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Demography, Capital Accumulation and Growth

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Abstract

Europe will be challenged by demographic changes over the next few decades, even under favourable assumptions about fertility and migration, but the economic effects are not yet fully understood. This paper studies the effects of population ageing on economic growth, capital deepening and robotisation in 27 European Union (EU) labour markets. First, we econometrically assess the effects of ageing and potential labour market shortages on growth. Second, we test the hypothesis of whether ageing leads to faster adoption of new technologies. We distinguish between various capital asset types, including non-ICT and ICT capital, tangible and intangible capital and the adoption of robots. The analysis is based on Eurostat, the European Labour Force Survey (EU-LFS) and International Federation of Robotics (IFR) data. Results indicate that ageing and demographic changes might contribute to secular stagnation, which decelerates the adoption of new technologies.

Keywords: aging, growth, capital accumulation, new technologies, secular stagnation

JEL classification: J11, O33

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1 Introduction

This paper studies the effects of demographic changes on technology adoption and productivity growth in the European Union (EU). Major ageing trends, including the decline in population growth driven by long-run trends in fertility/mortality rates, migration and changes in age structures are analysed, and the major effects of ageing on economic growth and technology adoption across EU-27 countries are compared. This paper contributes to the literature in two ways. First, the analysis relies on European data and employs an EU-27 sample, whereas the majority of earlier studies focus on the world, Organisation for Economic Co-operation and Development (OECD) countries or solely on the US. Second, the paper uses a broader set of automation variables, such as information and communication technologies (ICT), including computer hardware, telecommunication equipment, software, databases and other asset types, whereas earlier literature mostly uses data from the International Federation of Robotics (IFR), which are also used for comparison.

In this paper, we will address the question of whether aging might lead to "secular stagnation", i.e. a phase of low growth, in the EU-27. We analyse how the shifting age structure of the total population and employees are associated with the dynamics of total gross domestic product (GDP) and GDP per capita.[1] We also assess how ageing impacts the accumulation of capital differentiated by various asset types, focusing on ICT capital, software and databases. We aim to test the argument that ageing leads to faster adoption of new technologies, which, in the recent literature, is often measured by increasing robots' intensity. Faster adoption of robots and the associated acceleration of productivity is widely discussed as a cure against demographic challenges.

The analysis draws on official data from Eurostat. First, National Accounts data provides information on real value-added growth and employment. Second, data from demography statistics and the EU Labour Force Survey (EU-LFS) are used for the development of age structures, which allows us to analyse ageing indicators. Third, Section 4 uses data on capital stocks from Eurostat to assess the relationship between ageing and capital deepening (i.e. changes in capital-labour ratios by various asset types). Finally, these relationships will be tested using data on robot intensity from the IFR.

The next section summarises the related literature. Section 3 presents and discusses the major results on the association between population ageing and growth, while Section 4 discusses the relationship between population ageing and capital deepening. The final section provides a conclusion.

[1] However, we do not address other potential factors that might foster secular stagnation (e.g. increased inequality, productivity slowdown) or offsetting factors, like foreign direct investment flows or fiscal and monetary policies. These factors are widely discussed particularly for the Japanese economy which faces a period of secular stagnation for a long time already (see Desai, 2022).

2 Related literature

There has been a long tradition of studying the relationship between population age structures and performance. For example, Hansen (1938) argues that population ageing leads to higher savings relative to investment, implicating secular stagnation (see also Summers, 2013 and Teulings and Baldwin, 2014). Acemoglu and Restrepo (2018b) provide evidence for a large sample of countries that the growth of GDP per capita is larger for countries experiencing more rapid ageing, and they argue that this could be explained by the more rapid adoption of technologies due to demographic pressures. In particular, they empirically consider 1990 to 2015 and find a positive relationship in many econometric specifications. This is further explained by a strong positive correlation between ageing and the adoption of robots, which is documented in more detail in Acemoglu and Restrepo (2018a). They also provide a theoretical framework with the explanation that labour scarcity encourages automation (see also Acemoglu and Restrepo (2018b). Focusing on advanced economies, the ordinary least squares (OLS) results for the OECD countries in their sample does not show any significant result of ageing on GDP per capita growth; however, when examining birth rates, the relationship becomes positively significant. Nevertheless, when the period is reduced to 2000 to 2015, the results in Acemoglu and Restrepo (2017) are not significant in any specification for OECD countries.

Maestas et al. (2022) investigate this topic across US states and find a negatively significant relationship. Relative to the results reported before, this might be explained by more similar technologies and the adoption of robots (or new technologies), which might explain that the effects argued in Acemoglu and Restrepo (2017) are absent.[2] Methodologically, Maestas et al. (2022) start from a production function approach that decomposes the effects into a contribution to labour productivity and labour force growth. They find that a 10% increase in a fraction of the 60+ population impacts negatively on growth by 5.5%, with two-thirds resulting from lower labour productivity growth and one-third from slow labour force growth. In older literature, Lind and Malmberg (1999) and Feyrer (2007) find that data before 1990 indicates a negative relationship between ageing (measured as the share of population aged above 50) and GDP per capita.

A specific and widely discussed case is the secular stagnation in Japan since the 1990s at least.[3] In the literature many factors leading to this stagnating period are debated, particularly, the huge excess saving as a result of structural causes and the decline in investment due to the demographic change (see Fukao et al., 2015). Particularly, they identify the role of declining labour (service input) growth as an important ingredient in the slowdown of Japan's economic growth. The decline in labour inputs is to a large extent driven by the decline in the working-age population (caused by low birthrate and population aging) together with a decline in the average working hours per worker. Additionally, they also conclude

[2] The same argument might apply for the sample and results for the OECD countries mentioned before. In this paper, we rarely find significant effects across European countries for which this argument applies.

[3] For a summary of causes and consequences as well as policy aspects see e.g. European Parliament (2020).

that "... the ICT revolution did not happen in Japan simply because Japan has not accumulated sufficient ICT capital ..." (page 29). As a reason for this they provide various explanations which one of these being slow human capital accumulation (particularly of software engineers). Other authors are more optimistic about the impact of demographic change on new technologies. Schneider et al. (2018) argues that the demographic change makes the country a laboratory concerning the interaction between population aging and shrinking and robotisation, but also point towards high uncertainties and the importance of various framework conditions in this process. Further, they highlight the fact that the proliferation of robots extends to various services including hospitals, care, nursing, etc. Fujiwara (2018) argues that in Japan labour shortages are and will continue to be a driver for robot adoption in Japan. Others, studying the impact of robots on employment, like Adachi et al. (2020) find a positive relation between robots growth and gross employment based on a detailed industry-level and commuting zone-level data set.

Prettner and Bloom (2020) overview the impact of demographic change on automation, which is also considered a response to the ongoing ageing patterns driven by the decline in fertility rates (as well as declining mortality rates). They hint that a declining dependency ratio (due to declining fertility) implies a rise in GDP per capita (even if productivity defined as GDP per employed person is constant). However, the impacts of declining mortality and increasing life expectancy are strongly dependent on the affected age group. For example, if old-age mortality decreases, there is likely to be a negative impulse on economic growth.Furthermore, indirect effects, such as increasing life expectancy, implies an incentive to invest in learning and education (due to a larger expected pay-off), which has a positive effect on productivity and growth.[4] However, in many advanced economies, increasing dependency ratios evolve with numerous economic, social and political consequences that might be counteracted by various responses (such as more investment in education, government investment in health and education, savings decisions, etc.).

One particular aspect is whether investments and automation could also be mechanisms for reducing the impact of ageing. A simple theoretic growth set-up (assuming a Cobb-Douglas production function) shows that a decline in labour force growth (or a decline in the labour force) results in an incentive to invest more in automation. It descriptively shows that robot density is higher in countries with stronger ageing trends (and vice versa). Abeliansky and Prettner (2017) demonstrate that a 1% decrease in population leads to an increase of 2% in robot density growth rate. Additionally, they discuss how robotisation impacts the replacement of jobs (with estimates between 12 and 65 million workers); however, these numbers are not compared to population projections.[5] Focusing on European economies, Leitner and Stehrer (2019b) calculate long-term GDP and productivity growth rates and trends in participation rates and conclude that, for several countries, demographic developments are likely to kick in and begin jeopardising further growth in the near future. Different simulation exercises demonstrate that in some

[4] This is also known as the "Ben-Porath mechanism"; see Ben-Porath (1967).

[5] In a wider debate, there are also several arguments that fertility decreases with automation, although a few counterarguments might be given as well.

EU countries, particularly in Central and Eastern Europe, labour supply-side constraints would already materialise in the mid-2020s. In a follow-up paper, Leitner and Stehrer (2019a) argue that higher productivity growth is needed, and the current labour productivity growth rate in the EU needs to more than double to circumvent a negative impact on growth due to a decline in the working-age population. Even though robots exhibit a positive impact on labour productivity growth in their analysis, this is not (yet) strong enough to close the gap between the recent and hypothetical labour productivity trend growth rate that would be required.

3 Ageing and growth

3.1 Description

In this section, we discuss demographic changes in EU-27 countries from 1995 to 2021, focusing on the shifting age structure of the working-age population and persons employed.

3.1.1 Working-age population

Looking at population age structures reveals diverging trends across countries (see Figure 3.1), largely reflecting long-term trends in fertility (facing substantial declines in birth rates), mortality rates, outward migration and the compensatory effect of migration inflows in several EU-27 countries. Over the period analysed (1995 to recent), migration was a major determinant of population dynamics on top of fertility trends. Bulgaria, Croatia, Estonia, Greece, Hungary, Latvia, Lithuania and Romania incurred a major drop in populations aged 15 to 64, with Latvia and Lithuania declining by 24% and 26% from 1995 to 2021, respectively. This observed negative dynamic is attributed to the massive emigration of the working-age population from the aforementioned countries when the Soviet Union dissolved and joined the EU. Notably, the overall drop in working-age population occurred due to a declining share of people aged 15 to 49 (see Figure 3.2), which is in line with earlier evidence on the prevailing share of younger workers among Eastern and South-Eastern European emigrants (see Favell, 2008). Several EU-27 countries experienced a major increase in the working-age population between 1995 and 2021, among others, Austria (12%), Belgium (13%), Cyprus (42%), Ireland (40%), Luxembourg (58%), Malta (39%) and Sweden (17%), whereas all other EU-27 countries incurred only minor variations (see Figure 3.1).[6]. Notably, the share of older people (those aged 50-64) rose substantially in the majority of EU-27 countries, with the starkest increases in Austria, Belgium, Italy, the Netherlands, Poland and Spain.

[6]The inflow of migrants is the major driver behind the observed positive dynamics, as birth rates have, if anything, declined in the last decade. For more information on (i) migration statistics for EU-27 countries, please refer to https://ec.europa.eu/eurostat/databrowser/view/MIGR_IMM8/default/table?lang=en&category=migr.migr_cit.migr_immi; (ii) for fertility statistics for EU-27 countries, please refer to https://ec.europa.eu/eurostat/databrowser/view/DEMO_FRATE/default/table?lang=en&category=demo.demo_fer.

3.1.2 Persons employed

The dynamics and demographic changes in the population of employed persons are depicted in Figures 3.3 and 3.4. A notable decline in employment is recorded from 2008 to 2010 because of the global financial crisis. Bulgaria, Estonia, Greece, Ireland, Latvia, Lithuania and Spain incurred the most pronounced drops in the number of employed people, with Greece, Latvia and Lithuania remaining below the pre-crisis level, even in 2020 (see Figures 3.3). The number of persons employed in Romania declined persistently from 1997 to 2020, with an overall drop of 19%. Yet, several countries reveal a positive trend in the number of employed individuals, with Luxembourg and Malta increasing to 80% from 1995 to 2020 in Luxembourg and 2000 to 2020 in Malta, whereas Sweden incurred a 22% increase from 1995 to 2020. The share of older workers (aged 50-64) increased in all countries, whereas the share of middle-aged workers (25-49) declined, except for Malta (see Figure 3.4). The share of older workers increased by more than double in Austria, Belgium, Italy, the Netherlands, Slovakia and Slovenia and almost double in Germany from 1995 to 2020. Notably, an increase in employed individuals exceeded the increase in total population (Figure 3.2) in the majority of sample countries, signalling rapid ageing, particularly among the employed, which could be attributed to both a decline in the overall share of youth (aged 15-24) and a decline in the labour market participation of youth due to enrolment in education.

3.1.3 Growth rates

Figure 3.5 displays the growth rates of the working-age population in total and across three age groups, while Figure 3.6 shows the respective growth rates in the employed population. The growth rates mirror the dynamics of demographic changes presented in Figures 3.1 and 3.2 for the working-age population and Figures 3.3 and 3.4 for employed people. Stark differences in growth rates in the younger and older age groups reflect the major demographic change and decreasing share of youth both in total population and among workers. In the employed population, the ratio of workers aged 50 to 64 increased in all EU-27 countries without exception, with the growth rate ranging from 0.2 in Romania to 4.4 in Luxembourg (see Figure 3.6). The growth rate of the population aged 50 to 64 appeared considerably slower than that of employed persons, reflecting the increasing role of older workers in response to looming labour demands and the declining share of the young workforce. As discussed above, an increasing propensity to enrol in higher education may reduce the labour market participation of the younger population.[7]. The ratio of youth aged 15 to 24 both largely declined, except for Ireland, the Netherlands and Sweden, as well as Finland and France in the case of the employed.

[7] For more information on education statistics, please refer to `https://ec.europa.eu/eurostat/databrowser/view/EDUC_UOE_ENRA05__custom_2276747/default/table?lang=en`

3.1.4 Old-age ratios

For econometrics, and to be consistent with the literature, we employed old-age ratios in two ways. The ratio of older people (aged 50-64) to younger (aged 15-24 or 15-49) increased in all EU-27 countries without exception, both in total population (see Figure 3.7) and among employed people (see Figure 3.8), yet the dynamics between 1995 and 2021 varied drastically across the countries. Austria, Belgium, France, Germany, Italy, the Netherlands, Portugal and Spain revealed a smooth and steady increase in the ratios of older people (50-64) to both younger youth (15-24) and older youth (25-49). A rapid growth in both ratios occurred between 1995 and 2010, with a subsequent deceleration in Czechia, Denmark, Finland and Slovakia and a sharp drop in Malta. Among employed people (see Figure 3.8), the gaps between the ratios of older people (50-64) to younger youth (15-24) and older youth (25-49) were much smaller due to the marginal share of people aged 15 to 24 among those in employment (see Figure 3.4). Once again, the latter is consistent with this age group's increasing propensity to enrol in education. The dynamics of ratios among employed persons reflect that of the total population, with Malta being the only exception, as both ratios increased insignificantly. These findings further support our earlier conclusion on the rapid ageing of the workforce in the EU, as the share of older people grows both in the total population and among the employed, inevitably resulting in labour shortages.[8]

[8] The gradual decline in the share of young people is largely driven by a downward trend in birth rates in many EU-27 countries, emigration, in the case of Eastern and South-Eastern EU Member States, increasing enrolment in education and lower labour market participation, with the latter reflecting the share of youth among the employed.

