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Long-term labour productivity and GDP projections for the EU25 Member States : a production function framework

by
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Long-term labour productivity and GDP projections for the EU25 Member States : a production function framework

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ABSTRACT

This paper presents the results of long run labour productivity and GDP growth rate projections (until 2050) for each of the 25 EU Member States and provides a detailed overview of the forecast methodology used. These projections were undertaken in order to provide an internationally comparable macroeconomic framework against which to assess the potential economic and fiscal effects of ageing populations. This assessment was carried out as part of the work undertaken by the EU's Economic Policy Committee, in its Ageing Working Group, to project the public expenditure implications of ageing on pensions, health care, long-term care, unemployment insurance and education.

The projections presented in this paper, using a common production function methodology for all 25 countries, show the GDP growth rate effects of an assumptions-driven extrapolation of recent trends in employment and labour productivity. These base case projections reflect the working assumption of "no policy change" and should not therefore be seen as forecasts of long run sustainable rates of growth but more as an indication of likely developments if past trends were to persist in the future. In overall terms, the EU25 baseline projection suggests a significant slowdown in potential growth rates in the Union as a whole, with the EU25 growth rate projected to fall from around 2 ½ % at present to half that rate over the period 2041-2050. While the decline in the growth rate of living standards is less dramatic, it is nevertheless significant, with EU25 GDP per capita growth rates expected to decline from 2 ¼ % at present to 1 ½ % in the 2040's.

Finally, various sensitivity tests are carried out to check the GDP per capita impact of some factors which have been excluded from the baseline scenario for reasons of simplicity or because of a lack of consensus in the academic literature. Some of the interesting conclusions that emerge from these sensitivity tests include :

- *Firstly, the GDP per capita impact of changes in the participation rate assumption used in the projections is much greater than for assumed changes in the share of part-time employment (i.e. in average hours worked per worker).*
- *Secondly, the negative effect of a change in the age-structure of the population is fairly limited, although it is accepted that the labour productivity of an individual is likely to decline after the age of 55. A very strong fall in the productivity of older workers compared with that of prime-age workers would be required to significantly depress total labour productivity. Such an outcome, on the basis of current evidence, appears rather unlikely.*
- *Thirdly, changing the TFP growth rate targets (e.g. use of the 1990's average instead of the long-term 1970-2004 average) could strongly affect the projections.*
- *Finally, an assumption of productivity convergence in levels substantially alters the projections for most EU10 countries but leaves the EU15 almost unchanged.*

JEL classification: O47, D24, J11, J21, J26, H55

Keywords: productivity, GDP growth, production function, long-term projections, ageing populations, pension reforms.

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1. INTRODUCTION

In 2004, the ECOFIN Council gave the Economic Policy Committee (EPC) a mandate to produce a new set of long-run budgetary projections by mid-2005 for all twenty five Member States covering pensions, health care, long-term care, education, unemployment transfers and, if possible, contributions to pensions/social security systems. To this end, it was agreed that the budgetary projections should be made on the basis of common demographic projections, to be provided by Eurostat, and using macroeconomic assumptions to be validated in the EPC 's Working Group on Ageing (EPC-AWG) [1]. It was also accepted that the projections would be made on the basis of a "no policy change" assumption, i.e. reflecting enacted legislation, including provisions which were expected to enter into force in a phased manner over time. The guiding principles of simplicity, comparability, consistency, prudence and transparency have underpinned the work of DG ECFIN and the EPC-AWG in preparing the new common budgetary projections.

This study presents the production function methodology, which was chosen by the EPC-AWG as the preferred approach for projecting labour productivity and GDP until 2050. In terms of structure, the study starts with some stylised facts about labour productivity growth, its main driving forces and the issues to be considered when making projections over such a long time horizon. It goes on to present the essential details of the various approaches which could be employed to make such projections, as well as providing a detailed overview of the specific methodology used in the present paper. Regarding the latter, the paper describes both the production function framework and the set of assumptions used to project its components over the medium to long run. On the basis of this agreed framework, the paper goes on to present the baseline projections which it produces for the EU25, EU15 and EU10 (new Member States) aggregates, whilst drawing some conclusions regarding the cross country differences as well as discussing a series of alternative scenarios. The essential conclusions to be drawn from the analysis are provided in the final section, with the detailed projections for each of the 25 Member States given in Annex 1.

[1] The Economic Policy Committee (EPC) is composed of senior officials from national economics and finance ministries and central banks and serves to prepare the work of the ECOFIN Council. The EPC's Ageing Working Group (henceforth EPC-AWG) was established to study the implications of ageing populations for the public finances in areas such as pensions, health and education. In 2001, the European Commission and the EPC-AWG produced a first set of comparable projections on the long-term budgetary impact of ageing through increased expenditure on pensions, health care and long-term care. See European Commission–EPC (2001).

2. STYLISED FACTS ABOUT LABOUR PRODUCTIVITY GROWTH AND ITS DRIVING FORCES

2.1. Historical trends in labour productivity

The simplest observable measure of labour productivity is GDP per person employed. This measure is particularly relevant in the context of the budgetary projections since, together with the projections of the labour force and the NAIRU, it permits the calculation of the total output growth rate over the projection horizon.

Table 1 : **Labour productivity growth by sub-periods (%)**

	1960-1970	1970-1980	1980-1990	1990-2000	*1990-1995*	*1995-2000*	2000-2003	1973-2003
BE	4.4	3.2	1.9	1.3	*1.1*	*1.4*	0.4	1.7
DK	3.5	1.6	1.2	1.8	*2.0*	*1.6*	1.4	1.4
DE	4.2	2.5	1.3	1.6	*2.1*	*1.1*	0.7	1.5
EL	9.3	3.9	-0.3	1.6	*0.7*	*2.5*	3.7	1.3
ES	6.7	4.2	1.9	1.3	*1.9*	*0.7*	0.5	1.9
FR	4.9	2.8	2.3	1.5	*1.5*	*1.5*	0.3	1.8
IE	4.2	3.7	3.8	3.4	*2.9*	*3.9*	3.1	3.5
IT	6.2	2.6	1.7	1.6	*2.1*	*1.1*	-0.3	1.6
LU	2.9	1.4	3.2	2.1	*1.3*	*2.8*	-2.2	1.7
NL	3.8	2.7	1.6	1.2	*1.3*	*1.2*	0.0	1.4
AT	5.1	3.0	2.3	2.0	*2.1*	*1.9*	0.8	2.1
PT	6.2	4.7	3.1	2.1	*2.3*	*1.9*	0.2	2.5
FI	4.4	3.5	2.5	2.6	*2.9*	*2.4*	0.9	2.5
SE	3.9	1.2	1.5	2.7	*2.9*	*2.5*	0.8	1.6
UK	2.7	1.7	1.9	2.2	*2.7*	*1.6*	1.4	1.7
CY	n.a.	n.a.	n.a.	n.a.	*n.a.*	*2.5*	1.4	n.a.
CZ	n.a.	n.a.	n.a.	n.a.	*n.a.*	*0.5*	2.0	n.a.
EE	n.a.	n.a.	n.a.	n.a.	*n.a.*	*7.6*	4.6	n.a.
HU	n.a.	n.a.	n.a.	n.a.	*n.a.*	*2.8*	2.8	n.a.
LV	n.a.	n.a.	n.a.	n.a.	*n.a.*	*5.9*	5.2	n.a.
LT	n.a.	n.a.	n.a.	n.a.	*n.a.*	*4.9*	9.3	n.a.
MT	n.a.	n.a.	n.a.	n.a.	*n.a.*	*3.8*	-0.2	n.a.
PL	n.a.	n.a.	n.a.	n.a.	*n.a.*	*4.7*	3.0	n.a.
SK	n.a.	n.a.	n.a.	n.a.	*n.a.*	*4.5*	3.6	n.a.
SI	n.a.	n.a.	n.a.	n.a.	*n.a.*	*3.8*	2.8	n.a.
EU-10	*n.a.*	*n.a.*	*n.a.*	*n.a.*	*n.a.*	*3.8*	*3.0*	*n.a.*
EU-25	*n.a.*	*n.a.*	*n.a.*	*n.a.*	*n.a.*	*1.5*	*0.8*	*n.a.*
EU-15	*4.6*	*2.6*	*1.7*	*1.7*	*2.1*	*1.3*	*0.6*	*1.7*
Standard deviation								
EU-10	n.a.	n.a.	n.a.	n.a.	*n.a.*	*1.8*	2.4	n.a.
EU-25	n.a.	n.a.	n.a.	n.a.	*n.a.*	*1.7*	2.3	n.a.
EU-15	1.6	1.0	0.9	0.6	*0.7*	*0.8*	1.3	0.6
US	2.3	1.2	1.3	1.7	*1.3*	*2.0*	1.9	1.3
JP	8.6	3.7	3.0	1.1	*0.8*	*1.4*	1.4	2.1
CA	2.4	1.1	0.9	1.7	*1.3*	*2.0*	0.6	1.0

Sources: AMECO database, European Commission.

Productivity growth has been rather uneven across the countries and sub-periods considered (see Table 1). During the 1960s and 1970s, the pattern of growth across countries was broadly consistent with the conventional "convergence" view, in particular that countries lagging behind in terms of labour productivity gradually closed the gap relative to the United States.

This convergence process appears to have continued in the 1980s and the first half of the 1990s, albeit to a much lesser extent. Conversely, the convergence process between the EU15 and the US has clearly reversed in the second half of the 1990s and the early 2000s[2]. This is particularly true for some of the larger EU15 countries, although a number of the smaller EU15 Member States (Greece, Ireland, Luxembourg, Finland and Sweden) have recorded a higher productivity growth rate compared with that of the US over the second half of the 1990s, enabling them to narrow the gap in terms of productivity levels. This development partly corresponds to the convergence of labour productivity growth rates within the EU15, with the standard deviation passing from 1.0% in the 1970s to 0.6% in the 1990s. However, this measure of dispersion seems to have risen in the late 1990s and the early 2000s. Looking at the new member States (EU10), their growth rates of labour productivity appear to be much higher (3.8% on average) than those of the existing Member States (1.3%) during the 1990s, which reflects the catching-up (or convergence) process in these economies.

2.2. Driving forces behind productivity developments

The main factors driving trend productivity growth derived from the standard Cobb-Douglas production function relate to labour input, capital input and technological progress, i.e. the residual which cannot be explained by the quantity and quality of either labour or capital. Several factors are worth considering in more detail.

Changes in hours worked *:* The sharp decline in hours worked per worker in the 1990s may explain why hourly labour productivity was higher than productivity per person employed in most of the continental European countries. Figures available for the euro area indicate that the growth in labour productivity per person employed is 0.6% points lower than labour productivity per hour worked in the three time periods considered in Table 2, which underscores the effect of the decline in average hours worked per person employed.

Table 2 **: The effect of changes in hours worked on labour productivity growth (average annual changes)**

	Period	Euro area	US
Productivity growth per person employed (%)	1982-1989	2.0	1.4
	1990-1995	1.7	1.2
	1996-2001	1.1	1.7
Productivity growth per hour worked (%)	1982-1989	2.6	1.2
	1990-1995	2.3	1.2
	1996-2001	1.7	2.0
Effect of changes in hours worked	1982-1989	-0.6	0.2
	1990-1995	-0.6	0.0
	1996-2001	-0.6	-0.3

Source: ECB; August 2002 ECB Monthly Bulletin

[2] See also European Commission (2003). For the 2000s, differences in productivity growth across countries are influenced by differences in cyclical positions. The slowdown in economic activity in the EU as a whole is partly responsible for the lower rate of labour productivity growth compared to the late 1990s.

Improvements in the average "human capital" of persons employed. As shown by the OECD[3], human capital can be proxied by the proportion of workers ranked by educational attainment and weighted by their relative wages. However, the rise in the overall skill level of those in employment conceals two different effects:

- *better education of the working-age population*: the proportion of those attaining tertiary education has increased in most countries since the 1970s and in particular over the 1990s*;*

- *the exclusion of the low skilled from employment*: in addition to the increased skills of the working-age population, the high labour productivity growth recorded in the 1980s and at the start of the 1990s was partly attributable in a number of EU countries to the massive unemployment of low-skilled workers. Conversely, the widening of the employment base (increasing employment among the low skilled) in the 1990s explained in part the slower productivity growth in some countries, such as Spain, compared to the previous decades. Thus, high productivity growth can mirror underemployment and slack in the labour market.

Capital deepening: apart from labour inputs (quality and quantity), the second main channel which can account for labour productivity gains is the accumulation of physical capital. For instance, the high level of investment in the new Member States (public infrastructure, private investment) following the restructuring and privatisation of state owned-companies as well as the stimulus provided by large FDI inflows has contributed to the relatively high productivity growth rates in these countries. This fast capital deepening corresponds to the transition phase of these economies, which is somewhat similar to the reconstruction period in Western Europe after the Second World War, characterised by a fast physical capital accumulation. As regards recent trends in productivity growth, and in particular the divergence in growth rates between the EU and the US since the mid-1990s, the following issues related to capital accumulation appear to have played an important role :

- *the role of information and communication technology (ICT)* in the process of accumulation of physical capital should be emphasised, as it could explain a part of the productivity gap between the US and the EU. Two effects can be identified: capital accumulation in ICT-producing sectors (of which the size increased fastest in the US, Ireland, Finland and Sweden in the 1990s) and capital accumulation across the whole economy through large investments in ICT. These two mechanisms are (at least partly) responsible for the marked divergence between the US and the EU over the second half of the 1990s.

- *lack of non-ICT productive investment:* the lack of such investment, especially relative to the US in the second half of the 1990's, may have also led to the EU's disappointing productivity performance. Indeed, the investment rate in the EU displayed a clear and worrying downward trend in the 1990s.

- *capital-labour substitution towards more employment intensive growth*: the smaller non-ICT capital accumulation in the EU appears to be also due to a

[3] See OECD (2003).

reversal of the employment-unfriendly capital/labour substitution of earlier periods. This move towards more employment may entail a temporary reduction in measured productivity growth, but this should not be regarded as a trade-off, since a higher employment rate implies an unambiguous increase in GDP per capita with no negative implications for long-run productivity growth in the existing workforce. In neoclassical economic growth theory, this long-run neutrality proposition is embodied in the concept of *labour-augmenting technical progress*[4].

Technological progress, embodied by Total Factor Productivity (TFP) growth. TFP is conventionally calculated as the Solow's residual, which corresponds to the component of productivity growth which cannot be explained by changes in the quality and quantity of labour and capital. Three stylised facts can be mentioned. First, the slowdown of TFP growth in most OECD economies since 1973 to half the levels observed in the 1950-1973 period is still largely unexplained. Second, higher TFP growth in Europe vis-à-vis the US in the period 1973-1995 probably reflects convergence towards the leading economy. Third, TFP growth in the US has been strong compared to the EU since the mid-1990s. Strong ICT investment is only part of the story since US productivity growth persisted during the most recent downturn when ICT investment and demand fell dramatically. The combination of ICT investment and organisational changes (new processes, corporate culture, better knowledge and information dissemination, etc) could explain the good TFP performance in the US. There are however still many open questions regarding long-term trends and prospects for TFP. Will the "new economy" be sustainable in the US in the long-run and will the EU catch up towards the US in the coming decades?

Other factors (e.g. changes in the sectoral composition of the economy). The shift of OECD economies towards larger service sectors mechanically induces a decline in the overall labour productivity growth rate, as on average services display lower productivity gains compared with the manufacturing sector (mainly due to lower capital-intensity). However, the growing share of ICT-producing sectors (both in manufacturing and services) may better explain the productivity results in some OECD countries.

2.3. Issues to be considered when thinking about long-term productivity projections

2.3.1. Economic convergence : theoretical and empirical Evidence

Various theories abound concerning the speed with which less developed economies develop over time, and whether if, or when, they converge to the income levels of the most advanced economies. Some economists, such as Romer (1986) and other advocates of the new endogenous growth theories, are quite pessimistic regarding the

[4] In essence, technical progress raises the productivity of both workers and machines. The increase in labour productivity leads to a rise in real wages, which causes some people to work more and others less, with a broadly neutral impact on overall employment. At the same time, higher wages and the increase in the productivity of capital cause firms to increase their investment in physical capital. Thus, there is a *balanced growth path*, along which labour productivity, real wages and the capital intensity of production grow at the same rate, driven by technical progress.

likelihood of convergence occurring even over long periods of time since productive technology is, in their view, of the increasing, as opposed to the more normally assumed decreasing, returns to scale variety and consequently once a country becomes a global technology leader it tends to remain so over extended periods of time due to knowledge spillovers or learning-by-doing effects. At the other end of the scale are economists such as J. Sachs and A. Warner (1995), who are quite optimistic concerning the potential for catching-up, with in their view an adequate policy framework being a sufficient condition for that to occur.

For Sachs et al.(1995) those countries which consistently implement efficient economic policies, including adherence to an open trading regime which is attractive to FDI flows and technology transfers, as well as establishing the normal institutions of a market economy, such as a properly functioning legal system with adequate protection for private property rights, will over time experience convergence. This view consequently stresses the importance of efficient economic institutions in ensuring growth and convergence. On this view of the world, if countries do not succeed in growing it has probably more to do with poor policy choices rather than technology deficiencies or low initial endowments of human capital.

Between these two extreme views is the one which is the most followed in empirical analysis and the one used in the EPC-AWG approach to make long-run projections, namely the Solow neoclassical growth framework, which predicts what is referred to as "conditional" convergence. The theory suggests that convergence does occur but not necessarily to the same higher level of income, since the growth potential of countries differs essentially because of differences in respective savings rates and population changes. When one allows for these differences in terms of the long run growth potential of countries, then one finds that poorer countries do in fact grow relatively faster and consequently do converge over time, but not necessarily to the same steady state standard of living. Furthermore, studies have found that the greater the gap between the present income levels of countries and their future potential, the faster they will grow. According to this line of reasoning, which has been termed "the "*convergence clubs*" hypothesis, in the long-run the per capita incomes of countries that are similar in their structural characteristic converge only if their initial conditions (their initial per capita output levels) are similar as well. Countries with different structural characteristic converge to different steady state. The theoretical support is provided by the endogenous models and in particular by models of poverty trap[5].

Given the wide choice of models to choose from, it is clear that the empirical evidence becomes a major deciding factor in terms of which model to use for any long run growth analysis. In overall terms, it would appear that the approach which has enjoyed the greatest degree of support in the literature is the neoclassical view. There is in fact now widespread empirical acceptance that "conditional" convergence does occur across countries. Typical of this line of research is a 1992 study by Mankiw, Romer and Weil which showed, using cross-country regression analysis, that the neoclassical growth model could explain nearly 80% of the differences in

[5] This body of new theoretical works on multiple equilibria predict the formation of "convergence clubs" (with member countries converging towards each other and diverging away from different clubs) and the polarisation of the distribution into "twin peaks" of rich and poor. In these new models, the dynamical system is characterised by multiple locally stable steady-state equilibria. See Quah (1995), Quah(1996).

international standards of living, using just three explanatory variables, namely population growth rates, savings rates and an indicator of human capital.

In addition, papers by Barro and Sala-i-Martin (1991), Islam (1995) and Sala-i-Martin (1996), amongst many others, all found evidence for ‘conditional convergence’ for ‘developed economies’ including the EU, with rates of convergence of 2% per annum being typical for these studies. With regard to the debate on openness and growth, a number of studies, such as Sachs and Warner (1995) and Ben-David (1996), using a modified neoclassical framework, found strong evidence of per-capita income convergence for open economies with strong trading links, a scenario which is typical of the EU, Japan and a number of the fast ageing economies.

In this regard, while the analysis undertaken in the present paper is predicated on the conditional convergence thesis, the importance of an appropriate policy framework is also stressed, including the role of policy institutions, along the lines of the arguments put forward by Sachs and Warner. In overall terms, the key points to be retained from the convergence literature are the following.

- ***Convergence is not assured*** – it is conditional on rates of capital accumulation and population growth and, at a wider level, on appropriate and efficient policy making institutions. As the experiences of Japan and the EU show, effective economic policies and institutions have an important role to play in the growth and convergence processes of these countries.

- The ***speed*** with which countries grow is dictated by their own long-run growth potential and their own initial conditions. While fast rates of growth can be achieved, countries should be realistic about the speed with which convergence will take place – in fact that process normally occurs at a much slower pace than most countries assume.

