltuvalt tööstusharust on keskealised kõrgepalgalised ehk kõige tootlikumad töötajad 40,5-77% tootlikumad, kui ettevõttesse jäänud töötajad. Kõigil juhtudel olid ettevõttest lahkunud töötajad üldiselt väiksema tootlikkusega, kui samal perioodil ettevõttesse jäänud töötajad. Seega oli majandustsükli jooksul võimalik töötajate struktuuri ümber korraldada, vallandades vähem tootlikke töötajaid (sh näiteks väiksema tootlikkusega üksused sulgeda).

Üldjuhul kasvas kõrgepalgaliste jääjate tootlikkus rohkem kui madalapalgaliste oma, kõige rohkem kõrgepalgaliste keskealiste tootlikkus. Seejuures ei saa öelda, et madalapalgaliste tootlikkus üldse ei kasvanud. Kui vanemaealiste madalapalgaliste töötajate tootlikkus kasvas, siis kasvas ka teiste vanuserühmade madalapalgaliste tootlikkus, kuid erinevus nende rühmade tootlikkuse kasvu vahel on statistiliselt mitteoluline. Tootlikkuse kasvu määr on keskealiste kõrgepalgaliste seas 24,9 protsendi võrra suurem kui vanemaealistel madalapalgalistel. Noortel ja vanadel kõrgepalgalistel on tootlikkuse kasvu määr ligikaudu 17% võrra suurem kui vanemaealistel madalapalgalistel. Ehkki on tööandjad koolitavad parema meelega pigem noori (Grund and Westergård-Nielsen, 2005) viitaks käesolev tulemus justkui sellele, et nii noori kui vanu kõrgepalgalisi koolitatakse võrdselt (eeldusel, et tootlikkuse kasv tuleneb ainult koolitamisest).

Seejuures ei pea jääjate tootlikkuse kasvu määr muutuma tingimata ainult koolituste tõttu. Statistiliselt olulised koefitsiendid ettevõttesse jäänud töötajate puhul võivad viidata selle, et ettevõtted viisid majanduskriisi ajal läbi erinevaid organisatsioonilisi innovatsioone, mille tulemusena osutus võimalikuks vähendada kõrgepalgalisi töökohti (eriti teenustes) ja samas säilitada tootlikkuse. See võib lisaks viidata ka teatud funktsioonide täitmisest loobumisele ja selle sisseostule väljastpoolt ettevõtet. Nende sammude tulemusena kõrgepalgaliste ettevõttesse jäänud töötajate tootlikkuse kasv on suurem kui vanemaealiste madalapalgaliste tootlikkuse kasv. Seega madalapalgaliste tootlikkuse kasv jääjate hulgas on sarnane sõltumata vanusegrupist.

Kokkuvõttes on struktuurimuutused kiirendanud töötajaskonna vananemist. Lisaks on meie andmete põhjal kõrgem töötajate keskmine vanus ettevõttes seotud madalama tootlikkusega töötaja kohta. Seejuures ei saa me dekomponeerimise abil näidata, et töötajate palkamise hetkel oleks vanemad madalapalgalised töötajad väiksema tootlikkusega kui teised vanuserühmad. Vanemaealised kõrgepalgalised on küll väiksema tootlikkusega kui keskealised kõrgepalgalised, kuid kõrgema tootlikkusega kui kõrgepalgalised noored. Majandustsükli mõju analüüsimisel selgus, et majanduslanguse ajal, kui töötute arv on kasvanud, saavad ettevõtted palgata tootlikumaid kõrgepalgalisi noori ja keskealisi kui majandusbuumi ajal. Seega on ka meie arvutuste kohaselt majandustsükli eri faasidel mõju töötajate tootlikkusele. Juhid peavad järjest enam arvestama, et töötingimused peavad olema sobivad vanematele inimestele. Juhtidel ei tasu siiski üldjuhul karta üle 50 aastaste töötajate palkamist. Kõrgepalgaliste töötajate puhul näitab analüüs, et vanemate inimeste tootlikkus on kõrgem kui noorimas rühmas ja madalapalgaliste puhul ei näidanud dekomponeerimine statistiliselt olulist erinevust eri vanuserühmade tootlikkuses.