Figure 3.1: Working population by age groups 1995-2021, mn

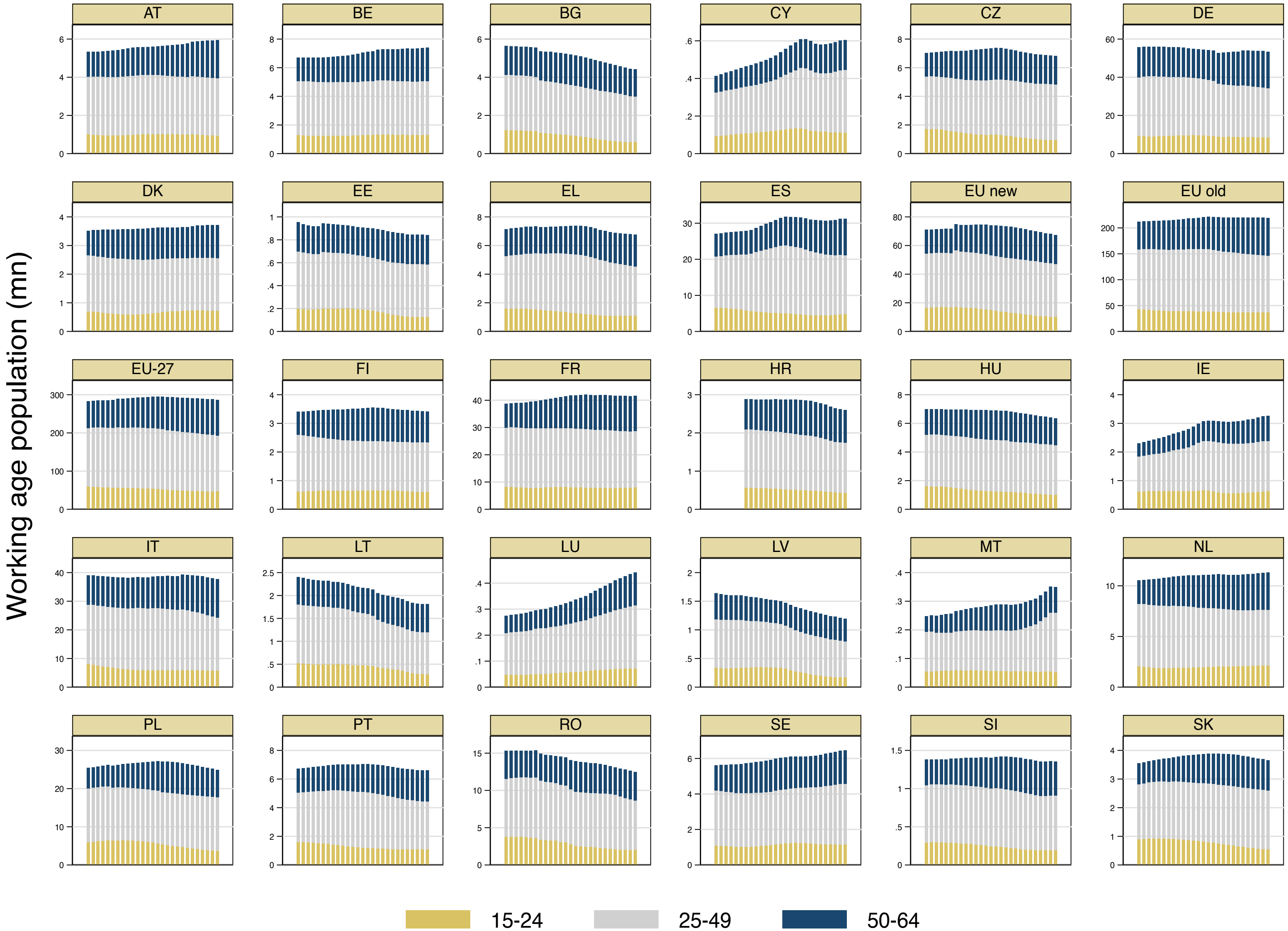


Figure 3.2: Working population by age groups 1995-2021, %

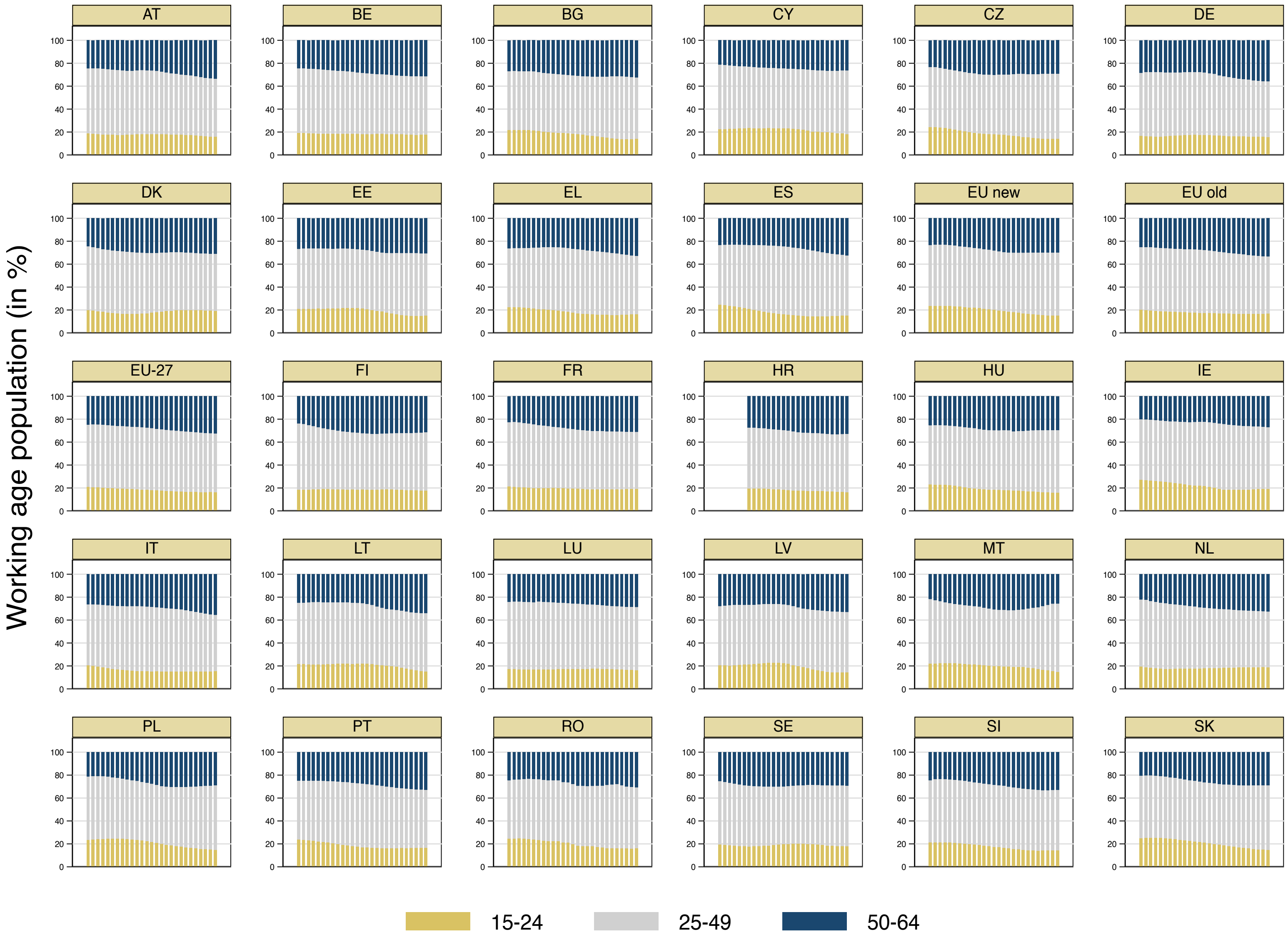


Figure 3.3: Persons employed by age groups 1995-2020, mn

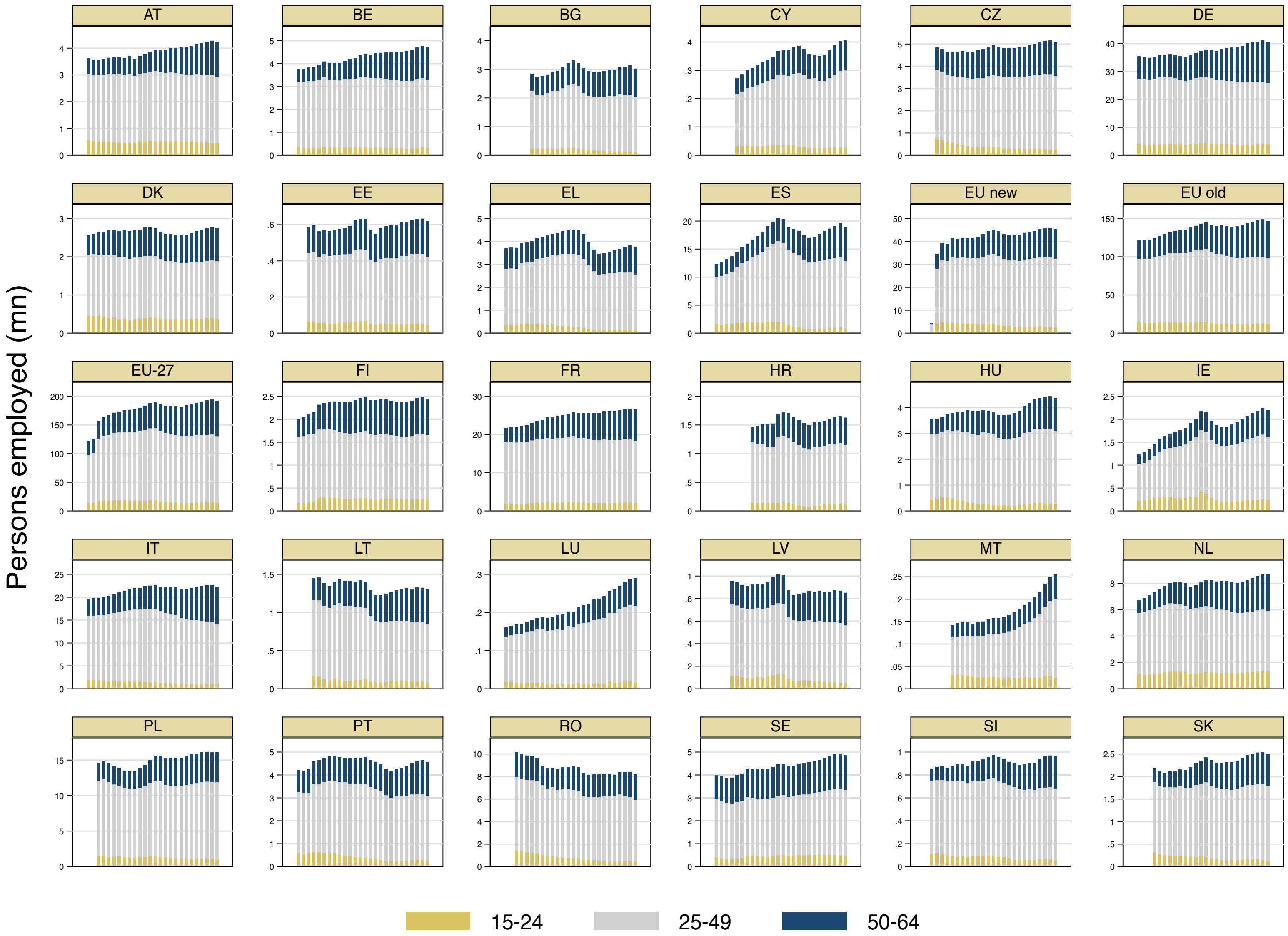


Figure 3.4: Persons employed by age groups 1995-2020, %

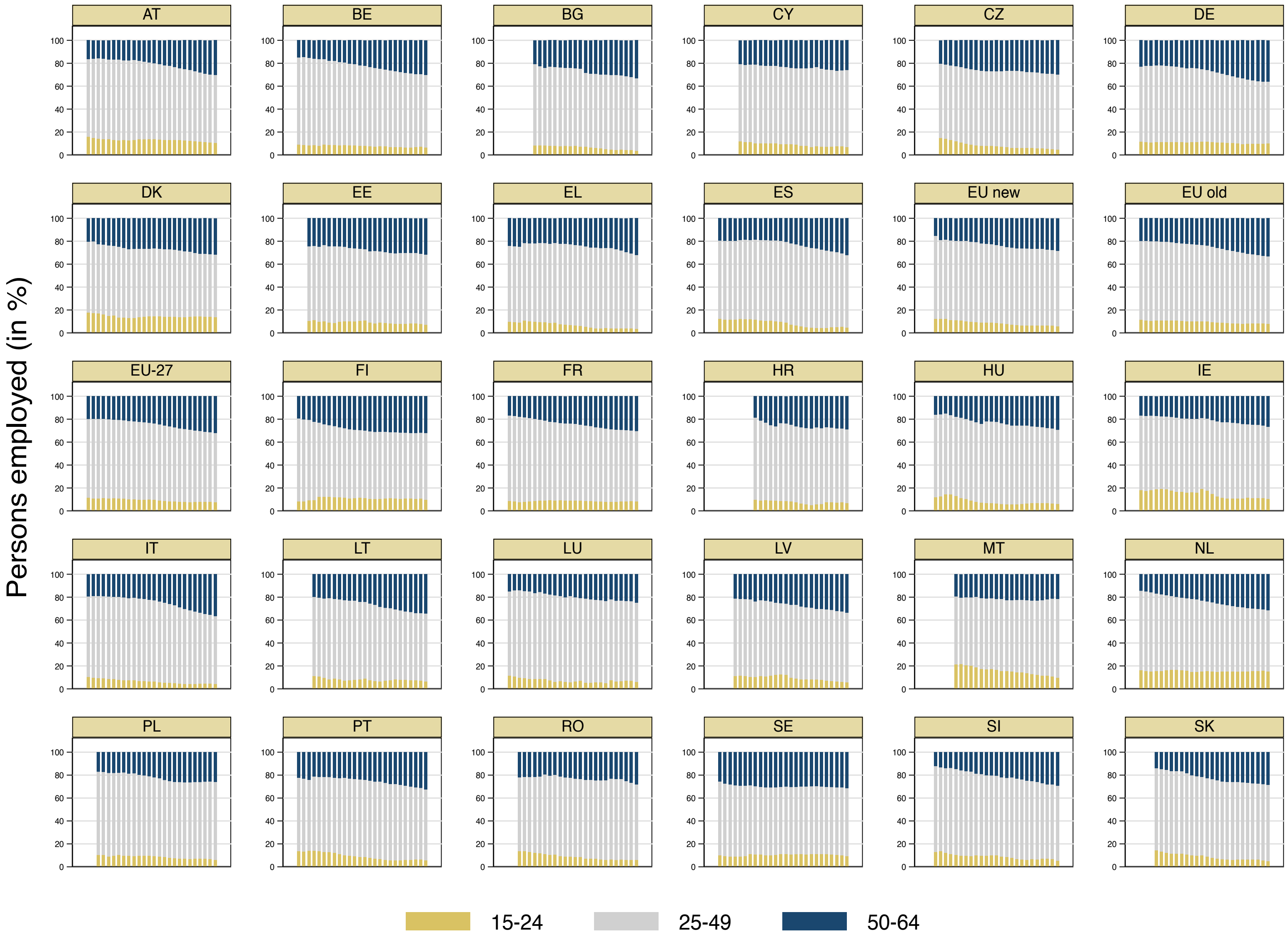


Figure 3.5: Growth rates of working-age population by age groups, %

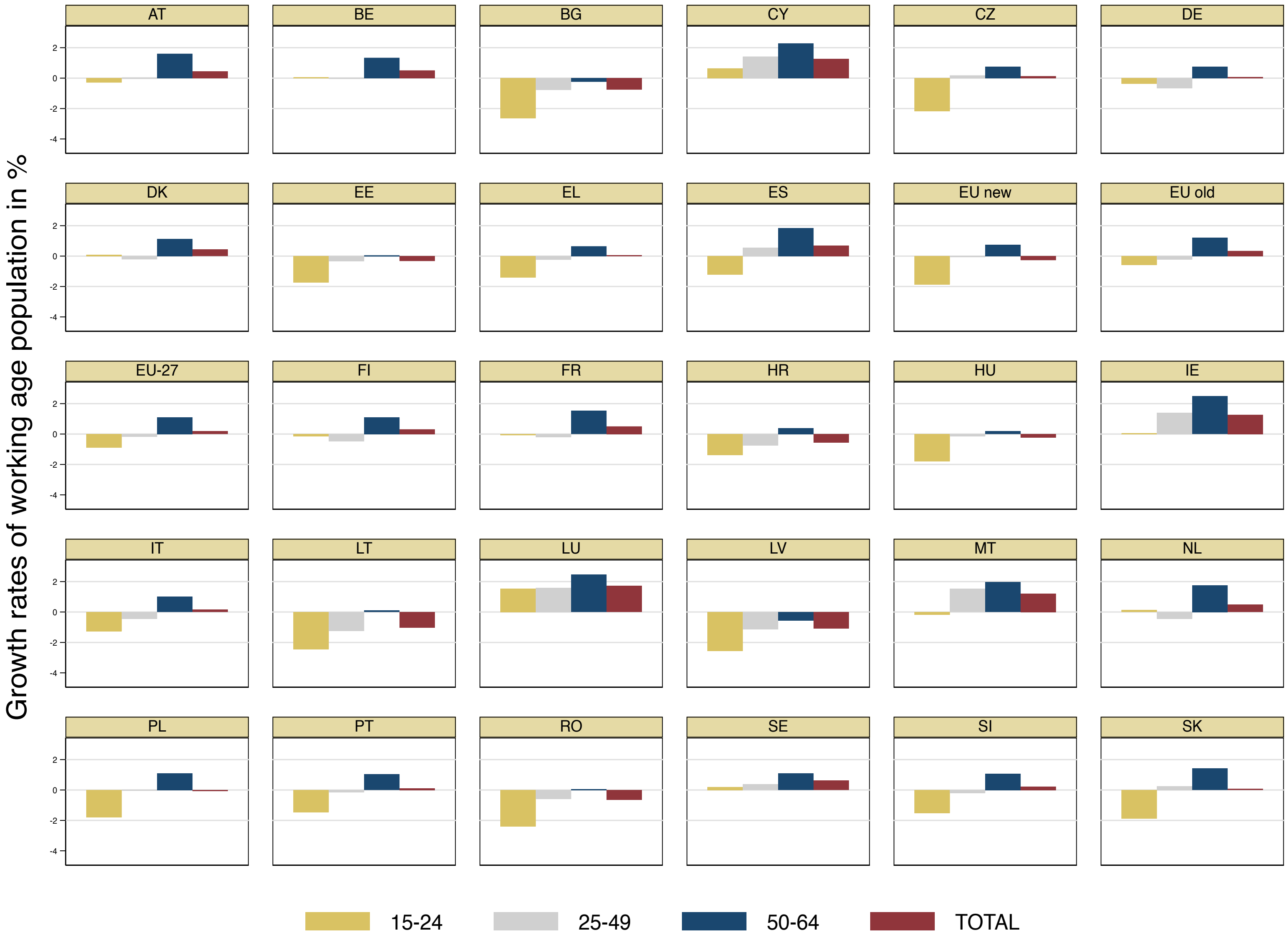