- On the basis of the empirical evidence presented above, it would appear that the road to prosperity is more difficult and the ***role of savings and investment***, both in physical and human forms of capital, is more important in determining steady state income levels than originally thought back in the 1950s, with the accumulation of all forms of capital, including knowledge, being crucial to the relative growth performance of countries.

As an operational consequence for the projections, we will refrain from assuming the existence of convergence *in levels*. As a much weaker form of convergence, we however make country–specific TFP converge in *growth rate*, allowing for some degree of technology diffusion. By contrast, labour input developments will remain very different across countries, as driven by differing demographics, cohort effects and impacts of recent reforms.

2.3.2. What impact is ageing likely to have on long run labour productivity trends in general and on capital deepening and TFP developments specifically ?

Direct compositional impact on overall labour productivity levels: Population ageing is often said to lead to a deterioration in the average quality of labour input and thereby to lower aggregate productivity: as the productivity of individuals is alleged to decline with age, the rising share of older workers should reduce overall productivity, even though age specific productivity remains constant. However, the profile of productivity by age is a complex issue since the identification of the age effect is blurred by cohort and selection effects[6].

On the basis of a survey of human resource executives, Barth et al. (1993) finds that older workers were seen as being more reliable, having better skills and adopting better work-friendly behaviour than their younger counterparts. Using an employer-employee dataset for the US, Hellerstein et al. (1999) shows that prime-age workers (aged 35-54) are equally as productive as younger workers. However, those aged 55 and over are less productive than younger workers. Surveying supervisors' ratings, work-sample tests, analyses of employer-employee datasets and other approaches assessing individual productivity across age groups, Skirbekk (2003) finds evidence suggesting "that productivity tends to follow an inverted U-shaped profile, where significant decreases take place from around 50 years of age. An important cause of these age-related productivity declines is likely to be reductions in cognitive abilities across the life span. Some abilities, such as perceptual speed, show relatively large decreases from a young age, while others, like verbal abilities, show only small changes throughout the working life. Although older individuals have longer experience, they learn at a slower pace and have reductions in their memory and reasoning abilities". Prskawetz et al. (2005) also argue that the analysis should not only consider the age variation in individual skills (supply for abilities), but also the changing importance of these skills in the labour market (shifting demand for abilities). For instance, cognitive abilities seem to have gained much prominence in firms' needs compared with physical strength, especially in services-based economy.

This bell-shaped relationship between age and individual productivity is broadly confirmed by Kotlikoff and Wise (1989) and Hansen (1993) for the US and Meghir and Whitehouse (1996) for the UK, which find that younger workers with little experience and older workers are both less productive than prime-age staff. However, Borsch-Supan (2003) shows that, even when assuming a pronounced bell shaped relationship, the projected fall in aggregate labour productivity remains fairly small. Borsch-Supan (2006) also argues that there is no evidence of dramatic productivity decline in the 45-60 age bracket, as the negative effect of age is offset by the positive effect of experience, which becomes more important in a service and knowledge society[7].

[6] An additional problem arises from the fact that the age-profile of productivity is deduced from that of hourly earnings, although some gaps between wages and productivity might occur especially for the older age cohorts (Hellerstein et al. 1999).

[7] The combination of a pure "age effect" and experience also explained the bell-shape of the relationship between age and productivity: those aged 15-24 are young but less experienced, while those 50-64 are older (less fit) but much more experienced. Borsch-Supan (2006) provides interesting evidence for a truck assembly plant based on the percentage of "errors" made by workers in the production process and concludes that the "error" curve is relatively "flat" across age.

Effects on total factor productivity : One of the critical assumptions to be made in relation to assessing the long-term economic impact of demographic change is the extent to which increased labour efficiency can offset the reduction in the rate of growth of the labour supply. This is a highly complex issue and one which has received a lot of attention in the empirical literature. From a review of the latter it would appear difficult to establish with any certainty whether demographic change will be positive or negative for productivity. According to one strand of research it could be detrimental to productivity growth if an ageing labour force turns out to be less dynamic and innovative (e.g. Barrel 2005) whereas other researchers take the alternative view that technological change may be boosted to offset the negative implications of the ensuing relative scarcity of labour.

Simon (1986), Wattenberg (1987), Romer (1990) and Jones (2002)[8] take the former view and argue that technical progress is slowed down by the anticipated ageing of the population because of the above mentioned loss of dynamism and since declining markets for capital goods ensures that innovation is less profitable. Barth et al. (1993) also shows that, notwithstanding their greater dedication at work, as well as their longer experience and better skills, older workers are considered by a panel of employers to be less flexible in accepting new assignments and less receptive to training, which may hamper innovation and the full exploitation of technical progress. Skirbekk (2003) and Prskawetz et al.(2005) note that older workers are likely to show less adaptability to changing working methods and less ability to learn in general. Denis, Mc Morrow and Röger (2004b) show that TFP growth could slow down substantially given the lesser human capital accumulation (embedded in a skrinking young population) and a lower labour amount devoted to R&D activities.

Disney (1996) takes the opposite view that ageing will have no adverse effects on productivity growth. In addition, in earlier research by Cutler et al (1990), empirical evidence was presented to support the contention that labour scarcity induces increased innovation i.e. the "scarcity is the mother of invention" argument. This scarcity view assumes that in a situation of relatively slow population growth, there is an acceleration, on a per capita basis, in human capital accumulation. In their cross-national analysis of 29 non-OPEC countries for the period 1960-1985, Cutler et al estimate that a decline in the annual labour force growth rate of 1 percentage point is associated with about a 0.5 percentage point increase in productivity growth. Furthermore, this view of Cutler et al. is supported in the context of ongoing research in relation to endogenous growth rate theories. For example, Fougère and Mérette (1997) suggest that investment priorities may change with population ageing, with the latter phenomenon increasing the incentive for human capital investment, resulting in a redistribution of investment away from physical towards human capital, with potentially favourable long-run effects in terms of the rate of economic growth. The empirical interest in this whole area of endogenous growth theory has been enormous in recent years, with the latter stressing that the total factor productivity (TFP) element of economic growth partially emanates from sources which are amenable to policy influence. If it is accepted that the behaviour of economic agents is susceptible to productivity enhancing policy interventions, then this would represent a major

[8] Jones takes the view that TFP is negatively affected by the ageing process and estimates that a 1% point decline in the OECD's population growth rate lowers the growth rate of TFP by .05 to .3% points.

departure from the standard neo-classical view which postulates that technical progress is exogenously determined.

Capital accumulation **:** One can assess whether the option is available of reducing the impact of ageing on potential growth and living standards via capital accumulation alone ? On the negative side, from a capital widening perspective, with the expected slowdown in GDP growth rates, due to falls in labour force growth, investment should be negatively affected. This was the historical pattern, with the productivity-induced slowdown in GDP growth over the last number of decades resulting in less investment opportunities in relative terms. On the other hand, savings and investment have a potentially important role to play in helping to offset the effects of rising dependency burdens, via capital deepening[9], with policies aimed at generating greater levels of savings leading to lower real interest rates, additional productive investment and stronger long-run growth. The negative impact on living standards due to the reduced rate of growth of the labour supply could in this way be potentially offset by higher rates of labour productivity growth emanating from a rising capital stock. However, this investment route to boosting output appears somewhat unrealistic, since not only is the national savings rate not expected to rise to finance the required higher investment rate, the most likely outcome, especially if one subscribes to the life cycle hypothesis, is for a fall in national savings, with the latter fall again largely demographically induced[10]. Moreover, capital accumulation may have feed-backs on Total Factor Productivity: If "vintage" effects are allowed for, the role of investment in the overall growth process over the next 50 years is greatly enhanced, with investment not only adding to the technical capacity of the economy via increases in the capital stock but also impacting on productivity via embodiment effects, with new "vintages" of capital adding to overall efficiency levels.

Consequently, prudence demands action to boost national savings rates over the medium to long run, with action in terms of government savings / dissaving allied to incentives to boost private sector retirement savings, being the most effective avenues to be explored. Since savings and investment coupled with technical progress are the key ingredients that influence long-term living standards, it is important to stress not only their individual contributions but also the possible links between investment and productivity developments.

[9] The future evolution of the capital to labour ratio depends crucially on real interest rates. Two offsetting factors are at work in terms of ageing – declining labour forces require less investment but the savings rate of an ageing population is going down. Which effect dominates is controversial. The majority of models predict a slight decline in real interest rates. However, work by Kotlikoff et al (2001) suggests the opposite conclusion of an increase in interest rates.

[10] In addition, the capital deepening option inevitably runs into problems of diminishing returns, with domestic over-investment occurring. A good example of this is the case of Japan. Following a sharp increase in the real investment to GDP ratio in Japan in the 1960's, this ratio has remained at very elevated levels over the subsequent period to 2000, although the ratio has been on a clear downward path since the beginning of the 1990's. As a result of these investment trends, the capital intensity of the Japanese economy has risen sharply, with the capital-output ratio close to doubling over the last 30 years, rising from around 2 in 1970 to 3.7 in 2000[10]. Over this period the capital-output ratio in the EU has been broadly stable at around 3, with the US ratio remaining in a relatively narrow range of 2½-3. Since the profit share in the EU, US and Japan is roughly equivalent, the capital-output ratio is a reasonable indicator of the relative efficiency/profitability of investment in the different countries[10]. On the basis of this indicator it would appear that with a structurally high rate of savings, Japan is under increasing pressure to invest abroad in order to avoid exacerbating the problem of declining rates of return on its domestic investments.

To conclude this section, therefore, the empirical evidence linking ageing directly to productivity trends is far from convincing, with even doubts regarding whether the association or direction of any effect is positive or negative. In these circumstances it seems prudent to take a rather "middle of the road" view with regard to future efficiency gains in terms of the projections work to be described in sections 4 and 5.

3. Evaluation of the different Approaches for making long-run productivity projections

3.1. Purely mechanical projections

This section intends to provide a brief survey of the current state of practice. It describes the two main approaches that can be used for projecting labour productivity growth, that is a "purely mechanical" approach and an economic approach. Within the first approach there are two main methodologies which are the extrapolation of past/recent trend growth and convergence to a benchmark.

3.1.1. Extrapolation of past/recent trend growth

An approach consisting of extrapolating past trend growth has the merit of being simple and reasonable if the growth rate of productivity is computed over a long and fairly homogeneous time period, e.g. the period starting from the first oil shocks of 1973, rather than the very recent past which has been very heavily affected by the business cycle. Past experience has also shown that annual productivity growth varies quite a lot from one decade to another and that extrapolating the trend labour productivity in the first half of the 1990s to the second half of the 1990s would have led to large forecasting errors (around -0.8 p.p. per year for the whole EU), which cannot be explained fully by changing cyclical conditions.

This simple approach has been used by several public and private bodies involved in pension projections. One of these, for example, is the Board of Trustees in the U.S., which reports each year on the current and projected financial condition of the Social Security program, which is financed through the Old-Age and Survivors Insurance Trust Funds. This was also the *de facto* approach followed by the AWG in the previous exercise. In the 2001 projection exercise[11], labour productivity growth (measured by GDP per worker) for each country converges towards an annual rate of 1¾ per cent between 2020 and 2030. Some catch-up is allowed for initially low-productivity countries such as Portugal, although in this case the assumptions for productivity growth were very high. Although this was not explicitly mentioned, this rate is very close to that recorded between 1973-2003 for the EU as a whole (around 1.7%) and corresponds to the median of the bracket 1.4%-1.9% in which most annual productivity growth averages of highly developed EU countries are contained (Belgium, Denmark, Germany, Spain, France, Italy, Luxembourg, the Netherlands, Sweden and the United Kingdom). Small countries such as Portugal, Finland and Ireland displayed much higher rates, which may reflect the "new economy" phenomenon and/or convergence processes. In the sensitivity analysis, labour productivity growth was assumed to be 0.5% lower/higher than in the baseline

[11] These assumptions are broadly the same as those used by both the OECD and the EPC-AWG projections. See European Commission-EPC (2001)..

scenario, which roughly corresponds to the standard deviation of productivity growth across EU countries in the 1990s (+0.6%).

3.1.2. Convergence to a benchmark

This alternative approach could be particularly useful with a view to projecting productivity growth in the catching-up countries, for example in some of the acceding countries which are going through a process of real economic convergence. This approach allows one to take into account the fact that some countries may be far from the steady state and that trend (medium-term) productivity may strongly differ from long-term productivity. Moreover, it tackles a shortcoming of slavishly extrapolating past trends, as the latter may lead to some incoherence, such as assuming growing divergence in absolute levels of productivity between OECD countries. In an increasingly integrated global economy, with free movement of capital and transfers of technology, sustained divergences in levels of productivity seem unlikely.

In this setting, the choice of the benchmark (US, EU as a whole, EU excluding some catching-up countries, etc.) and the horizon of convergence are crucial. However, this method can appear too mechanical, as specific factors may hinder the convergence in some countries. Moreover, the process of convergence may be even unexpectedly reversed (for example, Japan vis-à-vis the US in the second half of the 1990s).

3.2. Economic approaches : considering the determinants of productivity

By taking stock of the upward and downward risks, an economic approach is often used to allow the productivity forecast to deviate from the trend labour productivity or trend TFP seen over past periods.

3.2.1. Judgmental approach: balance of upward and downward risks

A judgemental approach would involve the introduction of deviations from past trend productivity growth based on an assessment of the upside/downside risks for the productivity growth facing each country. Table 3 lists the main downward and upward risks associated with productivity developments that could be taken on board in such an assessment. Although this approach is interesting, it remains highly speculative given the high level of uncertainty and the problem of quantification. It cannot justify *per se* a strong deviation from the past trend.

Based on the factors outlined in Table 3, it is very hard to draw clear cut conclusions on the prospects facing most EU countries in the coming decades as there are risks on both sides. A major uncertainty over the long-run emanates from the effect of ageing populations *per se* on productivity growth. The theoretical and empirical literature does not reach firm conclusions about the magnitude of the effect, although on balance the overall impact might be rather negative (see Annex 2). Several effects on TFP are at play. It has been argued that the marginal productivity of workers tends to start to decline when they reach their early fifties[12].

[12] See note ECFIN/213/04-EN entitled "ECFIN's Global Growth Scenario 2000-2050" (presented to the EPC)-AWG).

Table 3 . **Balance of risks for productivity growth in the EU**

Nature of the risks	Component of productivity affected	Horizon of the effect
Downward risks		
Further increases in the part-time employment rate (especially in countries where the participation rate is low) + continuation of long-lasting trend towards lower collective working hours.	Decreasing average hours worked per person employed	Medium-run (effect not negligible in some countries)
Labour market reforms and continued wage moderation should foster labour deepening.	Decreasing capital intensity (K/L)	Medium-run (fairly important effect)
Labour market reforms helping the low-skilled to join the labour market.	Decreasing the average skill of those employed (lower human capital)	Medium-run
Growing share of services sector (displaying relatively low productivity growth compared to manufacturing).	Decreasing capital intensity (K/L).	Long-run (small effect)
Impact of an ageing population on innovation and entrepreneurship.	Decreasing TFP through a less dynamic and innovative society + potential impact on capital intensity due to the disinvestment of the elderly (life cycle theory).	Long-run
Upward risks		
Product market reforms (including increasing R&D and deepening the connections between academia and firms) and increasing competition, in particular in the new and acceding Member States.	Increasing TFP by stimulating innovation (strengthening innovative capacity) + possible accumulation of physical capital induced by the short-term efficiency gains (dynamic efficiency)	Long-run/Medium run
Positive technology shock (ICT revolution): slow catching-up towards the US level of productivity through an increase in the share of the ICT sector plus greater use of ICT in the rest of the economy.	Increasing both TFP and capital intensity	Long-run/Medium run
Some labour market reforms, such as the reduction of adjustment rigidities and the promotion of flexible working time arrangements, may further increase innovative capacity by favouring organisational change.	Increasing TFP by stimulating organisational innovation and via the circulation/utilisation of innovative techniques within firms.	Long-run/Medium run
Increasing the average educational attainment of the working-age population	Increasing the average skill of those employed (higher human capital)	Long-run

The enthusiasm for reform and overall levels of dynamism and innovation in an economy may be detrimentally affected by having an older labour force. Moreover, when this ageing of the labour force is combined with the much slower rates of capital accumulation which are expected to occur, leading in turn to an increase in the mean age of the capital stock, the outlook for TFP could be significantly worse. An increase in the average age of the capital stock in an economy is generally considered to be negative for labour productivity since continuing investment in new equipment is essential for incorporating labour-embodied technical progress into the production process (i.e. “vintage” effects).

3.2.2. Partial equilibrium analyses: estimating the effects of different factors on productivity.

Judgemental assessment is based on experts’ knowledge but lacks strong analytical grounds. Alternatively, econometric analysis can separately be run on each major variable likely to explain productivity growth over time. This comes down to the examination of productivity determinants, *other things remaining equal*, in a partial equilibrium framework. In essence, this approach assesses the relative merits of the major hypotheses for explaining productivity: the role played by the regulatory environment (product, labour and financial markets); the degree of openness of economies; the efficiency of knowledge production (R&D and education); the determinants of physical investment levels; and finally the role played by demographics. More specifically, ageing is expected to operate through the following main channels: expenditure pressures on the public finances; "life-cycle" effects on private savings behaviour, as well as Ricardian equivalence effects operating through the deterioration in public savings; labour supply implications; potential impact on capital accumulation; effects on total factor productivity and finally, the equilibrating role of interest rates and exchange rates and shifts in external balances. While this approach is interesting and elucidating in terms of highlighting the key influences at work, it suffers from the fact that it excludes the crucial systemic effects of ageing, such as behavioural changes and shifts in financial market variables, which ideally must be taken into account in determining the final economic impact of ageing.

A similar method has been used by the OECD (2003), and Bassanini et al.(2001)[13] to estimate the long-run effects on productivity (output per working-age person). The OECD ran pool-time series regressions including macroeconomic variables, the tax burden, business R&D, tax expenditure, etc.

3.2.3. General equilibrium approach

An alternative to the partial equilibrium analysis is found in the general equilibrium approach, such as the one developed in the European Commission's (DG ECFIN) "Ageing" model, which provides estimates for the EU15 aggregate. This type of model, including several cohorts, is part of the family of "overlapping generations models" which have been made popular by the work of Auerbach and Kotlikoff. It allows one to simulate the impact of ageing, taking due account of various economic interactions, often neglected by partial equilibrium approaches. It rests on an analytical framework which combines standard growth regressions with recent developments in endogenous growth theory. A general equilibrium approach is generally regarded as the most complex but comprehensive methodology for predicting the long run effects of ageing populations since it overcomes a number of the key limitations of static, partial equilibrium, analyses. The latter fail to take into account the effect of important systemic, dynamic, forces that will undoubtedly kick into action once ageing starts to impact on the economic system.

DG ECFIN has already produced a global growth scenario up to 2050 using such an approach, where the worldwide economic and financial market effects of ageing populations over the next 50 years are presented on the basis of a five region, overlapping generations, model[14]. DG ECFIN regards this global ageing scenario as the benchmark against which the estimates produced within the framework of the EPC-AWG budgetary projection exercise (and presented in this paper) should be compared.

[13] OECD (2003). See also Bassanini et al.(2001).

[14] See Mc Morrow and Röger (2004).

However, one of the drawbacks of the general equilibrium approach is that the estimates produced are often too complex to be carried out for each EU Member State in a comparable manner. The effect of each determinant might not be the same across countries and consequently they might require a specific projection for each contributory factor. Moreover, the cross-country comparability cannot fully be guaranteed given the large number of parameters used and assumptions required.

3.3. The merit of a "hybrid" approach: a "statistical" method embedded in a production function framework

This third approach, and the one adopted for the present paper, is to calculate potential output using a combination of reasonable *ad hoc* assumptions for the long run and established time series methods to extrapolate short-term developments. In this approach, ageing is mainly taken into account to the extent that it is already influencing developments in the labour force (projected through a cohort method approach)[15].

Although this approach does not model nor take into account all relevant age-related factors, it is a clear improvement compared with the purely mechanical approach consisting in setting a common convergence target in labour productivity at the end of the projection horizon. The approach based on a production function is fairly standard in mainstream macro-models and is often used to make short-term (2-3 years) forecasts of productivity by international institutions[16] (OECD, ECB, IMF, EC, etc). This methodology provides a sound economic basis and takes into account the interactions of labour force and employment projections on medium run productivity trends. An additional advantage is that it takes into account the slow convergence to the steady state from the initial conditions. This makes the projections in the short and medium run much more realistic (because of the "Keynesian" dynamics and the impact of capital or labour deepening). However, in the longer run (say 10-20 years), the model should converge to the neoclassical equilibrium conditions.

Moreover, while clearly less comprehensive from an economic standpoint compared with the general equilibrium method, the statistical approach has nevertheless advantages in terms of conceptual simplicity; in terms of its greater flexibility in taking more country-specific factors into account; and finally in its ability to focus on the medium term effect of the demographic slowdown on productivity. For all these reasons, this statistical method based on a production function framework was chosen by the EPC-AWG to project labour productivity and GDP until 2050. In the rest of the paper we will present the methodology and the main results of the projections.

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[15] For details on the methodology used and of the major results from the labour force projections see Carone (2005).

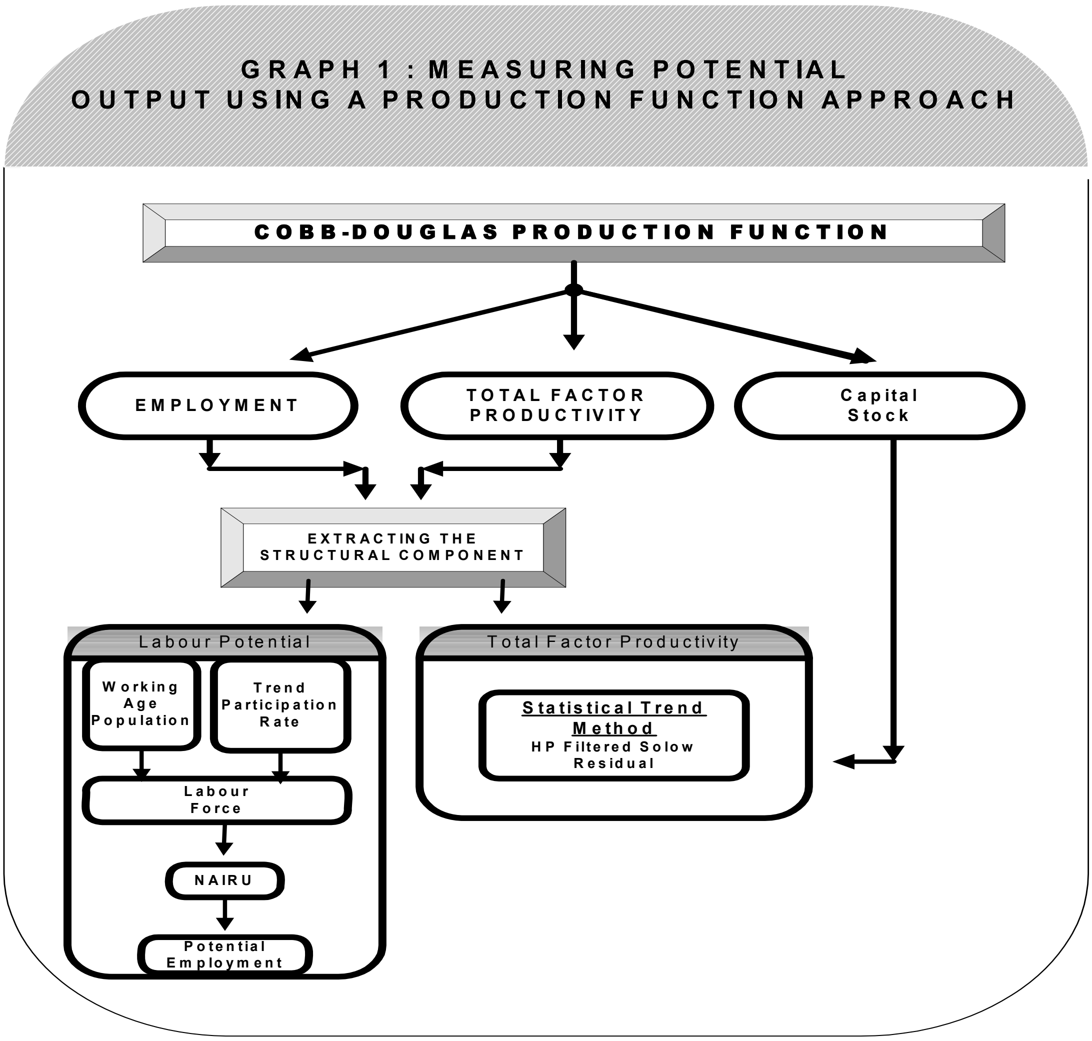
[16] Institutions such as the OECD, ECB and IMF used such a framework in their model. Moreover, *medium-term* projections of productivity (say with a time horizon of 5 or 10 years) are based on the idea that the gap between actual and potential output gradually declines to zero. This comes down to assuming that after some time, actual labour productivity growth equals potential labour productivity, which is the ratio of potential output to potential employment. For instance, on the basis of the production function used to build the long-run supply-side conditions of the OECD's INTERLINK models, Downes *et al.* (2003) have developed a medium-term reference scenario. It relies on the assumption that beyond the short-term projection horizon, gaps between actual output and potential output (with trend TFP and the unemployment rate at the medium-term NAIRU) are eliminated by 2009 in all OECD countries.

4. OVERVIEW OF THE METHODOLOGY ADOPTED FOR THE PRESENT PROJECTIONS

The "statistical / production function (PF)" approach was the preferred option of the EPC-AWG given its flexibility and sound analytical basis, especially in terms of understanding the main components driving labour productivity developments. The production function framework is presented in section 4.1. The adoption of the production function framework requires the making of some specific assumptions regarding developments in specific labour productivity components, namely TFP and capital deepening in the medium run (section 4.2) and in the long-run (section 4.3).

4.1. The production function (PF) framework

As shown in graph 1, within the analytical framework of a (Cobb Douglas) production function, potential GDP can be represented by a combination of factor inputs, multiplied with the technological level or total factor productivity (TFP). The parameters of the production function essentially determine the output elasticities to the individual inputs.



Total output can be expressed more formally using a Cobb-Douglas production function with constant returns to scale:

$$Y = TFP.L^{\beta}.K^{1-\beta} = \left(TFP^{\frac{1}{\beta}}.L \right)^{\beta}.K^{1-\beta} = (E.L)^{\beta}.K^{1-\beta} \qquad (2.1)$$

where:

L is the supply of labour, i.e. total employment (in number of persons employed if there is no change in hours worked per person);

K is the stock of capital;

E is the labour-augmenting technical progress (i.e. Harrod-neutral technical progress);

E.L is then interpretable as total employment in efficiency units. *TFP* and labour-augmenting technical progress are linked with a simple relationship: $TFP = (E)^{\beta}$;

β is the labour share, i.e. the share of labour costs in total value-added. It's value in the projection exercise is set at 0.65.[17]

However, as all these variables can be influenced by the business cycle in the short term, it is safer to project potential output, i.e. the output adjusted for cyclical movements in the economy. This requires estimating the trend components for the individual production factors, except for the capital stock, which can only adjust in the long run. Estimating potential output therefore amounts to removing the cyclical component from both TFP and labour input. Trend TFP is modelled as the HP Filtered Solow Residual. Potential employment is the total employment obtained when the unemployment rate equals the structural unemployment rate (NAIRU). It equals *LF*(1-NAIRU)*, where *LF* stands for the total labour force. Therefore, if we assume a stable NAIRU in the medium/long term as predicted, potential employment growth coincides with labour force growth. The potential output denoted Y_P can be expressed in logarithms as the sum (in logarithms) of trend TFP[18], potential employment weighted by the labour share in total value-added and the total capital stock multiplied by 1 minus the labour share. More formally, we get:

$$Log(Y_P)=Log(trendTFP)+\beta Log(LF*(1-Nairu))+(1-\beta)logK \quad (2.2)$$

As a result, potential labour productivity growth comes down to the following expression (where Y, L, E and TFP denote here "*potential*" output, potential employment, trend labour-augmenting technical progress and trend TFP):

---

17 Although there was some debate about the possibility of a further decline in the labour share, most economists assume that it should remain broadly constant in the long run. The EPC-AWG agreed to assume that real wages will grow in line with labour productivity and, thus, the wage share will be constant over the projection period. This simple rule is uniformly applied to all Member States in order to allow for consistent cross-country comparisons of the results. The assumption is also well-founded in economic theory. If the real wage is equal to the marginal productivity of labour it follows that under the standard features of the production function, real wage growth is equal to labour productivity growth and real unit labour costs remain constant.

18 It is expressed in terms of labour-augmenting efficiency (E^{β}) for the OECD and the IMF. In the IMF's model (*Multimod*), the production function for each country is specified as a Cobb-Douglas relationship between output and two factor inputs –the labour force and the real net capital stock – with a constant and an exogenous growth rate of total factor productivity.

$$\dot{\left(\frac{Y}{L}\right)} = \dot{TFP} + (1-\beta)\dot{\left(\frac{K}{L}\right)} = \beta\dot{E} + (1-\beta)\dot{\left(\frac{K}{L}\right)} \qquad (2.3)$$

Thus, the projection of TFP growth and the growth in capital per worker, so called *capital deepening*, are the key drivers of projected labour productivity over the medium run.

In the long-run, according to the neo-classical growth model (Solow model), the economy should reach its equilibrium (also called *steady state* or *balanced growth path*), where both the ratio of the capital stock to labour expressed in efficiency units, K/(L.E) and output to labour expressed in efficiency units (or output per effective worker), remain constant over time. As a result, both the capital stock per worker and productivity per worker grow at the same pace as labour augmenting technical progress *E*. Therefore, the growth rate of both coincides with TFP growth divided by the labour share β:

$$\dot{\left(\frac{Y}{L}\right)} = \dot{\left(\frac{K}{L}\right)} = \dot{E} = \frac{\dot{TFP}}{\beta} \qquad (2.4)$$

It should also be noted that, in the steady state, the contribution of capital deepening to output growth is a simple function of TFP[19], which becomes the single driver of labour productivity[20].

$$contrib\dot{\left(\frac{K}{L}\right)} = (1-\beta)\dot{\left(\frac{K}{L}\right)} = \frac{(1-\beta)}{\beta}\dot{TFP} \qquad (2.5)$$

[19] As the labour share β is set equal to 0.65, the long-run contribution of capital deepening to labour productivity growth is 0.54 times TFP growth rate and, under the assumption of a long-run TFP growth equivalent to 1.1% (see section 4.3), this implies a long-run contribution of capital deepening to labour productivity growth equal to 0.6%.

[20] This, in turn, implies that in the long run the growth rate of the capital stock is set equal to the sum of the growth rate of employment and labour augmenting technical progress (the so-called "capital rule").

BOX 1- **Further possible refinements of the production function**

In this paper, we will use a simple form of the production function. However, we can refine its specification to take into account various factors which are not modelled in the baseline but are tackled in the sensitivity tests at the end of the paper.

The key formula (2.3) can be augmented so as to separate out the effect of average annual hours worked per person denoted *h* and the enhancement in capital human HC (e.g. the relative productivity across age groups). If we denote N the number of persons employed and L the total labour input (skill-adjusted hours worked in the economy), we obtain the following relationship:

$$L = h.HC.N \qquad (2.6)$$

Using (2.6), we can rewrite (2.3) in the following way:

$$\dot{\left(\frac{Y}{N}\right)} = \dot{TFP} + (1-\beta).\dot{\left(\frac{K}{N}\right)} + \beta.\dot{HC} + \beta.\dot{h} \qquad (2.7)$$

Therefore, labour productivity growth as measured by the growth in GDP per worker is the weighted sum of the increase in TFP, the stock of physical capital per worker, a human capital indicator and average annual hours worked per worker. The effect of sectoral reallocations can be incorporated in the impact on TFP growth and the accumulation of capital.

However, in the long run, according to the Solow neoclassical model, output per effective worker (or skill-augmented hourly labour productivity growth) and capital per effective worker are constant. This implies that labour productivity growth should equal the growth in TFP (divided by the share of labour in output) in the steady state, when the stock of capital adjusts.. In other words, we get in the *long run*:

$$\dot{\left(\frac{Y}{N}\right)} = \frac{1}{\beta}\dot{TFP} + \dot{HC} + \dot{h} = \dot{E} + \dot{HC} + \dot{h} \qquad (2.8)$$

This means that productivity growth measured as GDP growth per person employed coincides with total factor productivity weighted by the labour share β in total value added, if there is no change in human capital and hours worked per person.

4.2. Short-to-medium term projections (2005-2009): underlying assumptions

For the short-to-medium term the EPC-AWG decided to use the same approach as that used to estimate potential output and thus the output gap. These estimates are used in the assessment of the cyclical budgetary position of Member States, within the surveillance framework of the Stability and Growth pact (SGP)[21]. The statistical approach used by DG ECFIN and the Output Gap Working Group (OGWG) is applied to historical (starting in the mid-1960's) and forecast data. For the historical period the series at hand are taken from DG ECFIN's AMECO databank, with the Commission services final Spring 2005 forecasts for the years 2005-2006 being used. A "Medium Term Extension" model is used to cover a period of 3 years from the end of the short-term forecasts i.e. in this case to run estimates from 2007-2009. It is important to stress that this technical extension is in no way a forecast for these years. It is simply an attempt to illustrate what would happen if the trends of the most recent years were to continue on, using established and transparent ARIMA procedures. The

[21] These estimates are carried out by DG ECFIN under the supervision of the Output Gap Working Group (OGWG), attached to the Economic Policy Committee. For further details, see Denis et al. (2002).

potential growth rates for the three extension years are calculated using the standard key inputs, calculated using the methodology presented below.

4.2.1. Trend Total Factor Productivity (TFP)

Trend TFP is modelled as the Hodrick-Prescott (HP) filtered Solow Residual. TFP is calculated until the end of the short term forecast horizon, using the forecasts for GDP, employment and the capital stock. For the medium term extension, a TFP forecast is generated with a simple autoregressive model, where the log of current TFP is explained by a constant, a time trend and lagged values of TFP. Lags up to three years are allowed such as to render the residual white noise. This is the simplest time series representation and is likely to provide smooth projections. The HP trend is then calculated on the whole series.

4.2.2. Kalman filter generated NAIRU

The trend specification chosen for the NAIRU implies that the best prediction for the change in the NAIRU in future periods is the current estimate of the intercept. This basically implies that the slope of the NAIRU in 2006 should be used for the projection until 2009. Such a specification seems problematic for longer-term projections since it will eventually violate economic constraints (such as non-negativity of the NAIRU, for example). An alternative specification which is more consistent with the common notion of the NAIRU as a stable long run level of the unemployment rate would be a random walk without drift. This specification would imply a flat extrapolation of the last NAIRU value. Though this specification does not work well in estimation for European data where persistent trend changes of the unemployment rate can be observed, it may be a more plausible specification for the projections. The final methodology for the medium term NAIRU agreed by the OGWG represents a compromise between the preceding two concepts. It was decided that the NAIRU would be projected according to the following simple rule:

$$NAIRU_{t+1} = NAIRU_t + .5 * (NAIRU_t - NAIRU_{t-1})$$

In forecasting the NAIRU, while taking into account possible lagged effects of recent reforms, 50% of the most recent decline is allowed for. This implies that the NAIRU is practically stable in 2009, because after 3 years the change in the NAIRU only amounts to 12.5% of the decline in 2006.

4.2.3. Population of working age

In terms of a projection for the population of working age for the three years 2007-2009, Eurostat's most recent population projections are used.

4.2.4. Participation rates

A "cohort component" approach is used to project participation rates by different age groups and gender on a single year basis[22]. In essence, this cohort methodology has the following features:

[22] We use the results provided by Carone (2005) within the same framework of the EPC-AWG projections.

- Entry and exit rates calculated, by single age and sex, as an average over the period 1997-2003.

- Entry rates are assumed to be constant throughout the whole forecasting period with no projected decline in participation rates in the age brackets 15-20.

- Adjustments to exit rates for persons aged 55 to 64 are made to take into account the effects of recent pension reforms in 18 countries.

Moreover, for several Member States (in particular Germany, Belgium and Luxembourg) labour force (and unemployment) figures projected using the labour force survey have been converted into national accounts or administrative data equivalents[23].

4.2.5. Capital formation: fixed investment-to-GDP ratio

Since the purpose of the short-run exercise is to get an estimate for potential output up to 2009, the investment to potential GDP series is used as an exogenous variable. Its projection for the period 2007-2009 is based on an autoregressive (AR) process allowing for a constant and a time trend estimated until 2006. Notice, this makes investment endogenous. For a constant investment to GDP ratio, investment responds to potential output with an elasticity equal to one. Simple investment projections are consistent with the efficient use of physical capital (see BOX 2).

[23] For details on these transformations of the labour input figures see European Commission (2005).

BOX 2- Consistency of the investment rule with the efficiency condition for capital

Cost minimisation requires that firms equate the marginal product of capital to capital costs. Intuitively, this efficiency condition for capital can be derived as follows. An investor in period t has the option of either investing in physical capital or nominal bonds. A unit of physical capital with price P_t invested in period *t* yields a nominal return equal to MPK^N plus the price that can be charged for the used capital good in period *t+1*. Denote this value by $(1-\delta)P_{t+1}$, where δ is the rate of depreciation. Alternatively, investment in nominal bonds yields a return equal to $(1+i_t)P_t$, where i_t is the nominal interest rate. Arbitrage implies that both strategies should yield the same return

(1a) $$(1+i_t)P_t = MPK_t^N + (1-\delta)P_{t+1}.$$

In real terms this can be written as

(1b) $$MPK_t^R = (i_t - \pi_{t+1} + \delta)$$

where π_{t+1} is expected inflation. Because of adjustment rigidities for capital the efficiency condition (1b) does not hold in each period exactly but should be approximately fulfilled over the medium term. Longer term deviations in both directions would signal inefficiencies. If MPK^R is consistently larger than the required return, then investors obviously do not exploit profit opportunities from real investment. If MPK^R is below the required return this would represent a clear case of overinvestment[24]. For a Cobb Douglas production function as assumed here, the marginal product of capital is proportional to capital productivity, where the scaling factor is the output elasticity of capital (1-β) which under constant returns to scale is equal to one minus the wage share

(2) $$MPK_t^R = (1-\beta)\frac{Y_t}{K_t}$$

Substituting the right hand side of equation (1b) in the left hand side of equation (2) and making the suitable arrangements, we get the following expression:

(3) $$K_t = (1-\beta)\frac{Y_t}{(i_t - \pi_{t+1} + \delta)_t}$$

Expressing (3) in terms of investment rate (i.e. ratio of investment to potential output) gives:

(4) $$\frac{I_t}{Y_t} = \frac{\Delta K_t}{Y_t} = \frac{(1-\beta)}{(i_t - \pi_{t+1} + \delta)_t}\frac{\Delta Y_t}{Y_t}$$

Assuming that the real interest rate, the rate of depreciation and the labour share are constant, at least in the medium-run and that potential output growth remains broadly unchanged in the medium-run (which is of course not true in the longer run), we can infer the investment rate is broadly constant in the medium run: the variation in the capital stick is a linear function of potential output in level. Therefore the projections for investment in the medium run based on the investment rule are consistent with the theory and, more precisely, the efficiency condition for capital. As the assumption of constant potential output growth is not valid in the long run anymore, we apply from 2010 to 2030 a transition rule to the steady-state, where capital stock growth strictly equals output growth ("capital rule"). The latter is fully consistent with the efficiency condition of capital, in particular with equation (3), written in terms of growth rate.

[24] Only for Sweden and Finland do we notice an increase in the marginal productivity of capital (MPK) over the next 50 years, using our standard projection for the investment rate. For these two countries the investment rate was therefore calculated such that the MPK remains constant over the next five decades.

4.3. Long run projections (2010-2050) : underlying assumptions

Three principles have been borne in mind when carrying out long term projections :

- Firstly, the need to ensure consistency between the medium term projection based on country-specific trends and the long-run projection based on convergence rules toward the same value of labour productivity at the end of the projection horizon. There is also an overriding constraint to ensure comparability across the EU through the use of a common methodology for all Member States.