Figure 3.6: Growth rates of persons employed by age groups, %

Figure 3.7: Population old-age ratio

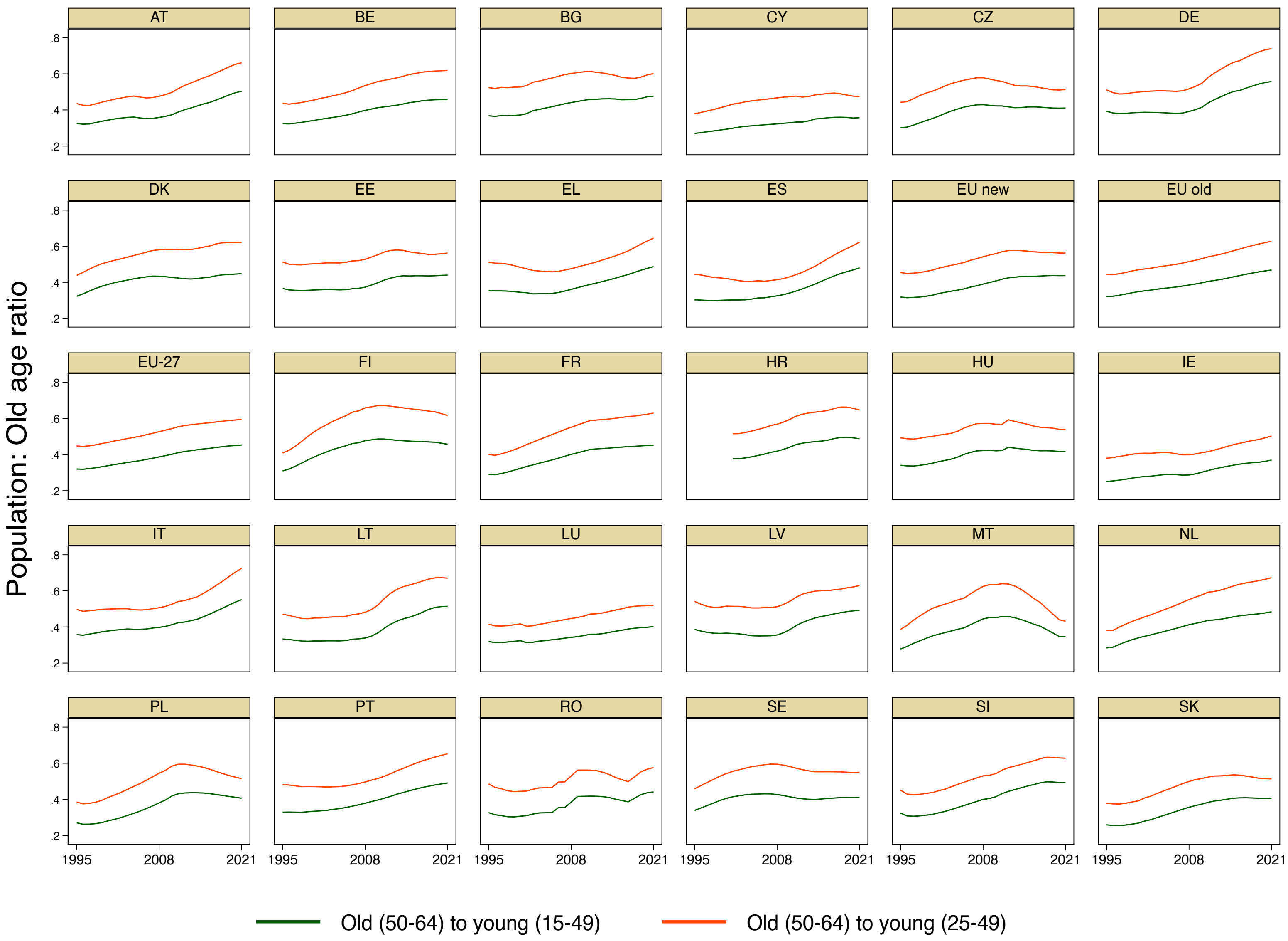
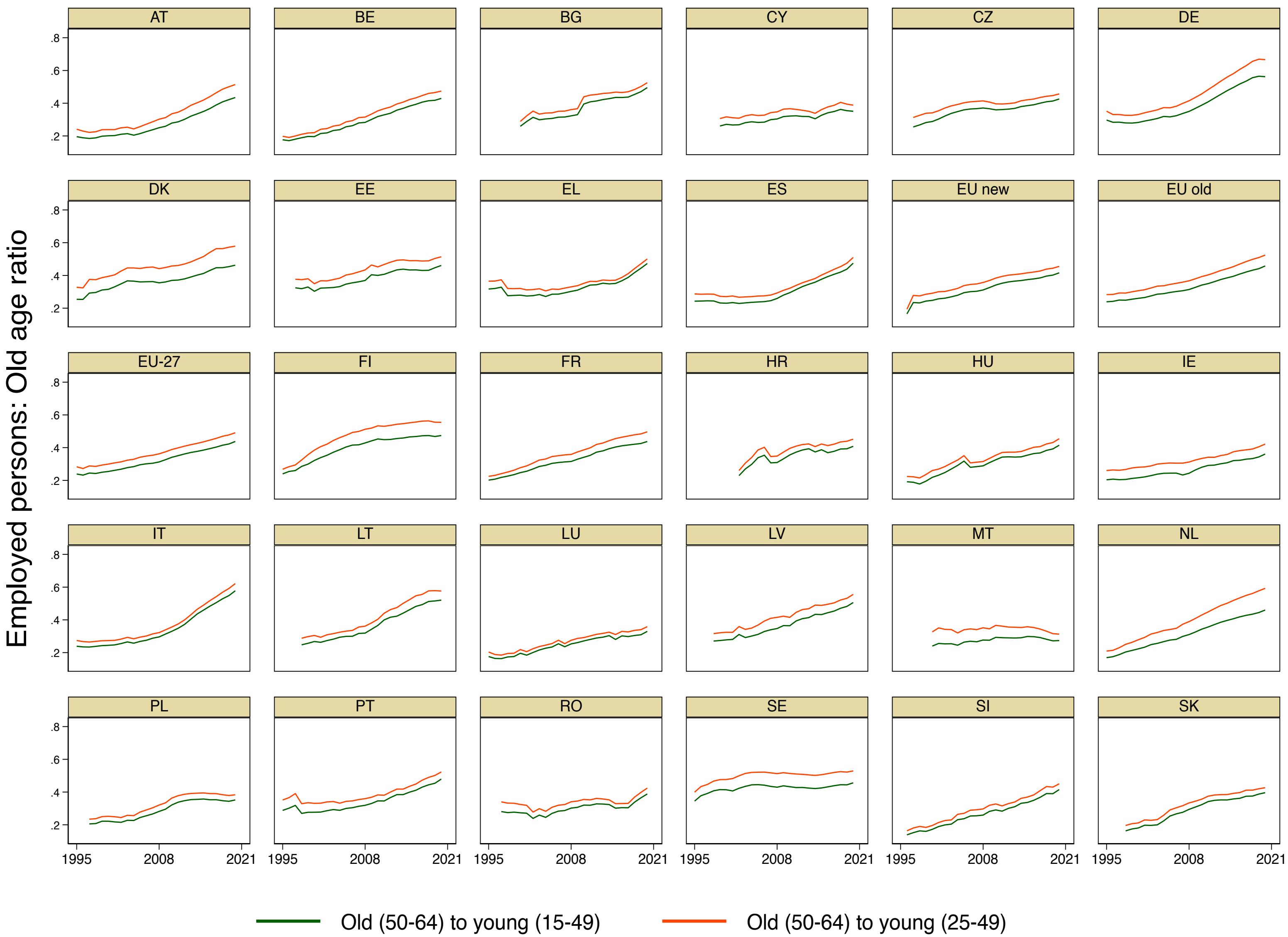


Figure 3.8: Employed persons old-age ratio



3.2 Demography-driven secular stagnation in the EU-27?

3.2.1 Long-run relationship between ageing and growth

In this section, we replicate the basic approach of Acemoglu and Restrepo (2017) for our sample. We begin by analysing the relationship between the annual growth of GDP and population ageing defined via four different measures.