- Secondly, as the cross-country comparability of results entails similar assumptions of productivity at the end of the projection, a key issue is whether this convergence should be achieved in growth rates or levels. While economic theory shows that real convergence is conditional upon crucial parameters such as the savings rate and demographic developments, the empirical literature does not support the idea of absolute convergence in levels between countries. So, we will assume convergence in *growth rates* in the present projection exercise. However, the level matters through its influence on the convergence speed and on the need for special TFP growth rate adjustments in a number of countries which have initially relatively low TFP levels (Greece, Italy, Portugal, Spain and all EU10 countries).

- Thirdly, there are large differences of opinion regarding the need for strict convergence to the same growth rate of labour productivity by 2030 across countries, including the newly acceded Member States. On the one hand, it can be argued that a convergence rule is important to ensure comparability of the age-related pension expenditure calculations. On the other hand, it is reasonable to assume ongoing differences after 2030, with these differences reflecting the different starting levels and growth rates of respective countries; different assumptions on convergence in growth rates; and finally the huge diversity in the EU25. As a compromise, the EPC-AWG agreed that the TFP projections could converge quickly to the same growth rate in order to take account of those EU15 countries which had very low or very high TFP growth rates at the start of the projection exercise. For the EU10 Member States, whilst accepting that it would be wrong to treat them as a homogeneous group, concerns were nevertheless expressed that the differences across countries were too great and persisting for too long a period. In addition, the capital deepening assumption for these countries could be adjusted to allow for greater convergence.

4.3.1. Total Factor Productivity

The assumption on TFP is crucial since in the long run (2010-2050), labour productivity growth (output per person employed) broadly coincides with TFP growth (divided by the share of labour in output). Different options were possible. The EPC-AWG agreed that a prudent assumption for TFP would be that country-specific TFP growth would converge by 2030-2050 to the past TFP growth rate recorded for the EU as a whole over a long period (1970-2004), i.e. 1.1% per annum, with the speed of the convergence process perhaps dictated by the size of the initial gap in TFP levels. According to DG ECFIN's AMECO database, this average rate is almost identical to that experienced in the leading economy in the world, i.e. the US, in the very long run (since the 1960s). However it is slightly lower than that seen in the US more recently (around 1.2% since 1990 compared with 0.8% in the EU15). In effect, it is safer to base longer term TFP projections on long-term past trends rather than on the most recent developments which are more likely to be influenced by special factors (such as the ICT boom in the 1990s). The other possible options, shown in Table 4, were considered more arbitrary.

Table 4 : **Some other options for the long-term TFP growth rate assumption**

Options	**Economic implications**
Using deterministic country trend model specification for TFP level (AR process + time trend)	The long run trend TFP reverts to the average trend estimated for *each country* over the considered historical period (say 1973-2003 or 1995-2005)
Using stochastic trend model specification for TFP level (unobserved component).	Trend TFP is heavily influenced by recent TFP growth rates recorded by each country.
Using the past trend (AR or HP-filtered) TFP growth for the *EU as a whole.*	This supposes a fast convergence of productivity levels in Europe, which is completed in 2008.
Convergence towards the US growth rate (an "*optimistic"* and illustrative scenario where all 15 EU countries converge to the US TFP growth rate, with the speed of the convergence process dictated by the size of the initial gap in TFP levels.)	This supposes that the TFP gap with the US should close rapidly, with the current contribution of TFP growth for the EU (around 0.8-0.9 percentage points) rising up to around 1.2 percentage points.

Therefore the assumptions are as follows :

- TFP growth rates will converge to 1.1% by 2030 for all EU15 Member States, with different speeds of convergence for individual Member States depending on the gap in TFP levels;

- for the EU10 Member States, TFP will converge to 1.75% by 2030 and, at the same pace, to 1.1% in 2050. In order to allow for a faster convergence both across the EU10 and between the EU15 and the EU10, three quarters of the convergence towards 1.75% and subsequently to 1.1% is achieved in 2015 and 2035 respectively;

- as the TFP level as a percentage of the EU15 average appears too low at the end of the projection period, some ad-hoc adjustments have been made for Greece, Portugal, and Spain (see BOX 3). These adjustments aim at avoiding any strong divergence in productivity levels in the cohesion countries, which are often considered to belong to the "convergence club", as opposed to the "frontier club". For Italy, the slightly faster convergence in growth rates takes into account the fact that recent (unfavourable) productivity trends may partly reflect special circumstances (i.e. the short-term adverse effects of labour market reforms and of dynamic employment growth on productivity) and should not be extrapolated for too long a time period.

These assumptions suggest that the projection relies on some degree of arbitrariness, which illustrates the uncertainty surrounding all long term projections. Moreover, for the sake of simplicity, the assumptions are not taking into account some specific effects of ageing populations, as TFP is supposed to be exogenous. In particular, while rising levels of participation, which is likely to benefit the less skilled workers or those without work experience, may depress TFP, the projected rise in educational attainment can be expected to enhance TFP growth. Likewise, the change in the age structure of the working population may weigh down on TFP given the age profile of productivity (for this issue see sensitivity tests in section 6). Nonetheless, available studies suggest that older workers are not systematically less productive than younger ones, the main factor being the level of education. Some also argue that older workers may be more inflexible and more reluctant to innovate and to embrace technological changes. Given the great deal of uncertainty attached to this issue, it has not been included in the productivity projections. On balance, the assumptions for TFP remain reasonable and are meant to avoid strong divergences in TFP levels.

BOX 3 - Country specific adjustments

These adjustments were made to take into account the specifc situation of the cohesion countries, which might require some additional convergence in levels, and to tackle a number of country specific issues in the "old" Member States. These adjustments have been made following the advice provided by the national delegates of the concerned countries in the EPC's Ageing Working Group.

Greece. Three quarters of the TFP convergence process to 1.1% is achieved by 2015 (high convergence from a lower level than that of the steady state). Then TFP growth converges linearly to reach 1.1% in 2030.

Portugal. TFP growth converges in 2013 towards 1.6% (i.e. 3/4 of the intermediate target for EU10) and stays at that level until 2026. Then TFP growth converges to 1.1% in 2030, like for the other EU15 countries. The projection of TFP allows for a fairly smooth convergence path to 1.6% and then to 1.1% by using reasonable transition periods (2010-2012 and 2027-2029) and a quadratic convergence pattern (rather than linear) so as to avoid implausible and excessively mechanistic dynamics. This ad hoc adjustment is motivated by the need to allow some real convergence in Portugal, given their low initial level of productivity and the strong catching-up dynamics in the EU10. However, as Portugal has been already in the EU15 since 1986, benefiting from a favourable economic environment for catching-up, its productivity convergence is projected to be significantly lower than in the EU10. The Portuguese delegation to the AWG also claims that such an adjustment is consistent with a closing of the human capital gap in Portugal and broadly corresponds to the estimated effect of increasing the average number of years of formal education in the same way as observed in Ireland, Italy, Spain and Greece in 1970-1998. It assumes that the human capital catch-up has been delayed and is expected to broadly have the same magnitude as that recorded by the other cohesion countries (plus Italy) in the past.

Spain. The new GDP and employment National Accounts data released for Spain are used at the start of the projection period. Moreover, the TFP convergence to 1.1% is achieved by 2012 instead of 2030.

Italy. TFP converges to 1.1% by 2015 instead of 2030. This higher speed of convergence results in an average labour productivity growth rate for Italy over the period 2011-2050 of around 1.7%. This labour productivity growth rate is now similar to the average rates assumed for other large Euro area countries such as Germany and France.

4.3.2. *Working age population*[25]

The population projection used to estimate GDP and labour productivity growth, is a variant of the Europop 2004 projections[26], prepared by Eurostat. Compared to Europop 2004, the EPC-AWG-variant produced by Eurostat contains two major changes, introduced upon a request from national statistical offices and members of the EPC-AWG:

- the first one is a convergence in life expectancy[27] across the EU15 Member States; [28]
- the second change is in the number of (working age) migrants in Germany and Italy, which is higher because of specific adjustments made to the level and/or age structure of migrants compared to Europop 2004. For Spain, only the age structure of net migration was adjusted, not the net flows of migrants. Table 5 shows the projections for life expectancy at birth and for the total population in both the Europop 2004 and the AWG variant scenario, as well as the difference between the two scenarios. Table 6 presents the net migration flows in the AWG variant scenario and the difference with the assumptions in Europop 2004 for Germany, Spain and Italy.

The main results of the demographic projections are reported in Table 7. The size and age structure of the EU25 population is projected to undergo dramatic changes in the coming decades due to the dynamics of fertility, life expectancy and migration rates. The overall size of the population is projected to be both smaller and older than it is now. Under the baseline scenario, the EU25 population is projected to increase slightly, by 3% until 2025, when it will peak at 470 million. Thereafter, a steady decline occurs and, according to the projections, the population in 2050 will be smaller than in 2004, at 449 million.

The working age population (15 to 64) is already declining in Germany, Italy, Hungary and Latvia. In many other countries the decline will start in 2010-2011 (Belgium, Greece, Spain, France, the Netherlands, Austria, Poland and others).

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[25] For details on the methodology and results see Carone (2005).

[26] See Eurostat (2005).

[27] A convergence rule is defined whereby a convergence coefficient is applied to adjust the life expectancy levels in the EUROPOP 2004 projections and to narrow the deviation from the EU15 average. The convergence rule is defined as follows:

For the EU15 countries (but not for the EU10 countries, where a convergence factor was already included in Europop 2004), the life expectancy *e* at age *x* for sex *s* in country *c* is forced towards the EU15 average emerging from the baseline of Europop 2004 by applying a convergence coefficient *k* varying along time *t*. The convergence coefficient increases linearly over time from k=0 in 2004 to k=0.5 in 2050, when the range of variation in life expectancy from the baseline of EUROPOP 2004 is halved.

[28] The Europop 2004 assumptions on life expectancy at birth already incorporate a convergence factor for the EU10 countries, and thus the AWG variant scenario does not cover the EU10 for which the original Europop 2004 projections are used.

Table 5: **Comparison of Europop 2004 and the EPC-AWG variant population scenario : life expectancy and population**

Country	Life expectancy at birth in 2050						Total population, in millions					
	Males			Females			Males			Females		
	AWG	*EUROPOP*	*Diff.*	*AWG*	*EUROPOP*	*Diff.*	*AWG*	*EUROPOP*	*Diff.*	*AWG*	*EUROPOP*	*Diff.*
Belgium	82,1	82,3	-0,2	87,5	88,3	-0,8	5,3	5,3	0,0	5,5	5,6	0,0
Denmark	81,4	80,9	0,5	85,2	83,7	1,5	2,7	2,7	0,0	2,8	2,7	0,0
Germany	82,0	82,0	0,0	86,8	86,8	0,0	38,0	36,7	1,3	39,7	38,0	1,8
Greece	81,1	80,3	0,8	85,9	85,1	0,8	5,3	5,3	0,0	5,4	5,4	0,1
Spain	81,7	81,4	0,3	87,3	87,9	-0,6	21,1	20,7	0,3	21,9	22,1	-0,2
France	82,3	82,7	-0,4	87,9	89,1	-1,2	31,9	32,1	-0,1	33,2	33,6	-0,4
Ireland	82,2	82,4	-0,2	86,8	87,0	-0,1	2,7	2,7	0,0	2,8	2,8	0,0
Italy	82,8	83,6	-0,8	87,8	88,8	-1,0	26,3	25,8	0,6	27,4	26,9	0,5
Luxembourg	81,8	81,6	0,2	86,7	86,7	0,0	0,3	0,3	0,0	0,3	0,3	0,0
Netherlands	81,1	80,2	0,9	85,2	83,6	1,6	8,7	8,7	0,1	8,9	8,8	0,1
Austria	82,8	83,6	-0,8	87,2	87,7	-0,5	4,0	4,0	0,0	4,2	4,2	0,0
Portugal	81,2	80,4	0,8	86,7	86,6	0,0	4,9	4,9	0,0	5,2	5,2	0,0
Finland	81,9	81,9	0,0	86,6	86,5	0,1	2,6	2,6	0,0	2,6	2,6	0,0
Sweden	82,6	83,3	-0,7	86,6	86,5	0,1	5,1	5,1	0,0	5,1	5,1	0,0
United Kingdom	82,4	82,9	-0,5	86,7	86,6	0,1	31,8	32,0	-0,1	32,4	32,4	0,0
Cypros	81,9	81,9	0,0	85,1	85,1	0,0	0,5	0,5	0,0	0,5	0,5	0,0
Czech Republic	79,7	79,7	0,0	84,1	84,1	0,0	4,4	4,4	0,0	4,5	4,5	0,0
Estonia	74,9	74,9	0,0	83,1	83,1	0,0	0,5	0,5	0,0	0,6	0,6	0,0
Hungary	78,1	78,1	0,0	83,4	83,4	0,0	4,3	4,3	0,0	4,6	4,6	0,0
Lithuania	75,5	75,5	0,0	83,7	83,7	0,0	1,4	1,4	0,0	1,5	1,5	0,0
Latvia	74,3	74,3	0,0	82,5	82,5	0,0	0,9	0,9	0,0	1,0	1,0	0,0
Malta	81,8	81,8	0,0	85,0	85,0	0,0	0,3	0,3	0,0	0,3	0,3	0,0
Poland	79,1	79,1	0,0	84,4	84,4	0,0	16,4	16,4	0,0	17,3	17,3	0,0
Slovak Republic	77,7	77,7	0,0	83,4	83,4	0,0	2,3	2,3	0,0	2,4	2,4	0,0
Slovenia	79,8	79,8	0,0	85,1	85,1	0,0	0,9	0,9	0,0	1,0	1,0	0,0

Source: Eurostat, Commission services.

Table 6: **Projected net migration flows in AWG-variant population scenario (‘000 persons, % of total population, simulated net inflows)**

	in thousands						*as a % of total population*		*cumulated 2004-2050*
	2004	2010	2020	2030	2040	2050	*2004*	*2050*	
Belgium	24	20	19	19	19	19	*0.23*	*0.17*	*897*
Denmark	8	7	7	7	7	7	*0.15*	*0.12*	*323*
Germany	270	230	215	205	200	200	*0.33*	*0.26*	*10180*
Greece	43	40	39	35	35	35	*0.39*	*0.33*	*1743*
Spain	508	112	110	105	104	102	*1.22*	*0.24*	*6235*
France	64	62	60	59	59	59	*0.11*	*0.09*	*2823*
Ireland	16	15	14	13	13	12	*0.41*	*0.23*	*645*
Italy	150	150	150	150	150	150	*0.26*	*0.28*	*7050*
Luxembourg	3	3	3	3	3	3	*0.63*	*0.43*	*132*
Netherlands	21	33	33	32	31	31	*0.13*	*0.18*	*1480*
Austria	25	24	21	19	20	20	*0.31*	*0.25*	*985*
Portugal	42	18	16	15	15	15	*0.40*	*0.15*	*808*
Finland	6	6	6	6	6	6	*0.12*	*0.12*	*288*
Sweden	28	24	23	22	22	21	*0.31*	*0.21*	*1069*
United Kingdom	139	116	103	99	99	98	*0.23*	*0.15*	*4939*
Cyprus	6	6	5	5	5	5	*0.83*	*0.50*	*238*
Czech Republic	4	3	10	22	21	20	*0.04*	*0.22*	*647*
Estonia	1	-2	0	2	2	2	*0.06*	*0.15*	*19*
Hungary	15	13	14	21	21	20	*0.15*	*0.22*	*795*
Lithuania	-6	-6	-1	5	4	4	*-0.16*	*0.15*	*28*
Latvia	-2	-3	-1	3	3	3	*-0.09*	*0.15*	*30*
Malta	3	2	2	2	2	3	*0.64*	*0.50*	*113*
Poland	-28	-35	-11	36	35	34	*-0.07*	*0.10*	*318*
Slovak Republic	-2	-2	1	5	5	5	*-0.04*	*0.10*	*109*
Slovenia	6	6	5	7	7	7	*0.31*	*0.35*	*287*
EU25	*1464*	*783*	*789*	*835*	*830*	*822*	*0.32*	*0.18*	*39710*
EU15	*1467*	*801*	*765*	*727*	*724*	*721*	*0.38*	*0.19*	*37123*
EU10	*-3*	*-18*	*24*	*107*	*105*	*101*	*0.00*	*0.15*	*2586*

Difference with EUROPOP2004

	in thousands						*as a % of total population*		Cumulated 2004-50
	2004	2010	2020	2030	2040	2050	2004	2050	
Germany	59.4	26.8	20.7	24.0	20.7	20.8	0.1	0.0	1199.6
Spain	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Italy	-180.0	31.9	31.9	36.2	36.1	36.2	-0.3	0.1	6405.2

ource: Eurostat, Commission services.

Table 7 : Population projections : baseline scenario: peaks and troughs

Total population

Country	Starting year:2003 *(value in thousands)*	Peak year	Value	Trough year	Value	Difference: from 2003 to peak		Difference: from peak to trough	
						Absolute	%	Absolute	%
Belgium	10356	2036	11012	2050	10849	656	6.3	-163	-1.5
Denmark	5384	2033	5607	2050	5493	223	4.1	-114	-2.0
Germany	82537	2020	83500	2050	77742	963	1.2	-5758	-6.9
Greece	11006	2020	11438	2050	10734	431	3.9	-704	-6.2
Spain	41551	2022	45634	2050	42977	4084	9.8	-2657	-5.8
France	59630	2040	65649	2050	65148	6019	10.1	-502	-0.8
Ireland	3964	2050	5475			1511	38.1		
Italy	57321	2014	58592	2050	53762	1271	2.2	-4831	-8.2
Luxembourg	448	2050	643			195	43.4		
Netherlands	16193	2038	17773	2050	17628	1581	9.8	-145	-0.8
Austria	8067	2029	8510	2050	8170	442	5.5	-340	-4.0
Portugal	10407	2019	10781	2050	10051	374	3.6	-730	-6.8
Finland	5206	2028	5446	2050	5218	240	4.6	-228	-4.2
Sweden	8941	2050	10181			1240	13.9		
United Kingdom	59438	2039	64679	2050	64210	5241	8.8	-469	-0.7
Cyprus	715	2050	975			260	36.3		
Czech Republic	10203	2004	10211	2050	8894	8	0.1	-1318	-12.9
Estonia	1356	2003	1356	2050	1126	0	0.0	-230	-17.0
Hungary	10142	2003	10142	2050	8915	0	0.0	-1227	-12.1
Lithuania	3463	2003	3463	2050	2881	0	0.0	-581	-16.8
Latvia	2331	2003	2331	2050	1873	0	0.0	-459	-19.7
Malta	397	2050	508			111	27.9		
Poland	38219	2003	38219	2050	33665	0	0.0	-4553	-11.9
Slovak Republic	5379	2004	5380	2050	4738	1	0.0	-642	-11.9
Slovenia	1995	2014	2019	2050	1901	24	1.2	-118	-5.8
EU25	**454649**	**2027**	**471553**	**2050**	**453755**	**16904**	**3.7**	**-17798**	**-3.8**
EU15	**380448**	**2029**	**400632**	**2050**	**388280**	**20183**	**5.3**	**-12351**	**-3.1**
Eurozone	**306686**	**2026**	**321057**	**2050**	**308397**	**14371**	**4.7**	**-12661**	**-3.9**
EU10	**74201**	**2003**	**74201**	**2050**	**65475**	**0**	**0.0**	**-8726**	**-11.8**

Working-age Population (15-64)

Country	Starting year:2003 *(value in thousands)*	Peak year	Value	Trough year	Value	Difference: from 2003 to peak		Difference: from peak to trough	
						Absolute	%	Absolute	%
Belgium	10356	2011	6988	2050	6286	-3368	-32.5	-702	-10.0
Denmark	5384	2008	3596	2044	3244	-1787	-33.2	-352	-9.8
Germany	82537	2003	55682	2050	44975	-26854	-32.5	-10707	-19.2
Greece	11006	2010	7557	2050	5877	-3450	-31.3	-1680	-22.2
Spain	41551	2010	30301	2050	22937	-11249	-27.1	-7365	-24.3
France	59630	2011	40068	2050	37440	-19562	-32.8	-2628	-6.6
Ireland	3964	2035	3311	2050	3166	-653	-16.5	-144	-4.4
Italy	57321	2004	38549	2050	29342	-18772	-32.7	-9208	-23.9
Luxembourg	448	2050	394			-54	-12.1		
Netherlands	16193	2011	11238	2039	10428	-4954	-30.6	-811	-7.2
Austria	8067	2012	5607	2050	4698	-2460	-30.5	-909	-16.2
Portugal	10407	2008	7135	2050	5514	-3272	-31.4	-1622	-22.7
Finland	5206	2010	3526	2050	3015	-1680	-32.3	-511	-14.5
Sweden	8941	2050	6046			-2895	-32.4		
United Kingdom	59438	2011	40491	2050	37763	-18947	-31.9	-2728	-6.7
Cyprus	715	2043	608	2050	590	-107	-14.9	-18	-2.9
Czech Republic	10203	2007	7252	2050	5023	-2951	-28.9	-2229	-30.7
Estonia	1356	2006	917	2050	670	-439	-32.3	-247	-26.9
Hungary	10142	2003	6949	2050	5182	-3193	-31.5	-1768	-25.4
Lithuania	3463	2006	2322	2050	1717	-1141	-32.9	-605	-26.1
Latvia	2331	2003	1589	2050	1108	-742	-31.8	-482	-30.3
Malta	397	2041	311	2050	309	-86	-21.7	-2	-0.8
Poland	38219	2011	27165	2050	19399	-11053	-28.9	-7767	-28.6
Slovak Republic	5379	2010	3887	2050	2741	-1492	-27.7	-1147	-29.5
Slovenia	1995	2011	1414	2050	1065	-581	-29.1	-349	-24.7
EU25	**454649**	**2011**	**311039**	**2050**	**259102**	**-143610**	**-31.6**	**-51936**	**-16.7**
EU15	**380448**	**2011**	**259033**	**2050**	**221300**	**-121415**	**-31.9**	**-37733**	**-14.6**
Eurozone	**306686**	**2011**	**208974**	**2050**	**174219**	**-97713**	**-31.9**	**-34755**	**-16.6**
EU10	**74201**	**2009**	**52125**	**2050**	**37803**	**-22076**	**-29.8**	**-14322**	**-27.5**

Source: Eurostat Commission services.