Table 3.1: Annual average GDP growth and ageing

VARIABLES	(1) eq1 GDP growth	(2) eq2 GDP growth	(3) eq3 GDP growth	(4) eq4 GDP growth
EU Members 2004+	0.014***	0.014***	0.016***	0.015***
	(0.004)	(0.004)	(0.004)	(0.004)
Δ old-age ratio (population)	-0.846			
	(0.583)			
Δ old-age ratio (employment)		-0.782*		
		(0.446)		
Δ share 50-64 (population)			-1.607	
			(1.672)	
Δ share 50-64 (employment)				-1.663
				(0.980)
Constant	0.020***	0.022***	0.018***	0.023***
	(0.005)	(0.005)	(0.005)	(0.006)
Observations	27	27	27	27
R-squared	0.489	0.507	0.465	0.504
F	11.47	12.34	10.41	12.17

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.1 presents the OLS regression estimates of the average annual (log) growth in GDP over the available years[9] in terms of (i) changes in the ratio of the population aged 50 to 64 to population aged 25 to 49 denoted Δ *old-age ratio (population)*; (ii) changes in the ratio of the share of employed persons aged 50 to 64 and 25 to 49 (Δ *old-age ratio (employment)*); (iii) percentage point changes in the share of the population aged 50 to 64 in a population aged between 15 and 64 denoted Δ *share 50-64 (population)*; (iv) percentage point changes in the share of employed persons aged 50 to 64 in a population aged between 15 and 64 denoted Δ *share 50-64 (employment)*). All regression models include robust standard errors and an additional control for the new EU Member States (*EU Members 2004+*), i.e. the countries that joined the EU in 2004 or later. The latter control captures major cross-country differences in growth rates driven by the low initial level of GDP (in the first year of available data) at the beginning of our sample period when new EU Member States had substantially lower levels of economic development compared to the old EU Member States and experienced higher growth due to the subsequent convergence process.

Unlike Acemoglu and Restrepo (2017) for the US, our results do not indicate a significant positive association between GDP growth and ageing. On the contrary, the association is either insignificant or

[9]The data on the total working-age population is available for all countries for 1995-2021. The data on employed working-age population is available as follows: 1996-2020 for Hungary and Slovenia; 1997-2020 for Czechia, Estonia, Poland, Romania; 1998-2020 for Latvia, Lithuania, Slovakia; 2000-2020 for Bulgaria; 2002-2020 for Croatia; 1995-2020 for all other countries.

weakly negative in terms (Table 3.1). The only weakly significant negative association between GDP growth and ageing is documented in Column 2, which includes the ratio of older to younger people among those employed, with coefficient estimate -0.782 ($p < 0.1$). Estimated associations between all other ageing variables (Columns 1, 3 and 4) and GDP growth is economically negative yet statistically insignificant. Being a new EU Member State has a very strong positive association with GDP growth in all regression specifications. The latter estimate is in line with the economic convergence of new EU Member States, as economic growth was the strongest in countries with lower initial levels of GDP.

As a robustness check, Table 3.2 reports the same regression estimates as Table 3.1 but with annual growth in GDP per capita (averaged over years) as a dependent variable. The estimated association between population ageing and GDP per capita growth is insignificant for all ageing measures once again (Columns 1 to 4). Despite several coefficients turning economically positive (0.277 ($p > 0.1$) in Column 1 and 1.221 ($p > 0.1$) in Column 3), these are not sufficient to make conclusions about the potential positive association between ageing and growth for the EU.

Table 3.2: Annual average GDP per capita growth and ageing

VARIABLES	(1) eq1 GDP p.c. growth	(2) eq2 GDP p.c. growth	(3) eq3 GDP p.c. growth	(4) eq4 GDP p.c. growth
EU Members 2004+	0.024***	0.023***	0.023***	0.023***
	(0.004)	(0.004)	(0.004)	(0.004)
Δ old-age ratio (population)	0.277			
	(0.630)			
Δ old-age ratio (employment)		0.151		
		(0.491)		
Δ share 50-64 (population)			1.221	
			(1.754)	
Δ share 50-64 (employment)				-0.003
				(1.078)
Constant	0.006	0.007	0.005	0.008
	(0.005)	(0.006)	(0.006)	(0.006)
Observations	27	27	27	27
R-squared	0.603	0.601	0.608	0.600
F	18.23	18.11	18.60	17.99

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

As a robustness check, we analysed the association between annual average productivity growth (defined as GDP per hour worked) and population ageing. The results (see Table 3.3) are in line with previous regression estimates, and all four population ageing measures have a statistically insignificant association with the growth of GDP per hour worked. This finding further supports the earlier finding that points to a statistically weak relationship between population ageing and economic growth, defined as average annual growth in GDP, GDP per capita and GDP per hour worked. This results also holds when taking the growth rate of value added per employed person as dependent variable (see Table 3.4).

Thus, these results thus do not support the findings of Acemoglu and Restrepo (2017) for the US.

However, the estimated negative associations (though insignificant in many cases) are consistent with

Table 3.3: Annual average productivity (GDP per hours worked) growth and ageing

VARIABLES	(1) eq1 GDP p.h. growth	(2) eq2 GDP p.h. growth	(3) eq3 GDP p.h. growth	(4) eq4 GDP p.h. growth
EU Members 2004+	0.020***	0.019***	0.020***	0.019***
	(0.004)	(0.004)	(0.004)	(0.004)
Δ old-age ratio (population)	0.276			
	(0.621)			
Δ old-age ratio (employment)		0.013		
		(0.485)		
Δ share 50-64 (population)			1.547	
			(1.716)	
Δ share 50-64 (employment)				-0.206
				(1.062)
Constant	0.008	0.010	0.005	0.011*
	(0.005)	(0.006)	(0.006)	(0.006)
Observations	27	27	27	27
R-squared	0.526	0.522	0.538	0.523
F	13.32	13.11	13.96	13.15

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.4: Annual average productivity (GDP per person employed) growth and ageing

VARIABLES	(1) eq1 GDP p.e. growth	(2) eq2 GDP p.e. growth	(3) eq3 GDP p.e. growth	(4) eq4 GDP p.e. growth
EU Members 2004+	0.021***	0.020***	0.020***	0.020***
	(0.005)	(0.004)	(0.004)	(0.004)
Δ old-age ratio (population)	0.508			
	(0.688)			
Δ old-age ratio (employment)		0.064		
		(0.542)		
Δ share 50-64 (population)			2.101	
			(1.902)	
Δ share 50-64 (employment)				-0.248
				(1.186)
Constant	0.001	0.004	-0.001	0.006
	(0.006)	(0.006)	(0.006)	(0.007)
Observations	27	27	27	27
R-squared	0.488	0.477	0.502	0.478
F	11.45	10.94	12.09	10.97

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

results for the US presented in Maestas et al. (2022), who report a negative effect of population ageing on economic growth in the US. In this respect one should also note that Acemoglu and Restrepo (2017) found no significant relationship between ageing and growth for OECD countries either. Summarising, there is no indication of demography-driven secular stagnation over the long run for the EU over the period since 1995 despite the demographic shifts ongoing as documented in the beginning of this section.[10]

[10]When using the growth rates of the old-age dependency ratios there are not significant effects either. We also tested using the levels of the old-age dependency variables which in most cases are again negative and/or insignificant.

Table 3.5: GDP growth and ageing (panel model)

VARIABLES	(1) eq1 GDP growth	(2) eq2 GDP growth	(3) eq3 GDP growth	(4) eq4 GDP growth
Δ old-age ratio (population)	-0.161			
	(0.179)			
Δ old-age ratio (employment)		-0.219		
		(0.138)		
Δ share 50-64 (population)			-0.555	
			(0.491)	
Δ share 50-64 (employment)				-0.894***
				(0.265)
Constant	0.022***	0.023***	0.023***	0.026***
	(0.002)	(0.002)	(0.002)	(0.002)
Observations	562	560	562	560
R-squared	0.002	0.005	0.002	0.021
Number of i	27	27	27	27
F	0.807	2.528	1.279	11.37

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

3.2.2 Panel estimation results

Additionally, we estimate the association between economic growth and population ageing using an empirical approach similar to Maestas et al. (2022). Specifically, we estimate regression models similar to those presented in Tables 3.1 and 3.2 employing fixed-effects (FE) panel regressions with country fixed-effects. Instead of the average annual changes the ageing controls are calculated on a yearly basis.[11] The estimated effects of population ageing on GDP growth (see Table B.9) are in line with the findings of Maestas et al. (2022), with all ageing variables having either an insignificant or – in one case – a significant negative association with economic growth. Our estimates suggest that a one percentage point larger increase in the share of the older employment (aged 50-64) in the overall employment is associated with a 0.9 percentage-point ($p < 0.01$) decline in GDP growth (Column 4).[12]

Table B.10, replicates Table 3.2 using a panel regression approach and evaluates the association between population ageing and GDP per capita, reporting an insignificant association between yearly change in the ratio of older to younger people both in the total working-age population and among the employed (Columns 1 and 2). Similar to above, we find an insignificant effect of the change in the share of old-age persons in total population, however a significant effect of the changes in the share of old-age employed with a similar magnitude.

Table B.11 presents regression results similar to Table B.10 and reports statistically and economically weak positive associations between the ratios of older to younger and the share of old-age persons in working-age population. However, when using GDP per person employed (see Table B.12) we find significantly negative effects of a higher old-age dependency ratio in employment and a higher share of

[11] As we include country fixed-effects there is no need for introducing again a dummy for the new member states.
[12] To put in perspective, note that the sample mean of this variable is 0.3%.

Table 3.6: GDP per capita growth and ageing (panel model)

VARIABLES	(1) eq1 GDP p.c. growth	(2) eq2 GDP p.c. growth	(3) eq3 GDP p.c. growth	(4) eq4 GDP p.c. growth
Δ old-age ratio (population)	0.117			
	(0.182)			
Δ old-age ratio (employment)		-0.155		
		(0.140)		
Δ share 50-64 (population)			0.170	
			(0.499)	
Δ share 50-64 (employment)				-0.790***
				(0.270)
Constant	0.018***	0.020***	0.019***	0.023***
	(0.002)	(0.002)	(0.002)	(0.002)
Observations	562	560	562	560
R-squared	0.001	0.002	0.000	0.016
Number of i	27	27	27	27
F	0.414	1.224	0.116	8.536

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.7: Productivity (GDP per hours worked) growth and aging (panel model)

VARIABLES	(1) eq1 GDP p.h. growth	(2) eq2 GDP p.h. growth	(3) eq3 GDP p.h. growth	(4) eq4 GDP p.h. growth
Δ old-age ratio (population)	0.204			
	(0.129)			
Δ old-age ratio (employment)		-0.149		
		(0.099)		
Δ share 50-64 (population)			0.414	
			(0.354)	
Δ share 50-64 (employment)				-0.292
				(0.192)
Constant	0.018***	0.020***	0.018***	0.020***
	(0.001)	(0.001)	(0.001)	(0.001)
Observations	562	560	562	560
R-squared	0.005	0.004	0.003	0.004
Number of i	27	27	27	27
F	2.496	2.273	1.365	2.310

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

old-age workers in employment on productivity growth.[13]

Next, we ran a robustness check following Maestas et al. (2022), using 10-year lags for all four ageing measures. In this case, the estimates presented in Tables 3.9 and 3.10 point towards significantly negative effects on GDP and GDP per capita growth with similar magnitudes as before. However, there are no significant effects on productivity growth as reported in Tables 3.11 and 3.12.[14]

[13] However, when using the growth rate of the old-age dependency ratio in the population we find significantly positive effects on GDP per hour worked and GDP per person employed growth. When using levels of old-age dependency measures we find significantly negative effects on growth (see Appendix).

[14] Again, when using the growth rate of the old-age dependency ratio in the population we find significantly positive effects on GDP per hour worked and GDP per person employed growth.When using levels of old-age dependency measures we find significantly negative effects on growth (see Appendix).

Table 3.8: Productivity (GDP per person employed) growth and aging (panel model)

VARIABLES	(1) eq1 GDP p.e. growth	(2) eq2 GDP p.e. growth	(3) eq3 GDP p.e. growth	(4) eq4 GDP p.e. growth
Δ old-age ratio (population)	0.207			
	(0.138)			
Δ old-age ratio (employment)		-0.220**		
		(0.106)		
Δ share 50-64 (population)			0.491	
			(0.379)	
Δ share 50-64 (employment)				-0.466**
				(0.206)
Constant	0.013***	0.016***	0.013***	0.017***
	(0.001)	(0.002)	(0.002)	(0.002)
Observations	562	560	562	560
R-squared	0.004	0.008	0.003	0.010
Number of i	27	27	27	27
F	2.236	4.321	1.678	5.138

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.9: Growth and ageing (panel model with long lags)

VARIABLES	(1) eq1 GDP growth	(2) eq2 GDP growth	(3) eq3 GDP growth	(4) eq4 GDP growth
Δ old-age ratio (population)	-0.392***			
	(0.116)			
Δ old-age ratio (employment)		-0.601***		
		(0.140)		
Δ share 50-64 (population)			-1.426***	
			(0.318)	
Δ share 50-64 (employment)				-1.191***
				(0.299)
Constant	0.252***	0.266***	0.270***	0.270***
	(0.010)	(0.014)	(0.011)	(0.016)
Observations	419	390	419	390
R-squared	0.028	0.048	0.049	0.042
Number of i	27	27	27	27
F	11.33	18.34	20.11	15.84

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.10: GDP per capita growth and ageing (panel model with long lags)

VARIABLES	(1) eq1 GDP p.c. growth	(2) eq2 GDP p.c. growth	(3) eq3 GDP p.c. growth	(4) eq4 GDP p.c. growth
Δ old-age ratio (population)	-0.171			
	(0.117)			
Δ old-age ratio (employment)		-0.400***		
		(0.142)		
Δ share 50-64 (population)			-0.905***	
			(0.322)	
Δ share 50-64 (employment)				-0.761**
				(0.302)
Constant	0.215***	0.221***	0.231***	0.222***
	(0.010)	(0.014)	(0.011)	(0.016)
Observations	419	390	419	390
R-squared	0.005	0.022	0.020	0.017
Number of i	27	27	27	27
F	2.132	7.984	7.913	6.371

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.11: Productivity (GDP per hours worked) growth and aging (panel model with long lags)

VARIABLES	(1) eq1 GDP p.h. growth	(2) eq2 GDP p.h. growth	(3) eq3 GDP p.h. growth	(4) eq4 GDP p.h. growth
Δ old-age ratio (population)	0.077			
	(0.088)			
Δ old-age ratio (employment)		-0.112		
		(0.106)		
Δ share 50-64 (population)			-0.237	
			(0.243)	
Δ share 50-64 (employment)				0.104
				(0.226)
Constant	0.190***	0.189***	0.202***	0.173***
	(0.007)	(0.011)	(0.009)	(0.012)
Observations	419	390	419	390
R-squared	0.002	0.003	0.002	0.001
Number of i	27	27	27	27
F	0.766	1.116	0.948	0.211

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.12: Productivity (GDP per person employed) growth and aging (panel model with long lags)

VARIABLES	(1) eq1 GDP p.h. growth	(2) eq2 GDP p.h. growth	(3) eq3 GDP p.h. growth	(4) eq4 GDP p.h. growth
Δ old-age ratio (population)	0.077			
	(0.088)			
Δ old-age ratio (employment)		-0.112		
		(0.106)		
Δ share 50-64 (population)			-0.237	
			(0.243)	
Δ share 50-64 (employment)				0.104
				(0.226)
Constant	0.190***	0.189***	0.202***	0.173***
	(0.007)	(0.011)	(0.009)	(0.012)
Observations	419	390	419	390
R-squared	0.002	0.003	0.002	0.001
Number of i	27	27	27	27
F	0.766	1.116	0.948	0.211

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Summarising, the results reported here for the EU (as well as the level results reported in the Appendix) thus by no means suggest any significant evidence of positive effects of population aging on economic growth as argued in Acemoglu and Restrepo (2017). Rather, we find in some cases significantly negative effects indicating that there is some evidence of secular stagnation stemming from demographic pressures.