In the EU25, the working age population is projected to record a sharp decline, down from 67.2% of the overall population to 57%, due to a reduction of more than 45 million people of working age (from 305.2 million in 2003 to 259.1 million in 2050), a drop of around 15%. This is the result of a projected shrinking of the youth (aged 15 to 24) and the prime-age population (aged 25 to 54), which is expected to decrease, starting from 2011 in the EU25. These trends will lead to a dramatic change in the ratio of people of working age to those in retirement.

4.3.3. Participation rates

The labour force projections taken as the basis for the EPC-AWG budgetary projection exercise are reproduced in Table 8. To summarise the outcome of the baseline scenario projection, the aggregate overall participation rates (for the age group 15 to 64) in the EU25 are projected to increase by about 6 percentage points over the period 2003 to 2050 (from 69.4% in 2003 to 74.6% in 2025 and to 75.2% in 2050).

Table 8 : **Projected changes in participation rates, 2003-2050**

	Changes in participation rates (age 15-64)			***Changes in participation rates (age 15-71)***		
	2003-2050	2003-2025	2025-2050	2003-2050	2003-2025	2025-2050
Belgium	5.0	4.3	0.8	2.8	2.0	0.8
Denmark	2.1	1.4	0.7	0.0	-1.0	1.0
Germany	6.4	6.1	0.3	3.8	4.0	-0.2
Greece	4.6	4.5	0.1	1.1	3.1	-2.1
Spain	9.2	8.0	1.2	4.0	6.3	-2.3
France	3.8	2.4	1.4	1.8	0.5	1.3
Ireland	8.4	7.4	1.0	3.9	5.4	-1.6
Italy	7.4	5.2	2.2	4.3	3.6	0.7
Luxembourg	3.4	2.8	0.5	1.8	1.0	0.7
Netherlands	4.0	2.6	1.4	1.6	-0.2	1.8
Austria	6.9	5.6	1.3	2.7	2.4	0.2
Portugal	5.0	4.4	0.5	1.8	3.3	-1.4
Finland	5.1	4.4	0.7	2.2	1.3	0.9
Sweden	3.6	3.3	0.3	2.0	1.5	0.5
United Kingdom	3.0	2.5	0.5	0.6	0.9	-0.3
Cyprus	9.9	10.9	-1.0	5.1	7.9	-2.8
Czech Republic	4.2	6.8	-2.6	-1.2	3.6	-4.8
Estonia	6.0	7.2	-1.2	3.2	5.6	-2.4
Hungary	5.9	8.0	-2.2	2.9	5.6	-2.7
Lithuania	7.1	9.0	-1.9	3.9	7.4	-3.4
Latvia	7.4	9.3	-1.9	4.6	7.8	-3.1
Malta	7.4	8.6	-1.2	3.4	5.2	-1.8
Poland	7.2	9.8	-2.5	1.4	5.6	-4.2
Slovak Republic	3.8	8.1	-4.3	-3.2	4.1	-7.2
Slovenia	6.1	6.7	-0.6	1.7	3.9	-2.2
EU25	**5.9**	**5.3**	**0.6**	**2.7**	**3.2**	**-0.5**
EU15	**5.7**	**4.6**	**1.1**	**2.9**	**2.8**	**0.1**
Eurozone	**6.2**	**5.1**	**1.1**	**3.2**	**3.2**	**0.1**
Nms10	**6.4**	**8.9**	**-2.5**	**1.2**	**5.3**	**-4.1**

Source: Commission services-DG ECFIN.

4.3.4. Moving from labour force to employment projections : assumptions on structural unemployment

In order to move from labour force projections to employment projections, the EPC-AWG agreed to use the NAIRU calculation as the best available proxy for a projection of a structural unemployment rate under a "*no policy change*" scenario. Although significant uncertainty remains around this assumption, it was agreed that, as a general rule, unemployment rates converge towards the 2009 European Commission-DG ECFIN estimates of the NAIRU's for each country, and afterwards they are kept constant. The EPC-AWG considered this a reasonable assumption which also had the advantage of ensuring consistency with other budgetary surveillance procedures in the European Union. Indeed, these NAIRU estimates are already used for the calculation of the output gap, and widely discussed and agreed upon by Member States' delegates in the EPC's Output Gap Working Group (OGWG).

As explained earlier, the 2009 NAIRU is calculated by projecting the latest estimates of the NAIRU (based on the Spring 2005 Commission services forecast) up to 2009 according to the following simple rule:

$$NAIRU_{t+1} = NAIRU_t + .5 * (NAIRU_t - NAIRU_{t-1})$$

Thus, in order to forecast the NAIRU and take into account possible lagged effects of recent reforms, 50% of the most recent decline in actual unemployment rates is attributed to a decline in the NAIRU.

To avoid extrapolating forward high NAIRU levels for countries still above the EU15 average (Germany, Greece, Spain, France, Italy and Finland), the EPC-AWG agreed a convergence to the 2009 EU15 average, over a period of 10 years. As regards the EU10 Member States which have relatively high unemployment rates (Poland and Slovakia), the EPC-AWG agreed a convergence towards the 2009 EU15 average NAIRU over a longer time horizon of 20 years. For the three EU10 Member States where the current unemployment rate is already below the proposed target (Cyprus, Hungary, Slovenia), it was agreed to keep the estimated trend unemployment rate in 2004 constant (3.8% in Cyprus, 4.8% in Hungary and 6% in Slovenia), while for the remaining EU10 Member States the convergence towards the EU15 2009 average is completed in 10 years.

The methodology agreed by the EPC-AWG to guarantee the convergence of the unemployment rate of some Member States towards the 2009 EU15 average by 2015 had the effect of reducing the euro area average. As a result, those countries where unemployment rates were close to the EU15 average in 2003 (such as Belgium, Italy, and the Czech Republic) and below the euro area unemployment rate in 2003, were penalised in terms of their relative position within the euro area, ending up with a long-run unemployment rate higher than the euro area average. The EPC-AWG agreed to adopt a simple solution in the final calculations, i.e. to reduce by a further 0.5% points the long-term unemployment rate in Belgium, Italy and the Czech Republic in order to stay in line with the long-term euro area average.

Table 9 shows the results of the projection, carried out following the agreed approach. Overall, a reduction in the unemployment rate of around 3 percentage points is projected for the EU25 (from 9.2% in 2005 to 6.2% in 2025) and a bit lower for the EU15 (2 percentage points, from 8% to 6%). This difference is due to the agreed path of convergence for Poland and Slovakia, which implies a substantial reduction in their unemployment rates (12.7 percentage points and 10.3 percentage points respectively) over the period 2004-2025.

Table 9 : **Unemployment rate assumptions (age 15-64) (in %)**

Country	2003	2005	2010	2015	2020	2025	2030	2050	Change 2003-2025
Belgium	8,2	7,7	7,0	6,5	6,5	6,5	6,5	6,5	-1,7
Denmark	5,5	4,9	4,3	4,3	4,3	4,3	4,3	4,3	-1,2
Germany	9,9	9,4	8,5	7,0	7,0	7,0	7,0	7,0	-2,9
Greece	9,8	9,3	8,6	7,0	7,0	7,0	7,0	7,0	-2,8
Spain	11,6	10,4	8,7	7,0	7,0	7,0	7,0	7,0	-4,6
France	9,0	9,1	8,3	7,0	7,0	7,0	7,0	7,0	-2,0
Ireland	4,8	4,0	3,4	3,4	3,4	3,4	3,4	3,4	-1,4
Italy	8,9	8,2	7,3	6,5	6,5	6,5	6,5	6,5	-2,4
Luxembourg	3,7	4,0	4,2	4,2	4,2	4,2	4,2	4,2	0,6
Netherlands	3,7	3,5	3,2	3,2	3,2	3,2	3,2	3,2	-0,5
Austria	4,3	3,9	3,4	3,4	3,4	3,4	3,4	3,4	-0,9
Portugal	6,7	6,0	5,6	5,6	5,6	5,6	5,6	5,6	-1,1
Finland	9,2	8,0	6,8	6,5	6,5	6,5	6,5	6,5	-2,7
Sweden	5,7	5,0	4,3	4,3	4,3	4,3	4,3	4,3	-1,4
United Kingdom	5,1	4,8	4,6	4,6	4,6	4,6	4,6	4,6	-0,5
Cypros	4,4	4,0	4,2	4,2	4,2	4,2	4,2	4,2	-0,2
Czech Republic	7,9	7,8	7,3	6,5	6,5	6,5	6,5	6,5	-1,4
Estonia	10,3	9,1	7,8	7,0	7,0	7,0	7,0	7,0	-3,3
Hungary	5,9	5,3	4,8	4,8	4,8	4,8	4,8	4,8	-1,2
Lithuania	12,5	11,2	8,9	7,0	7,0	7,0	7,0	7,0	-5,5
Latvia	10,7	9,1	7,6	7,0	7,0	7,0	7,0	7,0	-3,7
Malta	7,6	8,5	8,3	7,0	7,0	7,0	7,0	7,0	-0,6
Poland	20,1	18,7	15,8	12,9	9,9	7,0	7,0	7,0	-13,1
Slovak Republic	17,6	16,7	15,2	12,5	9,7	7,0	7,0	7,0	-10,6
Slovenia	6,8	6,0	5,5	5,5	5,5	5,5	5,5	5,5	-1,2
EU25	**9,3**	**8,7**	**7,8**	**6,7**	**6,4**	**6,1**	**6,1**	**6,1**	**-3,1**
EU15	**8,2**	**7,7**	**7,0**	**6,1**	**6,1**	**6,1**	**6,1**	**6,0**	**-2,2**
Eurozone	**9,0**	**8,5**	**7,6**	**6,5**	**6,5**	**6,5**	**6,5**	**6,4**	**-2,5**
EU10	**14,8**	**13,8**	**12,0**	**10,0**	**8,3**	**6,6**	**6,6**	**6,6**	**-8,3**

Source: Commission services-DG ECFIN.

4.3.5. Capital formation : transition to the steady state

In the medium run (up to 2009), the capital stock is derived from the ratio of investment to GDP (i.e. the "investment rule"). As the latter is extrapolated from historical values using time-series techniques, it turns out broadly constant up to 2009. This scenario works very well for the EU15 countries but leads to excessively optimistic investment performances for a number of the EU10 Member States since it extrapolates forward very high investment rates which are associated with the structural transition process. Moreover, this rule is fine provided that the user cost of capital remains stable, which should not be the case with declining economic growth rates associated with ageing. Indeed, movements in interest rates are supposed to broadly follow developments in potential output in the long run, as indicated in the golden rule of the Solow or Ramsey models.

Therefore, one might impose that, in the long-run, the capital stock adjusts to the steady state path. The so-called *"Capital Rule"* provides that the growth rate of the capital stock is set equal to the sum of the growth rate of employment and labour augmenting technical progress. As seen in section 4.1, this fulfils the steady state property, as the ratio of capital stock to labour expressed in efficiency units remains constant over time. Consequently the labour productivity growth rate coincides with that of labour-augmenting technical progress.

Nevertheless, this scenario results in very sharp shifts in investment rates for a large number of countries in the year in which the rule is introduced. When this rule is directly introduced from 2010 onwards, the investment rate is unacceptably large for a substantial number of countries (even if the breaks in the investment series become smaller over time as one moves to the balanced growth path). In addition, the introduction of the rule in 2010 results in relatively pessimistic productivity projections for a large number of the catching up countries whilst making little difference for those countries which are already close to their long run TFP growth rates.

Therefore, a transition between the investment rule and the capital rule should be worked out to smoothen the profile of investment. The following pattern for capital formation has been used:

(i) the capital stock dynamics is derived from the investment/GDP ratio until 2009, which is kept broadly constant ("investment rule");

(ii) the transition to the constant capital/labour ratio assumption is introduced gradually over the period 2010-2030 in a linear manner ("transition rule");

(iii) the capital/labour ratio (in efficiency units) is constant from 2030 to 2050 ("capital rule").

5. MAIN RESULTS OF BASELINE PROJECTIONS

5.1. Results for EU25, Euro Area, EU15 and EU10

Table 10 presents the outcome of the projections for potential growth rates up to 2050 as well as its determinants. For the EU25, the annual average potential GDP growth rate of 2.4% in the period 2004 to 2010 is projected to decline sharply, down to 1.5% in the period 2021-30 and to stabilise at 1.2% in the period 2031-2050. The projected fall in potential growth rates is much higher in the EU10 (3.6 percentage points) than in the EU15 (about 1 percentage point). For the EU10, the potential growth rate of 4.2% between 2004 and 2010 is projected to fall to only 0.6% between 2041 and 2050, lower than the projected growth rate of 1.3% for the EU15 at the end of the projection period. Over the whole period 2004-2050, output growth rates remain much higher in the EU10 than in the EU15, reflecting the strong expected economic catch-up in the EU10 Member States. However, GDP growth rates in the EU25 are very close to those in the EU15, as the latter represents more than 90% of the EU25 total output at the start of the projection period.

Tables 11 and 12 indicate the contribution of productivity per person employed and employment to projected potential growth rates. The much stronger decline in potential growth rates in the EU10 occurs especially because of less favourable demographic projections. Moreover, the productivity growth rates of the EU10 and of the EU15 Member states are assumed to converge to the rate of 1.7% at the very end of the projection horizon. This means that, compared with the period 2004-2010, labour productivity growth should slightly increase in the EU15 and sharply fall in the EU10 from a quite high starting level of 3.5%.

Table 13 and 14 show the contribution of the main determinants of productivity per person employed, i.e. TFP growth and capital deepening. TFP growth explains most of the productivity growth per person employed. This is all the more so since, in the long-run, the capital deepening contribution follows TFP growth (times the labour share). By construction, TFP growth converges towards the rate of 1.1% at the end of the projection for all Member States, which, given the use of the "capital rule", implies a labour productivity growth rate of 1.7% for all countries in the steady state (reached in 2030 for the EU25 and in 2050 for the EU10).

While the capital deepening profile is in line with that of TFP growth from 2030, the capital dynamics in the period 2004-30 is more complex and worth describing further. In the EU15, the contribution of capital deepening rises from 0.4 p.p. in 2004-2010 to 0.7 p.p. in 2011-2030, mirroring the positive impact of the demographic slowdown on the capital/labour ratio. Then, the capital deepening contribution takes its "steady state" value of 0.6 p.p. in the period 2030-2050. For the EU10, the capital deepening contribution is initially very high (around 1.6 p.p. between 2004 and 2020), consistent with the caching-up process of converging economies and the strong slowdown in employment growth. Then, the contribution gradually declines to the steady state value of 0.6 p.p., as the growth in the capital stock slowly adjusts to employment growth. Overall, the contribution of capital deepening in the EU10 is almost double that in the EU15 on average over the whole period 2004 to 2050.

Table 15 presents the projections for GDP per capita growth rates. As expected, the projected decline in output per capita growth rates in both the EU15 and the EU10 is smaller than the projected fall in output growth rates, since total population growth rates are also projected to drop over the period 2004-2050.

As a consequence of faster growth in GDP per capita in the EU10 than in the EU15 and despite the very severe population ageing in the EU10, the level of income per capita in the EU10 is projected to increase from 50% of the EU15 average in 2004 to 78% in 2050 (see Table 16). As indicated in Table 17, these developments result from the strong rise in projected EU10 productivity levels relative to the EU15, which reach 83% in 2050.

Table 10 : **Projected potential growth rates (based on underlying assumptions to be used in baseline EPC projection exercise (annual average growth)**

	2004-2010	2011-2020	2021-2030	2031-2040	2041-2050	2004-2050
BE	2.4	2.1	1.4	1.5	1.5	1.7
DK	2.0	1.9	1.4	1.3	1.8	1.7
DE	1.7	1.8	1.0	1.1	1.2	1.3
GR	2.9	2.0	1.2	0.8	0.8	1.5
ES	3.0	2.5	1.5	0.6	0.6	1.6
FR	2.2	1.9	1.7	1.6	1.6	1.8
IE	5.5	4.1	2.6	1.8	1.4	2.9
IT	1.9	1.8	1.2	0.8	1.1	1.3
LU	4.0	3.0	2.9	3.0	3.0	3.1
NL	1.7	1.8	1.4	1.6	1.8	1.7
AT	2.2	2.1	1.2	1.2	1.3	1.5
PT	1.9	2.4	1.9	0.8	0.8	1.5
FI	2.7	1.9	1.5	1.6	1.4	1.8
SE	2.7	2.7	2.1	1.8	1.9	2.2
UK	2.8	2.5	1.7	1.5	1.5	2.0
CY	4.3	4.1	2.9	2.3	1.5	2.9
CZ	3.5	2.9	2.2	1.0	0.7	2.0
EE	6.1	3.7	2.4	1.6	0.8	2.7
HU	3.7	2.8	2.3	1.2	1.0	2.1
LT	6.5	4.3	2.3	1.4	0.9	2.8
LV	7.7	4.4	2.4	1.5	0.7	3.1
MT	2.2	2.7	2.9	2.2	1.7	2.4
PL	4.6	3.8	2.7	1.2	0.5	2.4
SK	4.6	4.2	2.6	0.9	0.3	2.4
SI	3.7	2.8	2.1	1.3	1.0	2.1
EU25	2.4	2.2	1.5	1.2	1.2	1.7
EU15	2.2	2.1	1.4	1.2	1.3	1.6
EU12	2.1	2.0	1.3	1.1	1.2	1.5
EU10	4.7	3.5	2.5	1.2	0.6	2.4

Table 11: **Determinants of potential growth rates : labour productivity (annual average growth rates)**

	2004-2010	2011-2020	2021-2030	2031-2040	2041-2050	2004-2050
BE	1.5	1.8	1.8	1.7	1.7	1.7
DK	1.9	1.9	1.8	1.7	1.7	1.8
DE	0.9	1.5	1.7	1.7	1.7	1.6
GR	2.1	1.8	1.8	1.7	1.7	1.8
ES	1.1	2.0	1.8	1.7	1.7	1.7
FR	1.4	1.7	1.7	1.7	1.7	1.7
IE	3.4	3.1	1.9	1.7	1.7	2.3
IT	0.7	1.6	1.7	1.7	1.7	1.6
LU	1.8	2.1	1.8	1.7	1.7	1.8
NL	1.1	1.7	1.7	1.7	1.7	1.6
AT	1.5	1.8	1.8	1.7	1.7	1.7
PT	1.2	2.5	2.4	1.7	1.7	1.9
FI	2.1	2.1	1.9	1.7	1.7	1.9
SE	2.2	2.5	2.0	1.7	1.7	2.0
UK	2.1	2.3	1.9	1.7	1.7	1.9
CY	2.4	2.9	2.8	2.1	1.8	2.4
CZ	3.4	3.2	2.8	2.1	1.8	2.6
EE	5.3	4.2	3.1	2.1	1.8	3.2
HU	3.2	3.0	2.8	2.1	1.8	2.5
LT	5.7	4.1	3.1	2.1	1.8	3.2
LV	6.5	4.9	3.3	2.1	1.8	3.5
MT	1.0	1.9	2.5	2.1	1.8	1.9
PL	3.8	3.3	2.9	2.1	1.8	2.7
SK	3.9	3.6	3.0	2.1	1.8	2.8
SI	3.3	3.1	2.8	2.1	1.8	2.6
EU25	1.5	2.0	1.9	1.8	1.7	1.8
EU15	1.3	1.9	1.8	1.7	1.7	1.7
EU12	1.1	1.7	1.8	1.7	1.7	1.6
EU10	3.6	3.4	2.9	2.1	1.8	2.7

Table 12: **Determinants of potential growth rates : employment (annual average growth rates)**

	2004-2010	2011-2020	2021-2030	2031-2040	2041-2050	2004-2050
BE	0.9	0.2	-0.4	-0.2	-0.2	0.0
DK	0.1	0.0	-0.4	-0.4	0.1	-0.1
DE	0.8	0.2	-0.8	-0.6	-0.5	-0.2
GR	0.9	0.2	-0.6	-0.9	-0.9	-0.3
ES	1.9	0.5	-0.4	-1.1	-1.1	-0.1
FR	0.8	0.2	0.0	-0.1	-0.1	0.1
IE	2.0	1.0	0.7	0.0	-0.3	0.6
IT	1.1	0.2	-0.5	-0.9	-0.6	-0.2
LU	2.2	1.0	1.1	1.3	1.3	1.3
NL	0.6	0.1	-0.3	-0.1	0.1	0.0
AT	0.7	0.3	-0.6	-0.5	-0.5	-0.2
PT	0.7	-0.1	-0.5	-0.9	-0.9	-0.4
FI	0.6	-0.2	-0.4	-0.1	-0.3	-0.1
SE	0.6	0.2	0.0	0.0	0.2	0.2
UK	0.7	0.2	-0.2	-0.2	-0.2	0.0
CY	1.9	1.2	0.1	0.2	-0.3	0.5
CZ	0.1	-0.3	-0.6	-1.1	-1.1	-0.6
EE	0.7	-0.5	-0.7	-0.5	-1.0	-0.4
HU	0.5	-0.2	-0.4	-0.9	-0.8	-0.4
LT	0.8	0.1	-0.9	-0.7	-0.9	-0.4
LV	1.2	-0.6	-0.9	-0.6	-1.1	-0.5
MT	1.2	0.8	0.4	0.1	-0.1	0.4
PL	0.7	0.4	-0.2	-0.8	-1.3	-0.3
SK	0.7	0.6	-0.4	-1.2	-1.5	-0.4
SI	0.4	-0.3	-0.7	-0.8	-0.8	-0.5
EU25	0.9	0.2	-0.4	-0.5	-0.5	-0.1
EU15	0.9	0.2	-0.4	-0.5	-0.4	-0.1
EU12	1.0	0.2	-0.4	-0.6	-0.5	-0.1
EU10	1.1	0.2	-0.4	-0.9	-1.2	-0.3

Table 13: **Determinants of labour productivity : Total Factor Productivity (annual average growth rates)**

	2004-2010	2011-2020	2021-2030	2031-2040	2041-2050	2004-2050
BE	1.2	1.2	1.1	1.1	1.1	1.1
DK	1.2	1.2	1.1	1.1	1.1	1.1
DE	0.8	1.1	1.1	1.1	1.1	1.1
GR	0.9	0.8	1.0	1.1	1.1	1.0
ES	0.3	1.1	1.1	1.1	1.1	1.0
FR	1.0	1.1	1.1	1.1	1.1	1.1
IE	2.6	2.0	1.2	1.1	1.1	1.5
IT	0.5	1.1	1.1	1.1	1.1	1.0
LU	0.8	1.1	1.1	1.1	1.1	1.1
NL	0.7	1.1	1.1	1.1	1.1	1.1
AT	0.9	1.1	1.1	1.1	1.1	1.1
PT	0.6	1.6	1.5	1.1	1.1	1.2
FI	2.0	1.6	1.3	1.1	1.1	1.4
SE	1.8	1.8	1.3	1.1	1.1	1.4
UK	1.4	1.5	1.2	1.1	1.1	1.2
CY	1.3	1.6	1.7	1.4	1.2	1.4
CZ	1.2	1.6	1.7	1.4	1.2	1.4
EE	2.5	2.1	1.8	1.4	1.2	1.7
HU	1.2	1.5	1.7	1.4	1.2	1.4
LT	3.0	2.2	1.8	1.4	1.2	1.8
LV	3.1	2.4	1.9	1.4	1.2	1.9
MT	0.1	1.2	1.6	1.4	1.2	1.1
PL	2.4	2.0	1.8	1.4	1.2	1.7
SK	2.2	2.1	1.8	1.4	1.2	1.7
SI	1.1	1.5	1.7	1.4	1.2	1.4
EU25	1.0	1.3	1.2	1.1	1.1	1.2
EU15	0.9	1.2	1.1	1.1	1.1	1.1
EU12	0.8	1.1	1.1	1.1	1.1	1.1
EU10	2.0	1.9	1.8	1.3	1.2	1.6

* Note: TFP growth rates can also be seen as the contribution in percentage points to the growth in labour productivity (i.e. GDP per person employed).

Table 14: **Determinants of labour productivity: capital deepening (contribution in p.p.)**

	2004-2010	2011-2020	2021-2030	2031-2040	2041-2050	2004-2050
BE	0.3	0.6	0.7	0.6	0.6	0.6
DK	0.7	0.7	0.6	0.6	0.6	0.6
DE	0.1	0.4	0.6	0.6	0.6	0.5
GR	1.2	1.0	0.7	0.6	0.6	0.8
ES	0.8	0.9	0.7	0.6	0.6	0.7
FR	0.4	0.6	0.6	0.6	0.6	0.6
IE	0.8	1.0	0.7	0.6	0.6	0.8
IT	0.2	0.6	0.6	0.6	0.6	0.5
LU	1.0	1.0	0.7	0.6	0.6	0.7
NL	0.4	0.6	0.6	0.6	0.6	0.6
AT	0.6	0.7	0.7	0.6	0.6	0.6
PT	0.5	0.9	0.8	0.6	0.6	0.7
FI	0.1	0.5	0.6	0.6	0.6	0.5
SE	0.4	0.7	0.7	0.6	0.6	0.6
UK	0.7	0.8	0.7	0.6	0.6	0.7
CY	1.1	1.3	1.1	0.7	0.6	1.0
CZ	2.2	1.6	1.1	0.7	0.6	1.2
EE	2.8	2.1	1.3	0.7	0.6	1.4
HU	2.0	1.5	1.1	0.7	0.6	1.1
LT	2.7	2.0	1.3	0.7	0.6	1.4
LV	3.4	2.6	1.4	0.7	0.6	1.6
MT	0.9	0.8	0.9	0.7	0.6	0.8
PL	1.4	1.3	1.1	0.7	0.6	1.0
SK	1.6	1.5	1.2	0.7	0.6	1.1
SI	2.1	1.6	1.1	0.7	0.6	1.2
EU25	0.5	0.7	0.7	0.6	0.6	0.6
EU15	0.4	0.7	0.7	0.6	0.6	0.6
EU12	0.3	0.6	0.7	0.6	0.6	0.6
EU10	1.6	1.5	1.1	0.7	0.6	1.1

Table 15 : **Projected GDP per capita growth rates (period averages)**

	2004-2010	2011-2020	2021-2030	2031-2040	2041-2050	2004-2050
BE	2.1	1.8	1.2	1.5	1.7	1.6
DK	1.8	1.8	1.2	1.3	2.0	1.6
DE	1.6	1.7	1.1	1.4	1.6	1.5
GR	2.6	1.8	1.3	1.0	1.2	1.5
ES	2.0	2.3	1.5	0.8	1.0	1.5
FR	1.7	1.6	1.5	1.5	1.7	1.6
IE	4.2	3.1	1.9	1.3	1.1	2.2
IT	1.6	1.8	1.4	1.0	1.5	1.5
LU	3.0	2.1	2.0	2.3	2.4	2.3
NL	1.3	1.5	1.2	1.5	1.9	1.5
AT	1.9	1.9	1.1	1.3	1.5	1.5
PT	1.5	2.3	2.0	1.1	1.2	1.6
FI	2.4	1.7	1.5	1.7	1.7	1.8
SE	2.3	2.3	1.7	1.6	1.8	1.9
UK	2.4	2.2	1.4	1.5	1.6	1.8
CY	2.9	3.1	2.3	2.0	1.3	2.3
CZ	3.6	3.2	2.5	1.4	1.1	2.3
EE	6.6	4.2	2.8	2.0	1.2	3.1
HU	3.9	3.1	2.6	1.4	1.3	2.4
LT	7.0	4.8	2.5	1.7	1.2	3.2
LV	8.3	5.0	2.8	1.9	1.0	3.5
MT	1.3	2.0	2.4	1.9	1.4	1.8
PL	4.7	4.0	2.9	1.6	1.0	2.7
SK	4.7	4.3	2.8	1.3	0.8	2.7
SI	3.6	2.8	2.2	1.5	1.3	2.2
EU25	2.2	2.1	1.6	1.4	1.5	1.7
EU15	1.9	1.9	1.4	1.3	1.6	1.6
EU12	1.8	1.8	1.4	1.3	1.5	1.5
EU10	4.6	3.8	2.7	1.5	1.1	2.6

Table 16 : **Projected GDP per capita levels relative to EU15**

	2004	2010	2030	2040	2050
BE	108	109	106	108	109
DK	110	110	107	107	111
DE	101	99	94	95	95
GR	72	74	72	70	68
ES	85	86	90	86	81
FR	105	104	101	103	103
IE	132	150	177	176	167
IT	100	98	97	94	94
LU	194	207	225	247	268
NL	108	105	98	100	103
AT	116	117	113	113	112
PT	68	66	73	71	68
FI	108	111	110	114	115
SE	112	115	123	126	129
UK	104	107	111	112	113
CY	81	87	107	113	110
CZ	64	71	89	90	86
EE	46	60	86	91	87
HU	54	60	76	77	75
LT	43	58	86	89	87
LV	42	60	93	99	94
MT	68	65	73	77	76
PL	45	53	75	77	73
SK	48	57	83	83	77
SI	73	80	94	96	94
EU25	92	93	97	97	97
EU15	100	100	100	100	100
EU12	99	98	97	97	96
EU10	50	59	80	82	78

Table 17: **Projected productivity levels relative to EU15**

	2004	2010	2030	2040	2050
BE	122	121	120	120	120
DK	98	100	100	100	100
DE	94	92	88	88	88
GR	84	80	79	79	79
ES	91	87	88	88	88
FR	113	113	110	110	110
IE	128	143	161	161	161
IT	116	112	108	108	108
LU	129	133	134	134	134
NL	93	94	92	92	92
AT	109	108	106	106	106
PT	60	63	71	71	71
FI	104	108	112	112	112
SE	104	107	116	116	116
UK	95	102	107	107	107
CY	77	77	94	97	97
CZ	59	69	86	90	90
EE	46	58	82	85	86
HU	61	66	81	84	84
LT	46	57	80	83	84
LV	42	57	88	91	92
MT	80	76	81	84	84
PL	54	59	76	78	79
SK	52	58	76	79	80
SI	71	77	96	99	100
EU25	93	94	97	97	98
EU15	100	100	100	100	100
EU12	101	99	98	98	98
EU10	56	62	80	82	83

5.2. Cross-country differences

All EU25 Member States should experience a marked slowdown in their potential growth rates in the future owing to an “across-the-board” demographic decline. However, growth rates differ substantially from country to country, as shown in Table 18. It appears that in the first half of the projection period, productivity growth is the main source of the discrepancy across countries, reflecting different historical trends in productivity growth, while employment developments have a dominant role in the second half of the projection period due to the mechanical effect of productivity convergence, along with uneven demographic developments. It should also be noted that productivity growth varies strongly across the EU10 countries.

This results in different changes in projected GDP per capita levels relative to the EU15 average across countries, as shown in Table 16. For the EU15, while the relative levels of GDP per capita decline somewhat in Austria, Germany, Greece, the Netherlands, Spain and Italy between 2004 and 2050, they are projected to remain broadly unchanged in Belgium, Denmark, France and Portugal and to increase in Ireland, Luxembourg, Finland, Sweden and the United Kingdom. They are projected to increase in all EU10 Member States, although with different speeds. Belgium, Cyprus, Denmark, France, Ireland, Luxembourg, the Netherlands, Austria, Finland, Sweden and the United Kingdom would exceed the EU15 average in terms of GDP per capita in 2050. However, these results should not be misinterpreted : a decline in the relative levels of GDP per capita does not mean that GDP per capita falls in the considered country, but only that the GDP growth rate is lower in that country compared with the EU15 average. Indeed, Table 15 clearly shows that GDP per capita is projected to grow by at least 1.5% a year on average in all countries over the whole projection period.

Table 18 summarises the projection results, by disentangling the GDP growth rate into its main components over the entire projection period. The negative impact of ageing on the GDP growth rate can clearly be seen, as the contribution from the working–age population is projected to be negative for all Member States. In the EU25, productivity growth (1.8%) will be the driving force behind GDP growth (1.7%), offsetting the slight decline in labour input (-0.1%). Total factor productivity will explain two thirds of labour productivity growth, the remaining third being due to capital deepening. The decline in labour input is projected to result from the declining share of the working-age population (ageing) despite the positive contribution of rising employment rates. Total population is expected to be neutral : it should remain broadly stable, as the number of elderly should sharply rise and compensate for the decline in the younger age groups. Given their economic weight in the EU25, the EU15 and the euro area are projected to share the same pattern of economic growth as the EU25 as a whole. By contrast, the GDP growth rate is projected to be much higher (2.3%) in the EU10 thanks to stronger productivity growth (2.6%), which in turn is caused by higher TFP growth and more capital deepening. However, labour utilisation is expected to decline faster than in the EU15 given the combined decline in total population and in the share of the working age population (-0.3%).

Table 18: **GDP Growth and its main components, 2005-2050**

	GDP growth in 2005-2050	**Productivity** ***(GDP per person employed)***	TFP	Capital deepening	***Labour Input***	Total Pop	Employ-ment rate	Share of Working age Pop	**GDP per capita growth in 2005-2050**
	1=3+6	***3=4+5***	4	5	***6=7+8 +9***	7	8	9	**10=1-7**
BE	**1.7**	***1.7***	1.1	0.6	***0.0***	0.1	0.2	-0.3	**1.6**
DK	**1.7**	***1.8***	1.2	0.6	***-0.1***	0.0	0.1	-0.2	**1.6**
DE	**1.4**	***1.6***	1.1	0.5	***-0.2***	-0.1	0.3	-0.3	**1.5**
GR	**1.4**	***1.8***	1.0	0.8	***-0.1***	-0.1	0.4	-0.5	**1.5**
ES	**1.5**	***1.7***	1.0	0.7	***-0.1***	0.0	0.4	-0.5	**1.5**
FR	**1.8**	***1.7***	1.1	0.6	***0.1***	0.2	0.2	-0.3	**1.6**
IE	**2.8**	***2.3***	1.5	0.8	***0.6***	0.7	0.3	-0.4	**2.1**
IT	**1.3**	***1.6***	1.0	0.6	***-0.3***	-0.2	0.3	-0.4	**1.5**
LU	**3.1**	***1.8***	1.1	0.8	***1.3***	0.8	0.7	-0.2	**2.3**
NL	**1.7**	***1.6***	1.1	0.6	***0.0***	0.2	0.1	-0.3	**1.5**
AT	**1.5**	***1.7***	1.1	0.6	***-0.1***	0.0	0.2	-0.4	**1.5**
PT	**1.5**	***2.0***	1.2	0.7	***-0.5***	-0.1	0.0	-0.4	**1.6**
FI	**1.7**	***1.9***	1.4	0.5	***-0.1***	0.0	0.2	-0.3	**1.7**
SE	**2.2**	***2.0***	1.4	0.6	***0.2***	0.3	0.1	-0.2	**1.9**
UK	**1.9**	***1.9***	1.2	0.7	***0.0***	0.2	0.0	-0.2	**1.8**
CY	**2.9**	***2.4***	1.4	1.0	***0.7***	0.6	0.3	-0.3	**2.3**
CZ	**1.9**	***2.6***	1.4	1.2	***-0.7***	-0.3	0.1	-0.5	**2.2**
EE	**2.6**	***3.1***	1.7	1.4	***-0.5***	-0.4	0.2	-0.3	**3.0**
HU	**2.1**	***2.5***	1.4	1.1	***-0.4***	-0.3	0.2	-0.4	**2.3**
LT	**2.8**	***3.1***	1.8	1.3	***-0.3***	-0.4	0.4	-0.3	**3.1**
LV	**3.0**	***3.5***	1.9	1.6	***-0.5***	-0.5	0.3	-0.3	**3.4**
MT	**2.4**	***1.9***	1.2	0.8	***0.5***	0.5	0.3	-0.3	**1.9**
PL	**2.4**	***2.7***	1.7	1.0	***-0.2***	-0.3	0.5	-0.4	**2.7**
SK	**2.4**	***2.8***	1.7	1.1	***-0.3***	-0.3	0.4	-0.4	**2.6**
SI	**2.1**	***2.5***	1.4	1.1	***-0.4***	-0.1	0.2	-0.5	**2.2**
EU25	**1.7**	***1.8***	1.2	0.6	***-0.1***	-0.01	0.2	-0.4	**1.7**
EU15	**1.6**	***1.7***	1.1	0.6	***-0.1***	0.0	0.2	-0.3	**1.6**
Euro area	**1.5**	***1.6***	1.1	0.6	***-0.1***	0.0	0.3	-0.4	**1.5**
EU10	**2.3**	***2.6***	1.6	1.1	***-0.3***	-0.3	0.4	-0.4	**2.6**

6. SENSITIVITY TESTS ON PRODUCTIVITY AND GDP PER CAPITA

There are three strong reasons to supplement the baseline scenario by a wide set of alternative scenarios, which will act as sensitivity tests for the underlying assumptions used for the baseline projection.

- Firstly, and most importantly, productivity projections are particularly difficult to make, given the number of different factors explaining its development.

- Secondly, there is no consensus in the academic community as to whether productivity should converge across countries and whether it should do so in terms of levels or growth rates. Neither is there a consensus regarding the value of the convergence target. During the peer review process of the AWG projections, some analysts argued that the labour productivity assumptions might be too optimistic compared with what has been observed in EU Member States during recent decades. These critiques warrant running several sensitivity tests with lower productivity assumptions.

- Finally, the baseline projection designed in the framework of the EPC's Ageing Working Group does not capture all the direct and indirect channels through which ageing can influence economic growth (e.g. the impact of part-time employment and changing age-structures on productivity), as the projection exercise is carried out on the basis of common and simple assumptions to help ensure cross-country consistency and clarity. While these gaps do not call into question the main findings of the projections in terms of the economic impact of ageing and should be mainly considered as refinements (somewhat more difficult to model), it is helpful to assess their impact on the projection outcome.

In order to tackle these potentially relevant issues, which are overlooked in the baseline projections, we build 8 scenarios in this section. Two of them specifically cover one of four different aspects : the underlying assumptions on labour inputs; the impact of changing demographic structures; the choice of TFP growth rate targets; and the convergence of productivity to a common level instead of a common growth rate. This section will explain the construction of each scenario and spell out its particular interest. The results will be systematically compared with the baseline.

6.1. Eight scenarios: rationale and construction

Except for scenario 1, which also alters the labour input assumptions, the following scenarios affect GDP per capita only through the productivity assumptions (TFP and capital deepening).