4 Capital deepening and ageing

4.1 Capital asset types

As already pointed out, Abeliansky and Prettner (2017) indicate that a decrease in population growth by 1% leads to a 2% increase in the robot density growth rate. Qualitatively similar conclusions are presented in Acemoglu and Restrepo (2017) for a large country sample for the US.

In this section, we test a similar hypothesis by econometrically assessing the relationship between capital deepening and age variables for the EU member states. In contrast to the literature, we focus on various asset types that are available in National Accounts data and listed in Table 4.1.[15] In total, four

Table 4.1: Asset types in National Accounts

Code	Description
N11N	Total fixed assets (net)
...N11KN	Total Construction (net)
... ...N111N	Dwellings (net)
... ...N112N	Other buildings and structures (net)
...N11MN	Machinery and equipment and weapons systems (net)
... ...N1131N	Transport equipment (net)
... ...N1132N	ICT equipment (net)
... ...N11321N	Computer hardware (net)
... ...N11322N	Telecommunications equipment (net)
... ...N11ON	Other machinery and equipment and weapons systems (net)
...N115N	Cultivated biological resources (net)
...N117N	Intellectual property products (net)
... ...N1171N	Research and development (net)
... ...N1173N	Computer software and databases (net)
... ...N117XN*	Other intellectual property products

*Note: N117XN = N117N - N1171N - N1173N

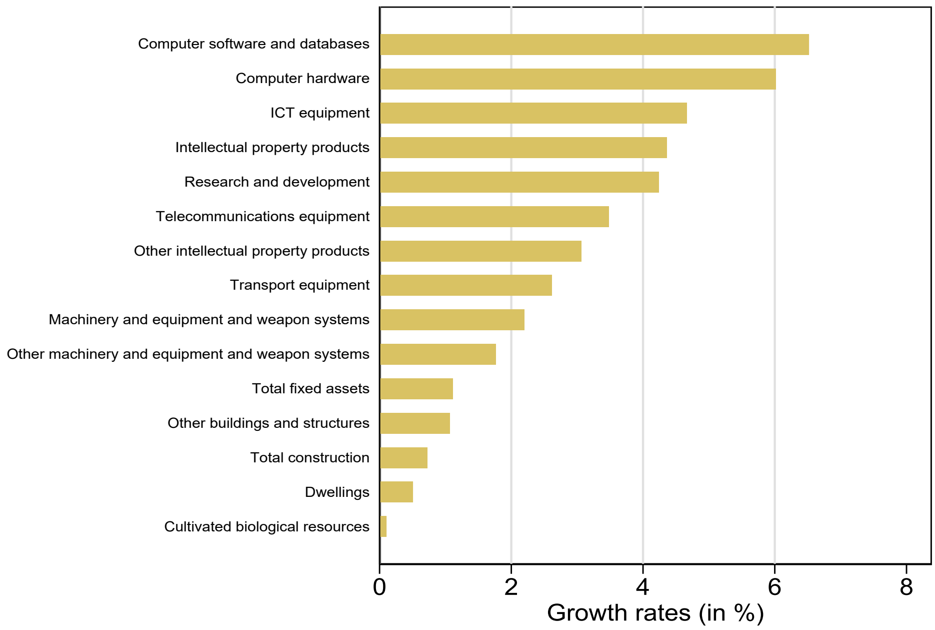
main asset types are available: total construction (N11K), machinery, equipment and weapons systems (N11M), cultivated biological resources (N115) and intellectual property products (N117). Data for several more detailed asset types are also available. In particular, machinery and equipment include ICT equipment (N1132) with additional subcategories, such as computer hardware (N11321) and telecommunications equipment (N11322), and intellectual property products also include computer software and databases (N1173). These latter asset types are particularly interesting because of the hypothesis that ageing should impact the adoption of new technologies. However, one should notice that machinery and equipment (N11M or N11O) should also include robots, which is the focus of most of the literature.

[15] An analogous exercise is undertaken including robots below.

4.2 Description

The hypothesis to be tested is whether ageing is related to changes in capital-labour ratios, i.e. capital deepening, which is defined in terms of persons employed. Thus, dividing capital stock (in chain-linked volumes, with 2015 as a reference) by the number of persons employed calculates the (log) growth rates. Figure 4.1 shows average growth rates over years and country by individual asset types. The growth rates in capital labour ratios are, in most cases, positive, which indicates that capital stocks have grown faster than employment. Furthermore, one can see that capital-labour ratios have been increasingly strong for asset types related to digital technologies, i.e. ICT, computers and databases, as well as intangible assets like R&D. The capital-labour ratios for tangible assets have also increased in general, but much less so for construction and cultivated biological resources. This also holds true for most

Figure 4.1: Capital deepening by asset types



Source: Eurostat National Accounts data, own calculations.

of the main and detailed asset types by country, as can be seen from Table 4.2. Only in a few cases are the growth rates of capital-labour ratios negative.[16] One can also see that growth rates tend, on average, to be higher for ICT equipment (N1132 and the subcategories of computer hardware N11321 and telecommunications equipment N11322), software and databases (N1173), i.e. for asset types that are associated with digitisation, new technologies or automation.

[16] This is particularly the case for cultivated biological resources (N115).

Table 4.2: Capital deepening by asset types (average annual growth rates 1995-2018* in %)

	Total	Construction			Machinery & equipment							Intangibles			
	N11	**N11K**	N111	N112	**N11M**	N1131	N1132	N11321	N11322	N11O	**N115**	**N117**	N1171	N1173	N117X
AT	0.8	0.7	0.7	0.7	0.9	1.0	1.3	2.8	1.0	0.7	-0.5	3.7	2.9	6.4	4.4
BE	0.6	0.4	0.8	-0.0	0.8	2.3	4.1	4.0	4.2	0.1	-1.5	3.3	3.0	5.4	4.1
BG	0.4	-0.2	-2.2	6.1	4.6	5.7	-0.5	-1.1	0.2	4.3	-5.2	5.1	3.6	5.0	10.9
CY	1.0	1.6	2.0	1.1	-2.2	-2.8	0.3	-1.2	1.0	1.0	-1.6	14.9	14.3	15.9	-34.1
CZ	2.1	1.7	2.9	1.0	4.3	5.2	5.7	6.2	4.2	3.9	-0.3	3.8	3.4	7.9	-2.4
DE	0.3	0.1	0.6	-0.6	0.8	2.1	3.3	3.9	2.8	0.0	-1.4	1.8	1.7	3.7	-0.2
DK	1.0	0.8	1.0	0.6	1.1	2.9	4.6	4.6	3.9	-1.3	-0.5	3.3	3.3	3.3	
EE	3.8	3.1	0.6	5.9	6.1	7.1	8.3	10.9	6.8	5.5	3.4	11.0	8.9	17.1	10.0
EL	0.9	0.6	0.4	1.1	2.5	2.0	3.6	2.2	4.0	2.4	2.4	3.0	5.0	9.0	-9.9
ES	1.3	1.3	1.6	0.9	1.1	1.6	2.8	2.8	2.8	0.8	8.9	4.5	4.3	4.9	3.9
FI	0.5	0.6	0.9	0.3	-0.1	-1.9	9.6	10.6	9.4	-0.3	-6.6	1.3	0.9	4.5	0.5
FR	-0.1	-0.4	-0.1	-0.9	1.3	3.1	5.0	7.9	3.8	0.6	-2.7	1.5	0.3	3.8	14.0
HR															
HU	0.6	0.2	-0.0	0.3	1.9	0.9	3.3	10.3	-0.6	2.1	-1.7	7.3	7.3	7.8	5.3
IE	4.2	1.5	1.0	2.2	2.8	4.2	6.4	9.6	1.9	1.2	-2.8	4.2	4.0	7.1	17.3
IT	0.5	0.4	0.5	0.3	0.5	-0.1	3.3	2.6	4.0	0.4	-1.2	1.8	2.0	2.0	-0.5
LT	2.8	1.8	0.9	2.3	8.4	9.5	11.4	10.2	12.4	7.0	6.3	14.4	21.3	12.3	17.0
LU	0.7	0.3	-0.9	1.1	2.4	3.3	5.8	4.9	7.5	0.2	-2.8	-1.1	0.6	4.7	-13.3
LV	0.2	-0.4	-0.4	-0.2	4.5	2.7	10.6	19.1	7.5	5.0	8.6	4.4	5.8	10.5	-0.9
MT	-1.1	-1.7	-2.7	-0.0	1.5	4.0	6.8	13.0	0.1	-0.5		2.9	-2.3	8.5	-6.8
NL	0.4	0.3	0.4	0.1	0.7	1.0	9.7	10.3	5.7	-0.0	-2.4	2.2	0.9	5.6	1.6
PL	2.5	2.3	1.4	2.8	2.7	4.9	5.8	6.0	5.3	1.8	0.5	8.0	6.6	6.5	22.7
PT	0.9	0.8	-0.2	1.7	1.8	-1.3	5.5	4.7	5.9	2.2	1.6	4.7	6.0	3.3	1.2
RO	3.2	2.8	3.6	2.0	4.1	6.4	3.2	3.2	3.2	4.1	11.0	7.8	7.8	8.6	7.5
SE	1.3	0.8	0.5	1.1	2.8	2.8	5.6	8.5	4.8	2.2	-0.9	2.0	0.7	4.9	18.6
SI	0.1	-0.1	-1.1	0.7	1.4	1.7	-0.2	-0.1	-0.9	1.4	-2.0	-0.0	0.9	3.2	-8.4
SK	0.5	0.2	0.3	0.2	2.5	2.4	-7.3	-2.8	-14.8	3.4	-1.7	0.0	2.5	-1.4	-3.5

Note: Time period depending on data availability. Main asset types are marked in bold.
Source: Eurostat, own calculations.

4.3 Ageing and capital deepening

In this section, we present the results using a panel FE model. In doing so, we use various measures for population ageing (partly also used in the previous section) and capital deepening, which is defined as the (log) growth rate of the capital employment ratio broken down by asset types. We provide the econometric results for all asset types, with the first set of tables presenting the results for the total fixed assets (N11) and the four main asset types (N11K, N11M, N115, N117) plus ICT (N1132). The second set of tables presents the results for the remaining detailed asset types.

4.3.1 Growth rates and changes in shares of population groups

The first specification tested was the relationship between capital deepening (i.e. growth of the capital employment ratio) and growth rates of the population aged 25 to 49 (middle age) and 50 to 64 (older age), including real value-added growth as a control, i.e.

$$\text{CapDeep}_{k,t}^{c} = \alpha \Delta \ln \text{Pop25to49}_{t}^{c} + \beta \Delta \ln \text{Pop50to64}_{t}^{c} + \gamma \Delta \ln \text{GDP}_{t}^{c} + \varepsilon_{t}^{c}$$

where k denotes the asset types. Results for total fixed assets, the four main asset types and ICT capital are reported in the upper panel of Table 4.3. The lower panel of this table presents the results of the changes in shares of these two age groups.

$$\text{CapDeep}_{k,t}^{c} = \alpha \Delta \text{shPop25to49}_{t}^{c} + \beta \Delta \text{shPop50to64}_{t}^{c} + \gamma \Delta \ln \text{GDP}_{t}^{c} + \varepsilon_{t}^{c}$$

Results for further detailed asset types are reported in Table 4.4. The results point towards a significant positive relationship between capital deepening and population growth for total construction (N11K) and ICT equipment (N1132). Machinery and equipment (N11M) is the only asset that had a significant (at a 10% level) negative relationship with capital deepening. Concerning more detailed asset types, positive and significant (at a 5% level) relationships (for at least one age group) were found for dwellings (N111), transport equipment (N1131), communication equipment (N11322), other machinery and equipment (N11O) and software and databases (N1173). A significant negative relationship for detailed asset types was not found in these assets. When using the changes in population share as explanatory variables, we found a significant negative relationship for biological resources (N115) and intellectual property products (N117) for all detailed asset types (see the lower panel in Table 4.4). For detailed asset types, we also found a significant negative relationship for computer hardware (N11321).

When considering long-term changes (results are reported in subsection B.2), we found hardly any significant results. Apart from main asset type machinery and equipment (N11M), we found a significantly negative result concerning the growth rate of the population aged 50 to 64; which was also the case for the

Table 4.3: Capital deepening and ageing by main asset types (growth rates)

VARIABLES	(1) N11 CapDeep	(2) N11K CapDeep	(3) N11M CapDeep	(4) N1132 CapDeep	(5) N115 CapDeep	(6) N117 CapDeep
Δ ln(Pop 25-49)	0.064	0.173*	0.196	0.775***	-0.113	0.138
	(0.113)	(0.101)	(0.150)	(0.266)	(0.394)	(0.274)
Δ ln(Pop 50-64)	0.097	0.136*	-0.215*	0.523***	-0.020	-0.143
	(0.086)	(0.077)	(0.115)	(0.200)	(0.278)	(0.207)
Δ ln(Value added)	-0.138***	-0.324***	0.166***	0.277***	-0.106	0.096
	(0.035)	(0.032)	(0.048)	(0.080)	(0.112)	(0.083)
Constant	1.372***	1.411***	2.081***	3.239***	0.526	4.366***
	(0.270)	(0.243)	(0.329)	(0.864)	(0.942)	(0.835)
Observations	571	571	571	571	552	571
Number of i	26	26	26	26	25	26

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

VARIABLES	(1) N11 CapDeep	(2) N11K CapDeep	(3) N11M CapDeep	(4) N1132 CapDeep	(5) N115 CapDeep	(6) N117 CapDeep
Δ Share Age 25-49	0.005	0.008*	0.005	-0.010	-0.038**	-0.036***
	(0.005)	(0.004)	(0.006)	(0.011)	(0.015)	(0.011)
Δ Share Age 50-46	0.006	0.008*	-0.006	-0.011	-0.034**	-0.042***
	(0.005)	(0.004)	(0.007)	(0.011)	(0.015)	(0.011)
Δ ln(Value added)	-0.153***	-0.331***	0.134***	0.275***	-0.164	0.046
	(0.036)	(0.032)	(0.048)	(0.082)	(0.113)	(0.083)
Constant	1.356***	1.381***	2.066***	4.225***	1.219**	5.219***
	(0.197)	(0.177)	(0.261)	(0.450)	(0.612)	(0.455)
Observations	571	571	571	571	552	571
R-squared	0.037	0.174	0.023	0.024	0.016	0.028
Number of i	26	26	26	26	25	26

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

other machinery and equipment (N11O) detailed asset type. In contrast to the panel results, there were no significant relationships between long-term changes (average annual changes) in capital deepening and population age groups.