6.1.1. Change in labour input assumptions

Alternative participation rate scenario (Scenario 1), where the age-specific participation rates are maintained constant at the 2004 rate. Unlike the baseline, there are neither cohort effects nor increases in older-worker participation rates induced by recently enacted pension reforms. The effect on productivity growth will be transmitted via capital deepening, which increases following the reduction in labour inputs, partly offsetting the negative impact on GDP per capita.

Part-time employment scenario (Scenario 2). In the baseline, hours worked are assumed constant. We relax this assumption by taking into account the likely increase in part-time employment brought about by the rise in female participation rates[29]. This scenario is all the more relevant since the reason for the further decline in hours worked over recent years has been an increasing share of people in part-time

[29] In this scenario, we assume that the expected strong rise in the number of older workers will not lead to an increase in part-time employment, as indicated by the relative stability of the "older-worker part-time employment rate" in the last five years, when older-worker employment rates surged by 7% points.

employment[30]. This scenario uses the regression coefficient of part-time employment rates on female participation rates, estimated by Buddelmeyer, Mourre and Ward (2004) using a panel of EU15 countries[31]. Running various estimates, and controlling for many effects, the authors found a determination coefficient of between 0.3 and 0.4. This scenario therefore assumes that a female participation rate increase of 1 p.p. gives rise to an increase of 0.35 in total part-time employment. Given that female full-timers work 40 hours against 20 hours for part-timers, a rise in the proportion of part-time employment would lead to a reduction in hours worked per person employed (compositional effect), reducing the productivity per employee[32].

6.1.2. Impact of changing age-structure on productivity

Model-based age-profile scenario –impact of declining youth share on TFP growth (Scenario 3 - "age-profile of productivity n°1"). While there is little hard evidence on the possible impact of ageing on innovation and TFP, there is a widespread suspicion that an older labour force will be less able or willing to create and use new technologies. Annex 2 (table 1) shows that ageing could be negatively related to TFP growth and estimated that a permanent decline of 10% points in the youth dependency ratio (i.e. those aged 0-14 over those aged 15-64) leads to a decrease of 0.25% points in the annual labour productivity growth rate. We use this estimated effect and Eurostat's population projections (Eurostat 2005) to compute the reduction in TFP caused by the changing structure of the population. The issue remains whether the youth dependency ratio, albeit a useful indicator, is the most precise measure of ageing. The next scenario tries to take into account the complete age profile of the workforce, especially at its upper end.

Calibrated age-profile scenario – simulating changes in the age structure of the labour force on labour productivity (Scenario 4 - "age-profile of productivity n°2"). This scenario is based on the idea that individual productivity varies over time and follows an age-profile, bell-shaped, relationship. In this scenario, productivity grows at the same pace for all age groups but displays varying levels across age groups. The change in overall productivity growth comes from a compositional effect induced by population ageing (lower share of youth and prime-age workers in the labour force and a higher proportion of older workers).This demography-based scenario uses a calibrated age-profile of relative productivity. We consider four age groups, 15-24, 25-49, 50-54 and 55-64. We also assume that those aged 15-24, 50-54 and 55-64 display 80%, 90% and 70% of the productivity level of prime-age workers (24-49). This is broadly in line with the literature and the bell-shaped age profile of productivity (Skirbekk 2003, Börsh-Supan 2003 and 2006). The evidence suggests that productivity starts to decline only for those at the upper end of the working-age

[30] Average hours worked appear to have slightly declined in 2005, after a marginal pick-up in 2004. This means a continuation of the trend decline in hourly labour utilisation, which was assumed to have reverted (or at least stopped) in the last number of years. The reason for the further decline is the increasing share of people in part-time employment. Their share in total employment rose from 17.5% in 2004 to 18.6% in 2005. According to the labour force survey, the average number of normally worked hours for one's main job has *neither fallen in full-time nor in part-time employment*. It even increased to 41.6 in 2005 from 41.4 hours per week in 2004 for those in full-time employment, while it remained constant at 19.5 hours per week for those in part-time employment.

[31] The part-time employment rate is the ratio of part-time to total employment.

[32] We also assume that men enter the labour market with full-time contracts only, which is consistent with the fact that men only represent 22% of those working part-time in the EU25 in 2004.

range (i.e. those aged 55 and over), as the "pure" negative effect of age outweighs the positive impact of experience. Given the uncertainty surrounding the relative productivity value across ages, we however carry out many sensitivity tests to assess how much productivity varies with respect to changes in parameters.

In order to take account of the age structure of the population, we combine the projection of employment levels up to 2050 (Carone 2005, EPC 2005) and the calibrated relative productivity rates mentioned above. Let us denote P the level of employment productivity (assuming unchanged age structure) and E the level of employment, while the subscripts *a, i*, and *t* refer to the age group, country and year respectively. $P_a/P_{25\text{-}49}$ is the productivity of the age group *a* relative to that of prime-age workers (aged 25-49), which is supposed to be constant over time and across countries. We compute the corrected productivity $P_{corrected}$, which explicitly controls for the change in the age-structure of employment from the start of the productivity projection:

$$P_{corrected\ i\,t} = P_{i\,t} \cdot \frac{\sum_{a\in\{15-24,25-49,50-54,55-64\}} \frac{E_{i\,a\,t}}{E_{i\ t}} \frac{P_a}{P_{25-49}}}{\sum_{a\in\{15-24,25-49,50-54,55-64\}} \frac{E_{i\,a\,2004}}{E_{i\ 2004}} \frac{P_a}{P_{25-49}}}$$

6.1.3. Changes in TFP growth rate targets

A more pessimistic convergence target for the TFP growth rate in the long run - 0.8% instead of 1.1% (Scenario 5). In this scenario, the annual TFP growth rate converges to 0.8% by 2030 in EU15 countries, instead of 1.1%, while it converges to 1.3% by 2030 and 0.8% by 2050 in the EU10 countries, instead of 1.75% and 1.1% respectively. The rate of 0.8% corresponds to the historical TFP growth rate recorded on average since 1990 in the EU15[33], while the growth rate used in the baseline is the average rate seen *over the last three decades* (1970-2004) both in the EU15 and in the US.

More optimistic (ad-hoc) convergence target for the TFP growth rate in the long run (Scenario 6). In this ad-hoc scenario, TFP growth increases so that the labour productivity growth rate progressively rises by 0.25 p.p. over the period 2009-2015 in comparison with the labour productivity growth rate in the baseline projection. Productivity growth thereafter remains 0.25 p.p higher than in the baseline. This scenario has been designed by the Ageing Working Group, as a pure sensitivity test for the budgetary projections. It is a "symmetric" scenario : if one assumes a progressive decline (instead of an increase) in productivity growth, the resulting change in productivity levels in 2050 is identical in magnitude - only the sign changes.

[33] This rate of 0.8% is lower than the rate of 1.2% recorded in the US in the same period (1990-2004).

6.1.4. *Productivity convergence in levels rather than in growth rates*

Convergence in levels for the 10 least productive countries (productivity lower than 80% of the EU15 average) (Scenario 7). In this scenario, the (ten) countries with a productivity level below **80%** of that of the EU15 in 2004 (Portugal, Cyprus, Czech Republic, Estonia, Hungary, Lithuania, Latvia, Poland, Slovakia and Slovenia) linearly converge toward **80%** of the average productivity level reached in 2050 (in the baseline) by the eight most productive countries in 2004 (Luxembourg, Ireland, Belgium, Italy, France, Austria, Finland and Sweden)[34]. The latter are characterised by the fact that their productivity level is higher than the EU productivity average in 2004. Moreover, these countries are still the most productive in 2050 in the baseline[35].

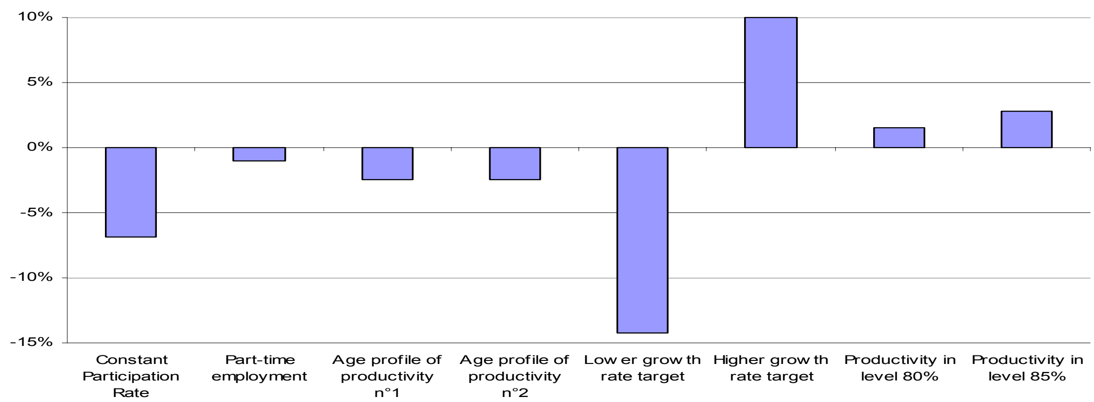
Convergence in the level of the 12 least productive countries (productivity lower than 85% of the EU15 average) (Scenario 8). In this scenario, the (twelve) countries with a productivity level below **85**% of that of the EU15 in 2004 (Greece, Portugal, Cyprus, Czech Republic, Estonia, Hungary, Lithuania, Latvia, Malta, Poland, Slovakia and Slovenia) linearly converge toward **85%** of the average productivity level reached in 2050 by the eight most productive countries in 2004 (Luxembourg, Ireland, Belgium, Italy, France, Austria, Finland and Sweden).

6.2. Main results of sensitivity tests

We will focus on the impact on the main aggregates (EU25, EU15, the euro area, EU10), whilst mentioning the most noticeable cross-country developments. Graph 2 and Table 19 show the change in the 2050 level of GDP per capita in the different alternative scenarios compared with the baseline. Graphs 3, 4 and 5 display the time profile of the relative change for each scenario for the EU25, EU15 and EU10 respectively.

Graph 2: **Change in the level of GDP per capita in the different scenarios for the EU25**

Percentage of the baseline



[34] Productivity levels are expressed in PPS.

[35] Except that Austria becomes the 9th most productive country and the UK the 8th most productive country.

Table 19: **Change in the level of GDP per capita in different scenarios**

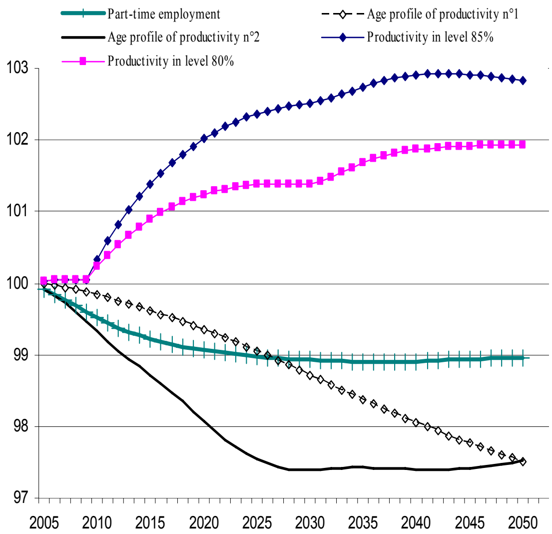
Percentage of the baseline

	baseline	1	2	3	4	5	6	7	8
	Cumulated growth rate 2004-2005	Constant Partic -ipation Rate	Part-time employ -ment	Age profile of prod'y n°1	Age profile of prod'y n°2	Lower TFP growth rate target	Higher TFP growth rate target	Prod'y in levels 80%	Prod'y in levels 85%
BE	111%	-7.8%	-1.2%	-2.0%	-2.5%	-12.4%	9.7%	0.0%	0.0%
DK	109%	-2.2%	-0.1%	-2.5%	-1.5%	-12.6%	10.0%	0.0%	0.0%
DE	97%	-6.5%	-1.2%	-2.2%	-3.3%	-14.5%	10.0%	0.0%	0.0%
GR	96%	-5.6%	-1.2%	-0.9%	-2.1%	-15.2%	10.0%	0.0%	8.6%
ES	99%	-10.3%	-2.2%	-0.9%	-2.7%	-18.5%	10.1%	0.0%	0.0%
FR	105%	-5.8%	-0.5%	-1.4%	-1.9%	-12.8%	10.0%	0.0%	0.0%
IE	163%	-8.1%	-1.8%	-4.4%	-1.7%	-7.0%	10.2%	0.0%	0.0%
IT	95%	-11.5%	-1.2%	-1.3%	-3.3%	-17.0%	10.0%	0.0%	0.0%
LU	188%	-6.9%	-1.3%	-1.7%	-2.1%	-14.2%	9.8%	0.0%	0.0%
NL	97%	-4.5%	-2.2%	-1.6%	-1.7%	-14.2%	9.9%	0.0%	0.0%
AT	101%	-8.3%	-1.3%	-4.1%	-3.3%	-13.5%	10.0%	0.0%	0.0%
PT	110%	-5.3%	-0.8%	-1.0%	-2.1%	-23.3%	9.9%	28.6%	36.6%
FI	121%	-5.5%	-0.4%	-0.6%	-1.4%	-12.9%	10.1%	0.0%	0.0%
SE	139%	-3.2%	-0.2%	-0.8%	-1.0%	-14.9%	10.0%	0.0%	0.0%
UK	124%	-3.6%	-0.8%	-4.2%	-1.6%	-13.7%	10.0%	0.0%	0.0%
CY	180%	-7.2%	-1.3%	-12.2%	-2.8%	-14.3%	9.9%	-6.8%	-1.0%
CZ	177%	-6.1%	-0.7%	-2.6%	-2.4%	-15.1%	9.8%	0.1%	6.4%
EE	295%	-3.9%	-0.5%	-2.0%	-1.5%	-8.6%	10.1%	5.8%	12.4%
HU	189%	-7.8%	-0.6%	-2.0%	-2.6%	-15.3%	9.9%	7.0%	13.7%
LT	314%	-5.6%	-0.6%	-7.8%	-4.0%	-6.7%	10.1%	8.2%	15.0%
LV	367%	-5.5%	-0.6%	-1.1%	-2.0%	-5.7%	10.2%	-1.0%	5.2%
MT	132%	-9.9%	-2.5%	-5.3%	0.7%	-19.7%	9.8%	-0.1%	14.4%
PL	238%	-10.9%	-0.7%	-6.4%	-3.5%	-9.3%	10.0%	14.5%	21.7%
SK	229%	-8.3%	-0.5%	-7.5%	-4.0%	-9.9%	10.0%	13.8%	20.9%
SI	168%	-8.9%	-0.9%	-1.3%	-3.5%	-15.4%	9.8%	-9.3%	-3.6%
EU25	119%	-6.9%	-1.0%	-2.5%	-2.5%	-14.2%	10.0%	1.5%	2.8%
EU15	108%	-6.6%	-1.1%	-2.1%	-2.4%	-14.6%	10.0%	0.6%	1.1%
EU12	103%	-7.6%	-1.2%	-1.7%	-2.6%	-14.8%	10.0%	0.7%	1.5%
EU10	223%	-8.8%	-0.7%	-5.1%	-3.1%	-11.1%	10.0%	8.9%	15.8%

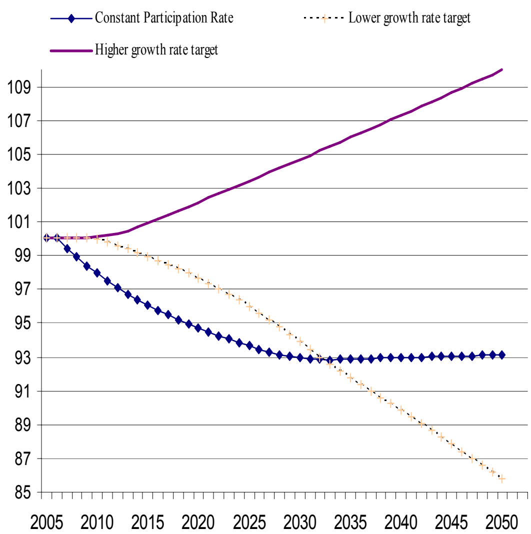
Graph 3: **Change in the level of GDP per capita in the EU 25 in different scenarios**

Percentage of the baseline

Fairly moderate changes



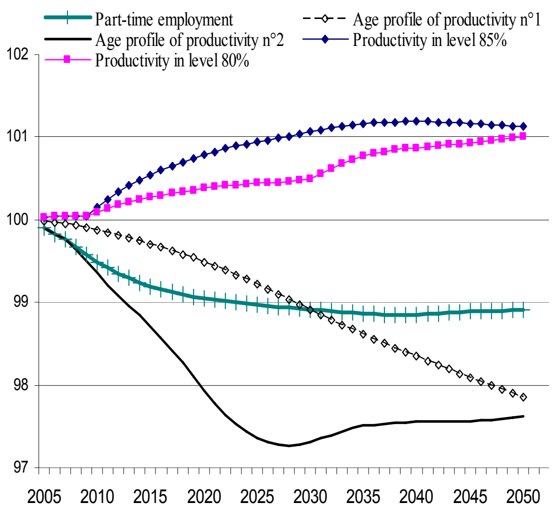
Strong changes



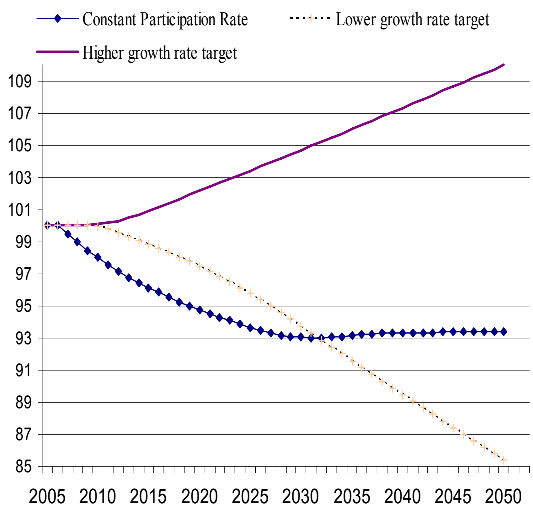
Graph 4: **Change in the level of GDP per capita in the EU 15 in different scenarios**

Percentage of the baseline

Fairly moderate changes

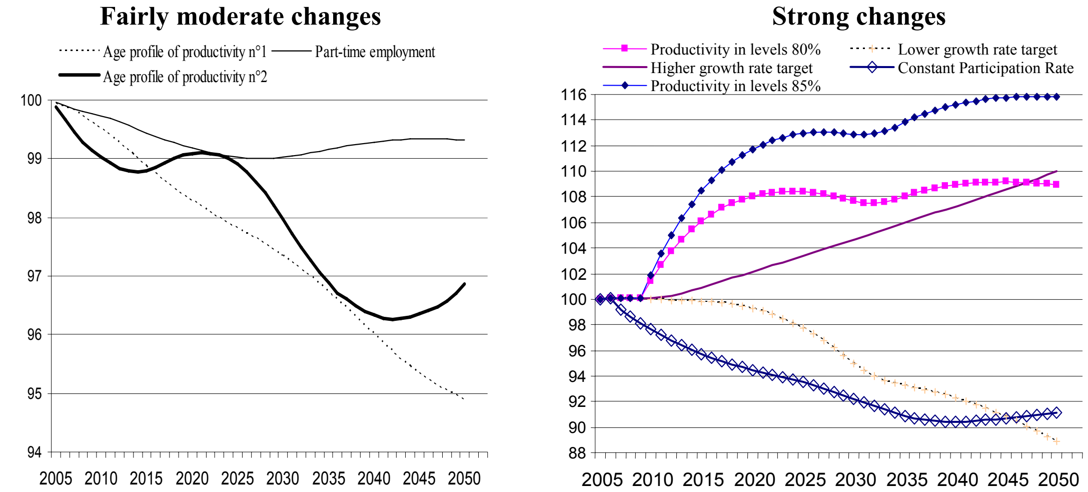


Strong changes



Graph 5: **Change in the level of GDP per capita in the EU 10 in different scenarios**

Percentage of the baseline



6.2.1. GDP per capita impact of assuming no change in participation rates is much greater than an assumed rise in the share of part-time employment

As suggested by Graph 2 and Table 19, assuming a constant participation rate at its 2004 level would lead to a relatively large negative effect on GDP per capita compared with the baseline (-7%). This drop would have been greater but for an associated rise in labour productivity owing to further capital deepening caused by the reduction in labour supply. Without the latter, the fall would have been around -11%. Graph 3 suggests that the "loss" in GDP per capita is quite rapid at the start of the projection period but stabilises at its long term level in 2025, when the cohort effect in the baseline comes to an end. The fall is slightly more pronounced in the euro area and the EU10, as it is particularly sharp in Spain, Italy and Poland.