4.3.2 Change in ageing ratio and old-age share levels

In the second specification, we regress capital deepening by asset types on changes in the ageing ratio (also used in the previous section). We also include the share of the old-age population and GDP growth rates as additional control variables.

$$CapDeep_{i,t} = \alpha_1 Aging_{i,t} + \alpha_2 shPOP50t64 + \alpha_3 grGDP_{i,t} + \mu_i + \varepsilon_{i,t}$$

where ageing is first defined as the difference in the (log) growth rates of the population aged 50 to 64 relative to the population aged 25 to 49, and second, as the change in the shares of the population aged 50 to 64. In these regressions, we also control for the share of the population aged 50 to 64 as well as GDP growth. Furthermore, we present the results including changes in the shares of the old-age

Table 4.4: Capital deepening and ageing by detailed asset types (growth rates)

VARIABLES	(1) N111 CapDeep	(2) N112 CapDeep	(3) N1131 CapDeep	(4) N11321 CapDeep	(5) N11322 CapDeep	(6) N11O CapDeep	(7) N1171 CapDeep	(8) N1173 CapDeep	(9) N117X CapDeep
Δ ln(Pop 25-49)	0.357***	0.106	0.687**	0.735	1.790***	0.532***	-0.034	0.938**	1.575
	(0.131)	(0.118)	(0.328)	(0.481)	(0.371)	(0.136)	(0.298)	(0.394)	(1.152)
Δ ln(Pop 50-64)	0.217**	0.162*	-0.243	0.266	0.928***	0.229**	-0.349	0.066	0.335
	(0.097)	(0.087)	(0.243)	(0.356)	(0.274)	(0.100)	(0.220)	(0.291)	(0.805)
Δ ln(Value added)	-0.324***	-0.346***	0.464***	0.362**	0.246**	-0.064	-0.001	0.460***	-0.324
	(0.038)	(0.034)	(0.096)	(0.140)	(0.108)	(0.040)	(0.087)	(0.115)	(0.320)
Constant	1.066***	1.739***	1.748***	4.811***	1.796***	1.661***	4.657***	5.304***	3.754**
	(0.193)	(0.174)	(0.484)	(0.710)	(0.547)	(0.200)	(0.439)	(0.581)	(1.506)
Observations	571	571	571	571	571	571	566	571	478
R-squared	0.131	0.162	0.054	0.017	0.064	0.037	0.005	0.040	0.006
Number of i	26	26	26	26	26	26	26	26	25

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

VARIABLES	(1) N111 CapDeep	(2) N112 CapDeep	(3) N1131 CapDeep	(4) N11321 CapDeep	(5) N11322 CapDeep	(6) N11O CapDeep	(7) N1171 CapDeep	(8) N1173 CapDeep	(9) N117X CapDeep
Δ Share Age 25-49	0.007	0.005	0.017	-0.041**	0.013	-0.001	-0.034***	-0.037**	-0.107**
	(0.005)	(0.005)	(0.013)	(0.018)	(0.015)	(0.005)	(0.011)	(0.015)	(0.042)
Δ Share Age 50-46	0.006	0.007	-0.007	-0.049**	0.005	-0.005	-0.046***	-0.053***	-0.123***
	(0.005)	(0.005)	(0.013)	(0.019)	(0.015)	(0.006)	(0.012)	(0.016)	(0.044)
Δ ln(Value added)	-0.315***	-0.339***	0.472***	0.329**	0.272**	-0.062	-0.039	0.429***	-0.372
	(0.039)	(0.035)	(0.096)	(0.141)	(0.112)	(0.040)	(0.086)	(0.115)	(0.319)
Constant	1.181***	1.743***	1.739***	6.324***	2.759***	2.054***	5.443***	6.730***	7.037***
	(0.212)	(0.189)	(0.526)	(0.768)	(0.610)	(0.221)	(0.472)	(0.627)	(1.751)
Observations	571	571	571	571	571	571	566	571	478
R-squared	0.116	0.159	0.053	0.025	0.012	0.006	0.028	0.050	0.020
Number of i	26	26	26	26	26	26	26	26	25

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

population instead of changes in the ageing ratio.[17] Results are reported in Table 4.5 for the main asset types and Table 4.6 for detailed asset types. Again, there was no significant relationship between capital

Table 4.5: Capital deepening and ageing by main asset types (ageing)

	(1)	(2)	(3)	(4)	(5)	(6)
	N11	N11K	N11M	N1132	N115	N117
VARIABLES	CapDeep	CapDeep	CapDeep	CapDeep	CapDeep	CapDeep
Δ ln(Age ratio)	0.035	0.013	-0.189**	0.007	0.025	-0.152
	(0.068)	(0.060)	(0.089)	(0.144)	(0.221)	(0.156)
Share Age 50-46	-0.216***	-0.276***	-0.364***	-1.105***	-0.899***	-0.681***
	(0.052)	(0.046)	(0.068)	(0.111)	(0.160)	(0.120)
Δ ln(Value added)	-0.186***	-0.375***	0.084*	0.136*	-0.257**	-0.013
	(0.036)	(0.032)	(0.047)	(0.077)	(0.112)	(0.083)
Constant	7.567***	9.335***	12.357***	35.145***	25.730***	23.555***
	(1.478)	(1.309)	(1.940)	(3.157)	(4.558)	(3.411)
Observations	571	571	571	571	552	571
R-squared	0.065	0.220	0.071	0.173	0.059	0.059
Number of i	26	26	26	26	25	26

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

	(1)	(2)	(3)	(4)	(5)	(6)
	N11	N11K	N11M	N1132	N115	N117
VARIABLES	CapDeep	CapDeep	CapDeep	CapDeep	CapDeep	CapDeep
Δ Share Age 50-46	0.003	0.002	-0.009**	-0.003	-0.007	-0.016*
	(0.003)	(0.003)	(0.005)	(0.007)	(0.011)	(0.008)
Share Age 50-46	-0.217***	-0.276***	-0.359***	-1.105***	-0.898***	-0.675***
	(0.052)	(0.046)	(0.068)	(0.111)	(0.160)	(0.120)
Δ ln(Value added)	-0.185***	-0.373***	0.082*	0.134*	-0.260**	-0.021
	(0.036)	(0.032)	(0.047)	(0.077)	(0.112)	(0.083)
Constant	7.561***	9.305***	12.253***	35.231***	25.949***	23.692***
	(1.475)	(1.307)	(1.938)	(3.152)	(4.548)	(3.397)
Observations	571	571	571	571	552	571
R-squared	0.066	0.221	0.070	0.173	0.060	0.064
Number of i	26	26	26	26	25	26

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

deepening and the changes in the ageing ratio; the only exception for this is main asset type machinery and equipment (N11M). When considering detailed asset types, this significant negative relationship was also the case for transport equipment (N1131). We found the same when using the changes in the population share of persons aged 50 to 64 as explanatory variables as well as for intangible assets, i.e. R&D (N1171) and software and databases (N1173). Interestingly, the contemporaneous share of the population aged 50 to 64 was negatively related to the growth rate of the capital-labour ratio (i.e. capital deepening). Finally, when considering long-term changes, no significant relationship appeared between capital deepening and changes in the old-age ratios or changes in the population share of those aged 50 to 64. In contrast to the panel approach, the initial share of the population aged 50 to 64 was positively related to capital deepening in some asset types.

[17] For other ageing measures, the results are qualitatively the same.

4.4 Robots

Finally, we present results concerning the relationship between ageing and increased robot intensity (following most of the literature) for our sample of EU economies. Table 4.7 (upper part) presents the results using a panel FE estimation that includes various specifications using the variables already introduced above. We did not find any significant results for such a relationship. Using a long-run specification, Table 4.7 (lower part) presents the results from an OLS regression with annual averages. When controlling for GDP growth or including a dummy for new EU Member States (those becoming members in 2004 or later), there was nothing significant in terms of the relationships between robotisation and ageing variables. However, when GDP growth was not included, the new EU Member States dummy showed a significant negative relationship between robotisation and ageing.[18]

5 Conclusions

This paper analyses the association between shifting age structures and an increasing share of older people in both the total population and the employed on economic growth and changes in capital-labour ratios, i.e. capital deepening and robotisation in the EU over the last few decades. The analysis relies on several data sources, including National Accounts data, Eurostat data on capital stocks, EU-LFS data and IFR data. The results of the paper point towards, if anything, a weak negative association between population ageing and economic growth, measured as total GDP and GDP per capita growth. This highlights the concern that ageing might contribute to secular stagnation (Hansen, 1938, and Summers, 2020). However, these results are not in line with those stated in Acemoglu and Restrepo (2017). Nevertheless, the results are in line with other literature, for example, Maestas et al. (2022), who found significant negative relationships between ageing and growth in US states.[19]

The second part of our analysis evaluates how population ageing relates to capital deepening, i.e. increases in capital-labour ratios, distinguishing between different types of capital. In the majority of regression specifications, we document no significant association between population ageing and capital deepening or ICT capital, software and databases. The current share of the population aged 50 to 64 has a negative relationship with capital-labour ratio growth, which suggests that increasing the proportion of older people in the population, if anything, reflects negatively on capital deepening, which poses policy challenges with respect to the training and upskilling especially needed for digital skills.

The final part of the analysis addresses the association between population ageing and robotisation, but no significant relationship was found when the GDP level and an identifier for a new EU Member

[18] It should be noted that in the previous tables (including capital asset types), results remain qualitatively unchanged when GDP growth is not included.

[19] A comparison to Japan is even more difficult as the Japanese economy is in a phase of secular stagnation since at least the 1990s with various reasons as widely discussed in the literature with demographic changes being only one of them (see Desai, 2022).

State were included. Hence, the results suggest that the level of robotisation depends largely on the level of economic development and, to a lower extent, on population ageing trends. Thus, our findings do not align with the results of Acemoglu and Restrepo (2017), who documented rapid population ageing and increased technological adoption in a large sample of countries; however, they also found no significant effects in the context of OECD countries. One has to acknowledge the substantial differences between our sample and the sample employed in Acemoglu and Restrepo (2017). Our sample is more homogeneous as we only considered EU-27 countries. Although there are sizeable gaps in economic performance across new and old EU-27 Member States, they are substantially smaller compared to economic discrepancies across a wider sample of countries.

Table 4.6: Capital deepening and ageing by detailed asset types (ageing)

VARIABLES	(1) N111 CapDeep	(2) N112 CapDeep	(3) N1131 CapDeep	(4) N11321 CapDeep	(5) N11322 CapDeep	(6) N11O CapDeep	(7) N1171 CapDeep	(8) N1173 CapDeep	(9) N117X CapDeep
Δ ln(Age ratio)	-0.004	0.053	-0.415**	-0.150	-0.108	-0.067	-0.261	-0.334	-0.398
	(0.072)	(0.064)	(0.183)	(0.259)	(0.206)	(0.074)	(0.159)	(0.215)	(0.580)
Share Age 50-46	-0.267***	-0.282***	-0.236*	-1.310***	-0.913***	-0.408***	-0.912***	-0.841***	-1.598***
	(0.056)	(0.049)	(0.141)	(0.199)	(0.159)	(0.057)	(0.122)	(0.166)	(0.438)
Δ ln(Value added)	-0.357***	-0.382***	0.435***	0.191	0.141	-0.114***	-0.128	0.353***	-0.546*
	(0.039)	(0.034)	(0.098)	(0.138)	(0.110)	(0.039)	(0.084)	(0.115)	(0.323)
Constant	8.843***	9.833***	8.592**	42.242***	28.721***	13.515***	30.314***	29.486***	49.976***
	(1.583)	(1.403)	(4.003)	(5.669)	(4.519)	(1.611)	(3.469)	(4.715)	(12.638)
Observations	571	571	571	571	571	571	566	571	478
R-squared	0.149	0.206	0.057	0.086	0.068	0.092	0.097	0.077	0.031
Number of i	26	26	26	26	26	26	26	26	25

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

VARIABLES	(1) N111 CapDeep	(2) N112 CapDeep	(3) N1131 CapDeep	(4) N11321 CapDeep	(5) N11322 CapDeep	(6) N11O CapDeep	(7) N1171 CapDeep	(8) N1173 CapDeep	(9) N117X CapDeep
Δ Share Age 50-46	0.001	0.004	-0.019**	-0.018	-0.004	-0.004	-0.022***	-0.025**	-0.041
	(0.004)	(0.003)	(0.009)	(0.013)	(0.011)	(0.004)	(0.008)	(0.011)	(0.030)
Share Age 50-46	-0.267***	-0.284***	-0.224	-1.304***	-0.910***	-0.406***	-0.905***	-0.830***	-1.576***
	(0.056)	(0.049)	(0.141)	(0.199)	(0.159)	(0.057)	(0.121)	(0.165)	(0.437)
Δ ln(Value added)	-0.356***	-0.381***	0.431***	0.181	0.141	-0.116***	-0.138	0.342***	-0.569*
	(0.039)	(0.034)	(0.098)	(0.138)	(0.110)	(0.039)	(0.084)	(0.115)	(0.323)
Constant	8.814***	9.835***	8.328**	42.437***	28.639***	13.495***	30.490***	29.549***	50.158***
	(1.580)	(1.400)	(4.002)	(5.653)	(4.513)	(1.608)	(3.448)	(4.696)	(12.592)
Observations	571	571	571	571	571	571	566	571	478
R-squared	0.149	0.206	0.055	0.088	0.067	0.092	0.105	0.082	0.034
Number of i	26	26	26	26	26	26	26	26	25

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4.7: Robot deepening (panel FE and OLS estimates)

VARIABLES	(1) eq1 CapDeep	(2) eq2 CapDeep	(3) eq3 CapDeep	(4) eq4 CapDeep	(5) eq5 CapDeep	(6) eq6 CapDeep
Δ ln(Value added)	-0.078	-0.087	-0.078			
	(0.278)	(0.277)	(0.278)			
Aging	-0.029			-0.029		
	(0.511)			(0.510)		
Δ ln(Pop 50-64)		0.807			0.801	
		(0.677)			(0.676)	
Δ Share Age 25-49			0.028			0.028
			(0.036)			(0.036)
Δ Share Age 50-46			0.023			0.023
			(0.037)			(0.037)
Constant	14.295***	13.330***	13.725***	14.112***	13.134***	13.542***
	(1.267)	(1.333)	(1.473)	(1.084)	(1.175)	(1.318)
Observations	421	421	421	421	421	421
R-squared	0.000	0.004	0.002	0.000	0.004	0.002
Number of i	22	22	22	22	22	22

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

VARIABLES	(1) eq1 CapDeep	(2) eq2 CapDeep	(3) eq3 CapDeep	(4) eq4 CapDeep	(5) eq5 CapDeep	(6) eq6 CapDeep
Δ ln(Value added)	5.898***	7.293***	5.761**			
	(1.909)	(2.031)	(2.014)			
EU member states 2004+	6.703	3.849	7.939	14.817**	18.306***	14.429**
	(5.618)	(5.902)	(6.219)	(5.979)	(5.502)	(6.848)
Aging	-4.969			-5.296		
	(4.871)			(5.863)		
Δ ln(Pop 50-64)		-4.825			-0.173	
		(3.063)			(3.540)	
Δ Share Age 25-49			0.060			0.114
			(0.197)			(0.232)
Δ Share Age 50-46			-0.129			-0.176
			(0.317)			(0.374)
Constant	5.287	2.633	3.415	15.932*	8.638	15.702
	(8.126)	(4.889)	(10.100)	(8.861)	(5.858)	(10.811)
Observations	22	22	22	22	22	22
R-squared	0.667	0.691	0.657	0.491	0.469	0.492
F	12.03	13.39	8.132	9.152	8.386	5.802

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

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A Theoretical outlines

A.1 Acemoglu and Restrepo, 2017

Acemoglu and Restrepo (2017) start from a Cobb-Dougblas aggregate production function given by

$$\ln Y = \int_0^1 \ln y(i) di$$

where $y(i)$ denotes output of task i. Part of the task $i \leq \theta$ can be automated and are produced by

$$y(i) = q(i)^{\eta} \big(k(i) + l(i)\big)^{1-\eta}$$

where $q(i)$ denotes intermediates, $k(i)$ is capital and $l(i)$ is labour; $0 < \eta < 1$ denotes the respective elasticities. Tasks $i > \theta$ can only be produced using labour and intermediates, i.e.

$$y(i) = q(i)^{\eta} \big(k(i) + l(i)\big)^{1-\eta}$$

Intermediates supplied by a monopolist at marginal costs plus mark-up. This monopolist can also chose $0 \leq \theta \leq 1$ which is interpreted as technology choice. Under some technical assumption (e.g. inelastic supply of capital and labour) and given supplies $K > L$ implies that automating tasks is profitable for the monopolist. Population aging is modelled as a reduction of L implying increasing labour scarcity.

Equilibrium aggregate output then is $Y = K^{\theta} L^{1-\theta}$ and profit maximisation of the monopolist implies the condition

$$\ln K - \ln L + \Gamma'(\theta) = 0$$

with $\Gamma(theta)$ reflects the profits of the monopolist from markups on intermediates minus costs of technology adoption. Differentiating with respect to labour implies

$$\frac{d\theta}{d \ln L} = \frac{1}{\Gamma''(\theta)} < 0$$

indicating that labour scarcity encourages automation. They then derive the relationship between output growth and change in labour supply which is given by

$$\frac{d \ln Y}{d \ln L} = (1 - \theta) + \frac{\ln K - \ln L}{\Gamma''(\theta)}$$

A lower L implies a decrease in GDP because of a decrease in labour supply. However, this can be counteracted by additional automation which happens if the gap between K and L is sufficiently large. Thus, it need not necessarily the case that a decline in labour supply leads to lower growth due to the technology response, however this finally remains an empirical question.

A.2 Prettner and Bloom, 2020

In Prettner and Bloom (2020)[20] the starting point is a Cobb-Douglas production function given by

$$Y_t = K_t^{\alpha}(L_t + P_t)^{1-\alpha}$$

where Y_t is output, K_t is capital, L_t is labour and P_t is automation capital (as a perfect substitute to labour). α denote the respective input shares (or elasticities). Under standard assumptions they derive wage rate to be

$$w_t = (1-\alpha)\Big(\frac{K_t}{L_t + P_t}\Big)^{\alpha}$$

The rates of return to automation and traditional capital, respectively, are given by

$$r_{P,t+1} = (1-\alpha)\Big(\frac{K_t}{L_t + P_t}\Big)^{\alpha} \quad \text{and} \quad r_{K,t+1} = \alpha\Big(\frac{L_t + P_t}{K_t}\Big)^{1-\alpha}$$

Accordingly, they argue that a decrease in the labour force L_t provides in an incentive to invest in automation capital P_t (due to the increasing marginal return) and a decreasing incentive to invest in traditional capital K_t (which is characterized by a declining marginal return).

[20]See also Prettner (2019) for details.

B Additional econometric results

B.1 Appendix to Section 3: Robustness checks using levels as independent variables

B.1.1 OLS results

Table B.1: GDP growth and ageing

VARIABLES	(1) eq1 GDP growth	(2) eq2 GDP growth	(3) eq3 GDP growth	(4) eq4 GDP growth
EU Members 2004+	0.016***	0.016***	0.016***	0.016***
	(0.003)	(0.004)	(0.003)	(0.004)
Old-age ratio (population)	-0.087**			
	(0.038)			
Old-age ratio (employment)		-0.016		
		(0.032)		
Share 50-64 (population)			-0.271***	
			(0.092)	
Share 50-64 (employment)				-0.083
				(0.071)
Constant	0.061***	0.020	0.092***	0.035*
	(0.021)	(0.013)	(0.026)	(0.018)
Observations	27	27	27	27
R-squared	0.543	0.450	0.592	0.474
F	14.29	9.803	17.38	10.81

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table B.2: GDP per capita growth and ageing

VARIABLES	(1) eq1 GDP p.c. growth	(2) eq2 GDP p.c. growth	(3) eq3 GDP p.c. growth	(4) eq4 GDP p.c. growth
EU Members 2004+	0.023***	0.024***	0.023***	0.023***
	(0.004)	(0.004)	(0.004)	(0.004)
Old-age ratio (population)	-0.013			
	(0.044)			
Old-age ratio (employment)		0.036		
		(0.033)		
Share 50-64 (population)			-0.074	
			(0.111)	
Share 50-64 (employment)				0.061
				(0.075)
Constant	0.015	-0.006	0.029	-0.007
	(0.024)	(0.014)	(0.032)	(0.019)
Observations	27	27	27	27
R-squared	0.601	0.619	0.607	0.611
F	18.10	19.50	18.55	18.83

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table B.3: Productivity (GDP per hours worked) growth and aging

VARIABLES	(1) eq1 GDP p.h. growth	(2) eq2 GDP p.h. growth	(3) eq3 GDP p.h. growth	(4) eq4 GDP p.h. growth
EU Members 2004+	0.019***	0.020***	0.019***	0.020***
	(0.004)	(0.004)	(0.004)	(0.004)
Old-age ratio (population)	-0.032			
	(0.043)			
Old-age ratio (employment)		0.028		
		(0.033)		
Share 50-64 (population)			-0.113	
			(0.108)	
Share 50-64 (employment)				0.045
				(0.074)
Constant	0.027	-0.001	0.042	-0.001
	(0.023)	(0.013)	(0.031)	(0.019)
Observations	27	27	27	27
R-squared	0.533	0.536	0.543	0.529
F	13.69	13.89	14.25	13.49

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table B.4: Productivity (GDP per person employed) growth and aging

VARIABLES	(1) eq1 GDP p.e. growth	(2) eq2 GDP p.e. growth	(3) eq3 GDP p.e. growth	(4) eq4 GDP p.e. growth
EU Members 2004+	0.020***	0.021***	0.020***	0.020***
	(0.004)	(0.004)	(0.004)	(0.004)
Old-age ratio (population)	-0.022			
	(0.048)			
Old-age ratio (employment)		0.043		
		(0.036)		
Share 50-64 (population)			-0.099	
			(0.121)	
Share 50-64 (employment)				0.083
				(0.082)
Constant	0.017	-0.012	0.033	-0.016
	(0.026)	(0.015)	(0.035)	(0.021)
Observations	27	27	27	27
R-squared	0.481	0.506	0.491	0.498
F	11.13	12.27	11.56	11.90

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

B.1.2 Panel results

Table B.5: GDP growth and ageing (panel model)

VARIABLES	(1) eq1 GDP growth	(2) eq2 GDP growth	(3) eq3 GDP growth	(4) eq4 GDP growth
Old-age ratio (population)	-0.135***			
	(0.029)			
Old-age ratio (employment)		-0.129***		
		(0.022)		
Share 50-64 (population)			-0.362***	
			(0.068)	
Share 50-64 (employment)				-0.268***
				(0.043)
Constant	0.094***	0.072***	0.124***	0.089***
	(0.016)	(0.009)	(0.020)	(0.011)
Observations	563	562	563	562
R-squared	0.039	0.061	0.050	0.068
Number of i	27	27	27	27
F	21.97	34.48	27.96	38.78

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table B.6: GDP per capita growth and ageing (panel model)

VARIABLES	(1) eq1 GDP p.c. growth	(2) eq2 GDP p.c. growth	(3) eq3 GDP p.c. growth	(4) eq4 GDP p.c. growth
Old-age ratio (population)	-0.126***			
	(0.030)			
Old-age ratio (employment)		-0.127***		
		(0.022)		
Share 50-64 (population)			-0.345***	
			(0.070)	
Share 50-64 (employment)				-0.263***
				(0.044)
Constant	0.087***	0.069***	0.117***	0.085***
	(0.016)	(0.009)	(0.020)	(0.011)
Observations	563	562	563	562
R-squared	0.033	0.057	0.043	0.063
Number of i	27	27	27	27
F	18.12	32.19	24.30	35.84

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table B.7: Productivity (GDP per hours worked) growth and aging (panel model)

VARIABLES	(1) eq1 GDP p.h. growth	(2) eq2 GDP p.h. growth	(3) eq3 GDP p.h. growth	(4) eq4 GDP p.h. growth
Old-age ratio (population)	-0.102*** (0.021)			
Old-age ratio (employment)		-0.084*** (0.016)		
Share 50-64 (population)			-0.281*** (0.049)	
Share 50-64 (employment)				-0.173*** (0.031)
Constant	0.074*** (0.011)	0.052*** (0.006)	0.099*** (0.014)	0.063*** (0.008)
Observations	563	562	563	562
R-squared	0.043	0.050	0.057	0.054
Number of i	27	27	27	27
F	23.96	27.85	32.61	30.65

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table B.8: Productivity (GDP per person employed) growth and aging (panel model)

VARIABLES	(1) eq1 GDP p.e. growth	(2) eq2 GDP p.e. growth	(3) eq3 GDP p.e. growth	(4) eq4 GDP p.e. growth
Old-age ratio (population)	-0.146*** (0.022)			
Old-age ratio (employment)		-0.129*** (0.017)		
Share 50-64 (population)			-0.389*** (0.052)	
Share 50-64 (employment)				-0.258*** (0.033)
Constant	0.093*** (0.012)	0.065*** (0.007)	0.125*** (0.015)	0.079*** (0.008)
Observations	563	562	563	562
R-squared	0.076	0.100	0.096	0.105
Number of i	27	27	27	27
F	44.30	59.61	56.70	62.87

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

B.1.3 Panel results (with long lags)

Table B.9: GDP growth and ageing (panel model with long lags)

VARIABLES	(1) eq1 GDP growth	(2) eq2 GDP growth	(3) eq3 GDP growth	(4) eq4 GDP growth
Old-age ratio (population)	-1.482***			
	(0.120)			
Old-age ratio (employment)		-1.186***		
		(0.093)		
Share 50-64 (population)			-4.425***	
			(0.272)	
Share 50-64 (employment)				-2.648***
				(0.183)
Constant	1.050***	0.718***	1.520***	0.929***
	(0.067)	(0.039)	(0.080)	(0.049)
Observations	425	425	425	425
R-squared	0.279	0.289	0.399	0.345
Number of i	27	27	27	27
F	153.5	161.5	264.1	209.3

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table B.10: GDP per capita growth and ageing (panel model with long lags)

VARIABLES	(1) eq1 GDP p.c. growth	(2) eq2 GDP p.c. growth	(3) eq3 GDP p.c. growth	(4) eq4 GDP p.c. growth
Old-age ratio (population)	-1.304***			
	(0.125)			
Old-age ratio (employment)		-1.127***		
		(0.095)		
Share 50-64 (population)			-4.055***	
			(0.287)	
Share 50-64 (employment)				-2.532***
				(0.188)
Constant	0.930***	0.672***	1.390***	0.876***
	(0.070)	(0.040)	(0.084)	(0.050)
Observations	425	425	425	425
R-squared	0.215	0.260	0.334	0.314
Number of i	27	27	27	27
F	109.0	139.5	199.2	182.1

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table B.11: Productivity (GDP per hours worked) growth and aging (panel model with long lags)

VARIABLES	(1) eq1 GDP p.h. growth	(2) eq2 GDP p.h. growth	(3) eq3 GDP p.h. growth	(4) eq4 GDP p.h. growth
Old-age ratio (population)	-0.779***			
	(0.096)			
Old-age ratio (employment)		-0.762***		
		(0.072)		
Share 50-64 (population)			-2.636***	
			(0.223)	
Share 50-64 (employment)				-1.637***
				(0.145)
Constant	0.628***	0.511***	0.965***	0.629***
	(0.054)	(0.030)	(0.065)	(0.039)
Observations	425	425	425	425
R-squared	0.142	0.219	0.260	0.242
Number of i	27	27	27	27
F	65.53	111.5	139.6	126.8

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table B.12: Productivity (GDP per person employed) growth and aging (panel model with long lags)

VARIABLES	(1) eq1 GDP p.e. growth	(2) eq2 GDP p.e. growth	(3) eq3 GDP p.e. growth	(4) eq4 GDP p.e. growth
Old-age ratio (population)	-0.901***			
	(0.101)			
Old-age ratio (employment)		-0.862***		
		(0.076)		
Share 50-64 (population)			-2.981***	
			(0.233)	
Share 50-64 (employment)				-1.849***
				(0.152)
Constant	0.667***	0.524***	1.038***	0.657***
	(0.056)	(0.032)	(0.068)	(0.041)
Observations	425	425	425	425
R-squared	0.166	0.245	0.291	0.270
Number of i	27	27	27	27
F	78.84	129.0	163.2	147.1

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

B.2 Appendix to Section 4

B.2.1 Growth rates and changes in shares of population groups

Table B.13: Capital deepening and ageing by main asset types (growth rates)

VARIABLES	(1) N11 CapDeep	(2) N11K CapDeep	(3) N11M CapDeep	(4) N1132 CapDeep	(5) N115 CapDeep	(6) N117 CapDeep
Δ ln(Pop 25-49)	0.242	0.013	0.168	-1.033	0.820	-0.294
	(0.574)	(0.562)	(0.672)	(1.812)	(2.239)	(1.934)
Δ ln(Pop 50-64)	-0.681	-0.273	-2.084***	-1.519	-3.068	-0.330
	(0.592)	(0.579)	(0.693)	(1.867)	(2.232)	(1.993)
Δ ln(Value added)	0.720***	0.257	1.155***	2.216***	0.772	0.420
	(0.245)	(0.240)	(0.287)	(0.774)	(0.927)	(0.826)
EU members 2004+	-0.999	-0.162	-1.042	-5.265**	-0.971	3.200
	(0.667)	(0.653)	(0.781)	(2.105)	(2.581)	(2.247)
Constant	0.676	0.531	2.376**	3.502	2.274	2.372
	(0.920)	(0.901)	(1.078)	(2.905)	(3.473)	(3.100)
Observations	26	26	26	26	25	26
R-squared	0.327	0.091	0.686	0.342	0.214	0.273
F	2.556	0.528	11.49	2.723	1.359	1.974

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

VARIABLES	(1) N11 CapDeep	(2) N11K CapDeep	(3) N11M CapDeep	(4) N1132 CapDeep	(5) N115 CapDeep	(6) N117 CapDeep
Δ Share Age 25-49	0.040*	0.020	0.042	-0.104	0.138	-0.029
	(0.022)	(0.022)	(0.038)	(0.076)	(0.085)	(0.075)
Δ Share Age 50-46	0.033	0.022	0.027	-0.109	0.115	-0.030
	(0.034)	(0.034)	(0.060)	(0.119)	(0.137)	(0.118)
Δ ln(Value added)	0.598**	0.188	0.610	1.470*	0.197	0.237
	(0.223)	(0.223)	(0.390)	(0.780)	(0.882)	(0.772)
EU members 2004+	-1.056	-0.183	0.393	-1.435	-0.268	4.181*
	(0.642)	(0.640)	(1.123)	(2.244)	(2.535)	(2.221)
Constant	-0.404	-0.063	0.211	4.080	-2.283	2.612
	(1.067)	(1.064)	(1.866)	(3.728)	(4.251)	(3.691)
Observations	26	26	26	26	25	26
R-squared	0.358	0.101	0.333	0.229	0.183	0.268
F	2.928	0.589	2.616	1.562	1.123	1.924

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table B.14: Capital deepening and ageing by detailed asset types (growth rates)

VARIABLES	(1) N111 CapDeep	(2) N112 CapDeep	(3) N1131 CapDeep	(4) N11321 CapDeep	(5) N11322 CapDeep	(6) N11O CapDeep	(7) N1171 CapDeep	(8) N1173 CapDeep	(9) N117X CapDeep
Δ ln(Pop 25-49)	-0.379	0.960	0.017	0.114	-0.821	0.135	-1.958	2.201	-5.643
	(0.751)	(0.793)	(1.152)	(2.176)	(2.321)	(0.634)	(2.334)	(1.934)	(5.114)
Δ ln(Pop 50-64)	0.260	-1.521*	-1.607	-3.194	-2.323	-1.765**	0.189	-2.652	-4.362
	(0.774)	(0.818)	(1.187)	(2.242)	(2.392)	(0.654)	(2.405)	(1.993)	(5.267)
Δ ln(Value added)	0.014	0.331	1.397***	3.243***	1.485	0.620**	0.886	0.835	6.571***
	(0.321)	(0.339)	(0.492)	(0.930)	(0.992)	(0.271)	(0.997)	(0.826)	(2.185)
EU members 2004+	0.040	-0.134	-0.630	-6.008**	-6.119**	0.539	2.778	0.990	-14.537**
	(0.873)	(0.922)	(1.338)	(2.528)	(2.697)	(0.737)	(2.712)	(2.247)	(5.978)
Constant	0.142	2.139	1.529	4.655	5.263	2.115*	0.924	7.059**	-1.230
	(1.205)	(1.272)	(1.846)	(3.488)	(3.722)	(1.017)	(3.742)	(3.100)	(8.239)
Observations	26	26	26	26	26	26	26	26	25
R-squared	0.014	0.284	0.456	0.404	0.269	0.706	0.265	0.293	0.429
F	0.0748	2.079	4.396	3.565	1.934	12.58	1.891	2.175	3.760

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

VARIABLES	(1) N111 CapDeep	(2) N112 CapDeep	(3) N1131 CapDeep	(4) N11321 CapDeep	(5) N11322 CapDeep	(6) N11O CapDeep	(7) N1171 CapDeep	(8) N1173 CapDeep	(9) N117X CapDeep
Δ Share Age 25-49	0.021	0.036	0.027	-0.102	-0.128	0.048	-0.017	-0.065	0.221
	(0.029)	(0.032)	(0.050)	(0.091)	(0.096)	(0.033)	(0.093)	(0.071)	(0.244)
Δ Share Age 50-46	0.045	-0.016	0.018	-0.194	-0.150	0.040	0.085	-0.226*	0.478
	(0.045)	(0.050)	(0.079)	(0.144)	(0.151)	(0.052)	(0.146)	(0.112)	(0.381)
Δ ln(Value added)	0.002	0.138	0.945*	2.278**	0.559	0.163	0.466	0.570	4.041
	(0.293)	(0.327)	(0.516)	(0.941)	(0.992)	(0.341)	(0.959)	(0.733)	(2.455)
EU members 2004+	-0.263	0.207	0.628	-1.355	-1.218	1.571	4.309	3.048	-8.860
	(0.844)	(0.942)	(1.485)	(2.708)	(2.855)	(0.982)	(2.759)	(2.109)	(7.045)
Constant	-0.485	1.398	-0.092	5.813	5.836	-0.038	-0.997	9.501**	-14.615
	(1.402)	(1.565)	(2.468)	(4.499)	(4.743)	(1.632)	(4.585)	(3.503)	(11.980)
Observations	26	26	26	26	26	26	26	26	25
R-squared	0.051	0.230	0.309	0.296	0.157	0.462	0.216	0.359	0.172
F	0.281	1.566	2.348	2.207	0.976	4.502	1.445	2.934	1.042

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

B.2.2 Change in aging ratio and old-age share levels

Table B.15: Capital deepening and ageing by main asset types (aging)

	(1)	(2)	(3)	(4)	(5)	(6)
	N11	N11K	N11M	N1132	N115	N117
VARIABLES	CapDeep	CapDeep	CapDeep	CapDeep	CapDeep	CapDeep
Δ ln(Age ratio)	-0.395	-0.134	0.135	1.667	-0.746	0.296
	(0.636)	(0.608)	(0.879)	(1.996)	(2.465)	(2.071)
Share Age 50-46	0.013	-0.008	0.530***	0.818*	0.545	0.125
	(0.128)	(0.122)	(0.176)	(0.400)	(0.498)	(0.415)
Δ ln(Value added)	0.606**	0.175	1.105***	2.255**	0.680	0.359
	(0.264)	(0.252)	(0.365)	(0.828)	(0.991)	(0.860)
EU members 2004+	-0.618	0.063	0.656	-2.994	1.049	3.750*
	(0.626)	(0.598)	(0.864)	(1.963)	(2.348)	(2.037)
Constant	0.135	0.645	-13.563**	-20.947*	-14.129	-1.468
	(3.778)	(3.609)	(5.215)	(11.847)	(14.794)	(12.293)
Observations	26	26	26	26	25	26
R-squared	0.272	0.064	0.528	0.296	0.159	0.266
F	1.962	0.358	5.880	2.208	0.944	1.900

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

	(1)	(2)	(3)	(4)	(5)	(6)
	N11	N11K	N11M	N1132	N115	N117
VARIABLES	CapDeep	CapDeep	CapDeep	CapDeep	CapDeep	CapDeep
Δ Share Age 50-46	0.011	0.010	0.059	0.038	0.113	0.001
	(0.035)	(0.033)	(0.047)	(0.111)	(0.137)	(0.114)
Share Age 50-46	0.060	0.016	0.597***	0.731*	0.786	0.102
	(0.126)	(0.120)	(0.167)	(0.398)	(0.486)	(0.408)
Δ ln(Value added)	0.670**	0.210	1.229***	2.185**	1.000	0.332
	(0.271)	(0.257)	(0.359)	(0.857)	(0.999)	(0.878)
EU members 2004+	-0.420	0.143	0.736	-3.629*	1.520	3.623*
	(0.571)	(0.542)	(0.755)	(1.803)	(2.111)	(1.847)
Constant	-1.994	-0.449	-16.963***	-17.592	-24.839	-0.467
	(3.835)	(3.638)	(5.070)	(12.113)	(14.927)	(12.406)
Observations	26	26	26	26	25	26
R-squared	0.262	0.065	0.562	0.277	0.183	0.265
F	1.868	0.367	6.728	2.008	1.121	1.893

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table B.16: Capital deepening and ageing by main asset types (aging)

VARIABLES	(1) N111 CapDeep	(2) N112 CapDeep	(3) N1131 CapDeep	(4) N11321 CapDeep	(5) N11322 CapDeep	(6) N11O CapDeep	(7) N1171 CapDeep	(8) N1173 CapDeep	(9) N117X CapDeep
Δ ln(Age ratio)	0.063	-0.906	0.203	0.517	1.986	0.072	2.297	-1.705	4.738
	(0.789)	(0.862)	(1.304)	(2.428)	(2.453)	(0.819)	(2.524)	(2.037)	(6.594)
Share Age 50-46	-0.131	0.138	0.424	0.922*	1.195**	0.426**	0.518	0.332	1.564
	(0.158)	(0.173)	(0.261)	(0.487)	(0.492)	(0.164)	(0.506)	(0.408)	(1.322)
Δ ln(Value added)	-0.143	0.300	1.341**	3.229***	1.711	0.554	0.867	1.019	5.203*
	(0.328)	(0.358)	(0.541)	(1.008)	(1.018)	(0.340)	(1.048)	(0.845)	(2.741)
EU members 2004+	0.135	0.363	0.779	-3.273	-3.308	1.982**	4.349*	1.404	-5.624
	(0.776)	(0.848)	(1.282)	(2.388)	(2.412)	(0.805)	(2.482)	(2.003)	(6.513)
Constant	3.842	-2.033	-11.253	-22.976	-30.243*	-10.728**	-14.623	-2.640	-50.191
	(4.685)	(5.116)	(7.739)	(14.412)	(14.561)	(4.860)	(14.981)	(12.088)	(39.153)
Observations	26	26	26	26	26	26	26	26	25
R-squared	0.042	0.255	0.385	0.347	0.281	0.568	0.243	0.309	0.163
F	0.228	1.800	3.293	2.785	2.054	6.909	1.683	2.351	0.975

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

VARIABLES	(1) N111 CapDeep	(2) N112 CapDeep	(3) N1131 CapDeep	(4) N11321 CapDeep	(5) N11322 CapDeep	(6) N11O CapDeep	(7) N1171 CapDeep	(8) N1173 CapDeep	(9) N117X CapDeep
Δ Share Age 50-46	0.019	-0.022	0.047	-0.038	0.052	0.058	0.151	-0.154	0.513
	(0.043)	(0.048)	(0.071)	(0.134)	(0.137)	(0.043)	(0.138)	(0.109)	(0.352)
Share Age 50-46	-0.111	0.184	0.470*	0.829*	1.101**	0.496***	0.529	0.270	1.855
	(0.155)	(0.173)	(0.254)	(0.477)	(0.488)	(0.155)	(0.492)	(0.389)	(1.252)
Δ ln(Value added)	-0.105	0.335	1.431**	3.093***	1.644	0.681*	0.999	0.827	5.967**
	(0.333)	(0.373)	(0.547)	(1.028)	(1.052)	(0.333)	(1.060)	(0.838)	(2.702)
EU members 2004+	0.152	0.706	0.801	-3.585	-4.049*	2.086***	3.702	1.787	-6.364
	(0.700)	(0.785)	(1.151)	(2.163)	(2.213)	(0.701)	(2.231)	(1.764)	(5.711)
Constant	2.813	-3.784	-13.636*	-18.703	-26.683*	-14.259***	-16.431	1.399	-67.321*
	(4.705)	(5.269)	(7.729)	(14.526)	(14.864)	(4.706)	(14.983)	(11.847)	(38.276)
Observations	26	26	26	26	26	26	26	26	25
R-squared	0.050	0.224	0.398	0.348	0.264	0.602	0.256	0.348	0.224
F	0.278	1.512	3.464	2.798	1.882	7.946	1.802	2.801	1.442

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

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Offenlegung nach § 25 Mediengesetz: Medieninhaber (Verleger): Verein "Wiener Institut für Internationale Wirtschaftsvergleiche", A 1060 Wien, Rahlgasse 3. Vereinszweck: Analyse der wirtschaftlichen Entwicklung der zentral- und osteuropäischen Länder sowie anderer Transformationswirtschaften sowohl mittels empirischer als auch theoretischer Studien und ihre Veröffentlichung; Erbringung von Beratungsleistungen für Regierungs- und Verwaltungsstellen, Firmen und Institutionen.