In contrast, an assumption of a decline in hours worked provoked by a rise in part-time employment, which is likely to accompany the upward movement in female participation rates, only leads to a very slight change in GDP per capita in the EU25 relative to the baseline (-1%). The highest changes, seen in Spain, the Netherlands and Malta, are only about -2%. The bulk of these small effects is expected to be seen before 2025.

The results derived from the first two scenarios confirm the findings of the labour market literature that the potential for higher labour utilisation in Europe is to be sought more from a rise in participation rates ("extensive margin") rather than from a change in hours worked per person ("intensive margin").

6.2.2. The negative effect of a change in the population age-structure is fairly limited

Scenario 3 ("age profile of productivity n°1") suggests that taking into account the change in the youth share in total population will cut the level of EU25 GDP per capita by only 2.5%, corresponding to a decline of around 0.05% points in annual productivity growth rates. This is a fairly moderate, albeit not negligible, effect.

However, the fall is projected to be severe in some EU10 countries (Cyprus, Malta, Poland, Lithuania and Slovakia). The profile of the impact on GDP per capita over time might look strange in the EU10 and, consequently in the EU25 as a whole, but it is fully explained by the presence of a double "baby boom"[36] in the EU10 that will unfold its effects over the period of projections.

Table 20: **Sensitivity test : change in the level of GDP per capita reached in 2050 for different age-profiles of labour productivity (Percentage of the baseline)**

Age profile of productivity (prime-age worker productivity=100)												
15-24	80%						90%					
25-49	100%						100%					
50-54	100%	90%	80%	70%	60%	50%	100%	90%	80%	70%	60%	50%
55-64	80%	70%	60%	50%	40%	30%	80%	70%	60%	50%	40%	30%
BE	-1.3%	-2.1%	-3.2%	-4.2%	-5.2%	-6.3%	-1.3%	-2.2%	-3.2%	-4.1%	-5.1%	-6.2%
DK	-1.1%	-1.2%	-1.8%	-2.2%	-2.7%	-3.2%	-0.7%	-1.1%	-1.5%	-1.9%	-2.3%	-2.8%
DE	-1.7%	-2.9%	-4.2%	-5.6%	-7.0%	-8.4%	-1.8%	-3.0%	-4.3%	-5.6%	-7.0%	-8.5%
GR	-0.9%	-2.0%	-3.0%	-4.1%	-5.3%	-6.6%	-1.1%	-2.2%	-3.2%	-4.4%	-5.5%	-6.8%
ES	-1.1%	-2.6%	-4.0%	-5.5%	-7.1%	-8.7%	-1.5%	-2.9%	-4.3%	-5.9%	-7.4%	-9.1%
FR	-1.3%	-1.7%	-2.7%	-3.4%	-4.2%	-5.0%	-1.3%	-2.0%	-2.7%	-3.4%	-4.2%	-5.0%
IE	-0.5%	-1.7%	-3.0%	-4.3%	-5.7%	-7.1%	-1.1%	-2.3%	-3.6%	-4.9%	-6.3%	-7.7%
IT	-1.8%	-3.0%	-4.4%	-5.8%	-7.3%	-8.8%	-1.8%	-3.1%	-4.5%	-5.8%	-7.3%	-8.8%
LU	-1.1%	-1.9%	-2.8%	-3.7%	-4.7%	-5.7%	-1.0%	-1.9%	-2.7%	-3.7%	-4.6%	-5.6%
NL	-1.0%	-1.4%	-2.2%	-2.9%	-3.6%	-4.3%	-0.9%	-1.5%	-2.1%	-2.7%	-3.4%	-4.1%
AT	-1.7%	-3.0%	-4.5%	-6.0%	-7.5%	-9.1%	-1.8%	-3.2%	-4.6%	-6.1%	-7.6%	-9.2%
PT	-0.9%	-1.9%	-2.9%	-4.0%	-5.1%	-6.3%	-1.2%	-2.1%	-3.2%	-4.2%	-5.3%	-6.5%
FI	-1.1%	-1.2%	-2.0%	-2.5%	-3.0%	-3.6%	-1.1%	-1.5%	-2.0%	-2.5%	-3.0%	-3.5%
SE	-0.9%	-0.9%	-1.3%	-1.5%	-1.8%	-2.1%	-0.7%	-0.9%	-1.2%	-1.4%	-1.6%	-1.9%
UK	-0.9%	-1.5%	-2.4%	-3.2%	-4.1%	-5.0%	-1.0%	-1.8%	-2.5%	-3.3%	-4.2%	-5.1%
CY	-1.4%	-2.6%	-4.2%	-5.7%	-7.3%	-9.0%	-1.8%	-3.2%	-4.6%	-6.1%	-7.7%	-9.3%
CZ	-1.4%	-2.3%	-3.2%	-4.1%	-5.1%	-6.2%	-1.7%	-2.5%	-3.4%	-4.4%	-5.4%	-6.4%
EE	-0.8%	-1.5%	-2.1%	-2.9%	-3.6%	-4.4%	-1.1%	-1.8%	-2.5%	-3.2%	-4.0%	-4.8%
HU	-1.5%	-2.4%	-3.6%	-4.7%	-5.9%	-7.1%	-1.7%	-2.7%	-3.8%	-4.9%	-6.0%	-7.3%
LT	-2.1%	-3.6%	-5.3%	-7.1%	-8.9%	-10.9%	-2.3%	-3.9%	-5.5%	-7.3%	-9.1%	-11.1%
LV	-1.0%	-1.9%	-2.7%	-3.6%	-4.6%	-5.6%	-1.4%	-2.2%	-3.1%	-4.0%	-4.9%	-5.9%
MT	0.6%	0.5%	0.1%	-0.2%	-0.6%	-0.9%	0.1%	-0.2%	-0.5%	-0.8%	-1.2%	-1.5%
PL	-2.0%	-3.3%	-4.9%	-6.5%	-8.1%	-9.7%	-2.2%	-3.6%	-5.1%	-6.7%	-8.3%	-9.9%
SK	-2.2%	-3.6%	-5.5%	-7.3%	-9.1%	-11.0%	-2.5%	-4.1%	-5.8%	-7.5%	-9.4%	-11.3%
SI	-1.8%	-3.1%	-4.6%	-6.1%	-7.6%	-9.2%	-2.1%	-3.5%	-4.9%	-6.4%	-7.9%	-9.5%
EU25	-1.4%	-2.3%	-3.5%	-4.6%	-5.8%	-7.0%	-1.5%	-2.5%	-3.6%	-4.7%	-5.8%	-7.1%
EU15	-1.3%	-2.2%	-3.3%	-4.4%	-5.5%	-6.7%	-1.4%	-2.4%	-3.4%	-4.5%	-5.6%	-6.7%
EU12	-1.4%	-2.4%	-3.6%	-4.7%	-6.0%	-7.2%	-1.5%	-2.6%	-3.7%	-4.8%	-6.0%	-7.3%
EU10	-1.8%	-2.9%	-4.3%	-5.7%	-7.1%	-8.6%	-2.0%	-3.3%	-4.6%	-5.9%	-7.4%	-8.8%

Note: In these sensitivity tests, the age structure of the population is that given by the baseline (see Carone 2005). Therefore, the labour input is left unaffected. As a result, the changes in GDP per capita in 2050 as a percentage of the baseline level are strictly equal to those in productivity levels in 2050 as a percentage of the productivity level in the baseline.

[36] While the age groups 15-30 and 45-55 are very large, those below 15, aged 30-40 and over 60 are much less numerous.

Scenario 4 ("age profile of productivity n°2") confirms the findings of scenario 3 : a drop of only 2.3% is expected in the EU25 when considering a change in the age-structure of employment. This change will translate into an increase in the share of older age groups at the expense of young and prime age workers which are expected to have a higher productivity. It illustrates the extent of the compositional effects when one assumes different productivity levels by age. In this scenario, which is more comprehensive than the previous one, the disparity across countries is smaller, although the impact remains slightly stronger in the EU10 than in the EU15.

The main difference between the two scenarios is in the timing of the decrease in living standards. The drop in GDP per capita occurs very rapidly in scenario 4 as the proportion of older workers also increases relatively quickly until 2020, due to the population ageing and the increase in the “older worker employment rate” induced by enacted pension reforms[37]. In contrast, in scenario 3, the fall takes place almost linearly, following the gradual decline in the youth dependency ratio, fostered by low and stalling fertility rates.

Table 20 presents a large set of sensitivity tests, using various profiles of relative productivity across age groups. Simulations show that to get a 5% decline compared with the baseline productivity level (i.e. a 0.1% point decline in annual average productivity growth rates) would imply assuming that the productivity of those aged 50-54 and 55-64 is only 70% and 50% of that of prime-age workers respectively, which is obviously very pessimistic. Looking further, lowering the relative productivity of young workers by 10% points only has a marginal impact on the simulation. More importantly, cutting the relative productivity of prime-aged workers by 10% points, which is huge, leads to a GDP per capita decline of only 1.1% points for the EU15 and 1.4% points for the EU10 at the end of the projection horizon. In the most extreme simulation (in which the productivity of those 55-64 is even below one third of that of prime age employees), only two small countries (Lithuania and Slovakia) record a GDP per capita fall greater than 10% (i.e. a 0.2% point decline in annual average productivity growth rates) and in Poland the fall is very close to 10 per cent.

This confirms the main finding by Börsh-Supan (2003) that even though the profile of productivity varies strongly with the age of employees, its impact on aggregate labour productivity would be small, and would not alter the projection results very much.

6.2.3. Changing the TFP growth rate assumption could strongly affect the projections

Taking a convergence target of 0.8% for TFP growth by 2030 in EU15 and by 2050 in EU10, rather than 1.1% in the baseline, has a considerable effect by 2050. It decreases GDP per capita by 14.6% points in the EU15 (i.e. a 0.3% point decline in annual productivity growth rates) and by 11% points in the EU10. The GDP per capita drop is particularly strong for Spain, Italy, Portugal and Malta.

[37] The share of older workers in the EU25 is projected to increase from 10.4% in 2004 to 17.3% in 2050, while the share of younger (15-24) is projected to fall from 11.3% to 10.1% and the prime-aged from 78.3% to 72.6%.

This shows that the convergence hypothesis for TFP growth is a crucial assumption. Therefore, a natural question arises (one in fact which was raised in the peer review of the baseline budgetary projections) whether the labour productivity growth rate assumptions are too optimistic compared with what has been observed in EU Member States recently[38]. Generally speaking, productivity projections are particularly difficult to make, given the number of different factors explaining its development. There is moreover no consensus in the academic community whether productivity should converge across countries and whether it should do so in terms of levels or growth rates. More specifically, several remarks are warranted :

- First and foremost, given the very long-term time horizon of the budgetary projections (up to 2050), the Commission and the AWG have based the productivity assumption on longer term developments, and not on the medium term observations since 1990, which are influenced by specific factors. The assumption of TFP convergence to 1.1% per annum corresponds to the growth rate recorded for the EU as a whole over a long period of time (1970-2004). This rate is almost identical to that experienced in the leading economy in the world, i.e. the US over the same period. Indeed, it would be an excessively pessimistic scenario to focus on the most recent period, which would mean that there would be no ICT catching-up in Europe in the long-run.
- Secondly, the productivity assumptions are slightly lower than those in the 2001 budgetary exercise (by 0.1 percentage points over the whole projection period). They are also very much in line with the assumptions used by international organisations (e.g. the OECD, which assumes a targeted growth rate of productivity of 1.7% consistent with 1.1% TFP growth) and national authorities (e.g. Australia) when making long-run budgetary projections.

Regarding scenario 6, the conclusions to be drawn do not add much to the insights provided by scenario 5. Its main merit is to stress that, symmetrically, an assumption of higher productivity growth (¼% point) leads to a strong increase in GDP per capita by 2050.

6.2.4. An assumption of productivity convergence in levels substantially alters the projections for most EU10 countries whilst leaving the EU15 almost unchanged.

Scenarios 7 and 8 stress that establishing a reasonable convergence rule in levels (i.e. 80% or 85%) instead of the growth rate convergence rule embedded in the baseline only has a moderate impact on EU25 GDP per capita (+1.5% and +2.8% respectively, compared with the baseline). This result is due to the fact that only the EU10 countries are affected and their weight is limited (the EU10 total population represents a maximum of only 16% of the EU25 population over the projection horizon). In the EU15, only Portugal (scenario 7) or Portugal and Greece (scenario 8) are affected (albeit strongly), so that setting up a reasonable convergence rule in levels only has a negligible impact on EU15 GDP per capita (0.6% and 1.1% respectively)[39]. The other EU15 countries are left unchanged by these two scenarios, as their productivity levels are above the threshold of 85% of the EU15 average. In

[38] In particular, some observers draw attention to the fact that, in the baseline scenario, total factor productivity (TFP) growth has been declining in the main EU15 countries since 1990, averaging only 0.8%.

[39] In scenario 8, Greece gains more than 8% relative to the baseline level of GDP per capita, while GDP per capita in Portugal increases by more than one third.

contrast, the effect of the convergence rule is very significant in the EU10 countries, ranging from 8.9% to 15.8%. While Cyprus, Latvia and Slovenia lose out a bit compared with the baseline, some EU10 countries (Estonia, Lithuania, Poland and Slovakia) display a sharp productivity increase relative to the baseline[40].

It should be noted that changing the convergence target from 80% of EU15 labour productivity to 85% strongly affects the results of the low-productivity countries, broadening the gap with the baseline by 6% points in 2050, although it does not significantly change the number of "converging countries". Only Malta and Greece join the convergence club in scenario 8 compared with scenario 7.

7. CONCLUDING REMARKS

In the context of the Commission's services and the EPC's common projections exercise on the public spending and growth implications of ageing populations, the present paper presents an overview of the long run productivity and growth effects from an application of the agreed production function (PF) methodology. This PF approach forms the central element of the macro assumptions part of the overall exercise. It is a variant of the ECOFIN Council agreed method used for the calculation of potential growth rates and output gaps when assessing the annual stability and convergence programmes. The approach is also based on a series of assumptions regarding the components of the production function (population, unemployment, participation rates, capital formation and TFP). In this approach, projected productivity is the outcome of an extrapolation of recent trends; of an assessment of the medium-run effects of demographics on capital deepening; and of some long run convergence assumptions regarding TFP (i.e. a return to the long-term historical average for the period 1970-2005).

Some of the most important points which the present paper has underlined are as follows :

- Firstly, the long run growth scenarios presented in the paper are based on the introduction of the EPC-AWG agreed assumptions for NAIRU's, participation rates and labour productivity, as well as Eurostat's latest demographic projections, into ECFIN's production function methodology[41]. This methodology provides an effective overall framework for the macroeconomic part of the 2006 projections, with its transparency adding to the credibility of the overall exercise and with the budgetary surveillance process being enhanced by having one consistent analytical framework.

- Secondly, in terms of the forecast methodology used, the GDP projections are based on an assumptions-driven extrapolation of recent trends in employment and labour productivity. All long-run projections need to be interpreted with caution, especially productivity projections, given the number of different

[40] In the baseline, Cyprus, Latvia and Slovenia show a strong catching-up of productivity - exceeding 80% of the average productivity of the 8 most productive countries. This is due to the combination of a relatively high starting level of productivity in 2004 (Cyprus, Slovenia); more favourable demographic developments (Latvia, Cyprus); and very strong productivity growth rates at the start of the projection (Latvia, Slovenia).

[41] See Denis et al. (2006).

factors explaining its development. There is moreover no consensus in the academic community whether productivity should converge across countries and whether it should do so in terms of levels or growth rates. They therefore remain projections, not forecasts. They only provide an indication as to what would happen on the basis of current policy settings under a number of prudent and transparent assumptions. In particular, the projected labour productivity growth rates rely on cross-country-consistent rules regarding the path of total factor productivity and of related capital stock developments. Although such patterns may or may not be realised over the coming decades, the projections are nevertheless based on the reasonable principle that whilst cross-country discrepancies in labour productivity growth rates are a plausible feature over a short to medium term time span, these differences should not be projected to persist indefinitely. In this context, the present exercise assumes that these divergences will fade away towards the end of the projection horizon.

- Thirdly, regarding the specific results which emanate from the application of this EPC-AWG agreed forecasting methodology, the most important conclusion to be underlined is the extent of the negative effects from ageing on EU potential growth rates :

    - The EU's present annual average potential growth rate of roughly 2 ½ % is projected to be cut in half over the coming decades, underlining why "grey" pressure has rapidly emerged as one of the key medium to long run policy concerns in the EU. This halving in potential growth rates will occur despite relatively favourable labour productivity projections, thereby underlining the extremely negative labour supply implications of Eurostat's latest population projections.

    - The projected fall in potential growth rates is much higher in the new Member States, compared with those countries which constitute the old EU15 aggregate. For the EU10, potential growth rates of 4.7% between 2004 and 2010 are projected to fall to only a small fraction of that rate (i.e. 0.6%) between 2041 and 2050. This is much lower than the projected growth rate of 1.3% expected for the EU15 grouping over the same period. While these developments partly reflect the fact that the EU10 and EU15 productivity growth rates are assumed to have converged by that time, they are nevertheless, in the main, driven by less favourable demographic developments.

- Finally, various sensitivity tests are carried out to check the impact of some factors, which have been excluded from the baseline scenario for reasons of simplicity. The main findings are:

    - Firstly, the impact of changes in the participation rate assumption have a much greater effect on GDP per capita developments compared with assumed changes in the share of part-time employment (i.e. in average hours worked per worker). More specifically, a rise in the share of part-time employment, driven by the projected increase in female participation rates, will only have a relatively weak impact on GDP per capita outcomes whereas participation rate changes have the potential to have much greater effects.

- Secondly, the negative effect of changes in the population age-structure appears to be fairly limited, although the labour productivity of an individual is likely to decline after the age of 55. A very strong productivity fall in the older age groups would be required to significantly depress the aggregate labour productivity growth rate. Such a scenario appears, at the present time, to be unlikely.

- Thirdly, changes in the assumed TFP growth rate targets could strongly affect the projections. More precisely, allowing TFP growth to converge towards the average growth rate recorded in EU15 since the start of the 1990's (i.e. 0.8%), rather than towards the long term average over the last 3-4 decades (i.e. 1.1%), leads to a strong decline in GDP per capita vis-à-vis the baseline.

- Finally, an assumption of productivity convergence in levels (as opposed to growth rates) substantially alters the projections for most of the EU10 countries but leaves the EU15 almost unchanged. The choice of the convergence target (i.e. 80% or 85%) has a considerable impact on the outcome of the simulations.

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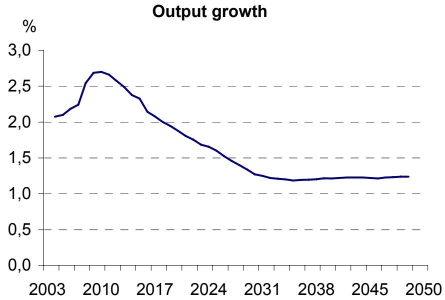
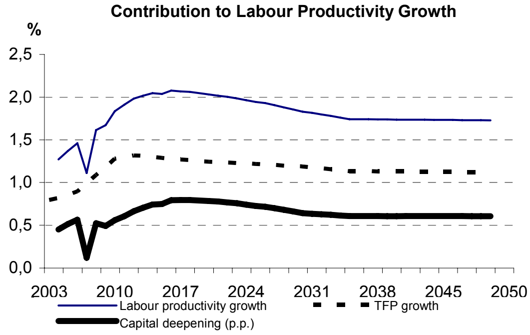
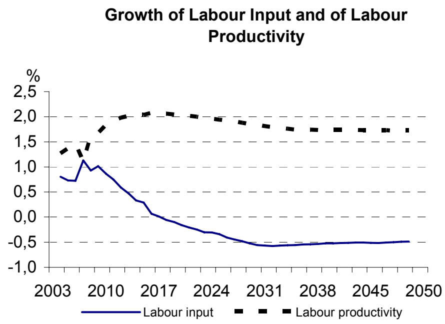
LIST OF TABLES

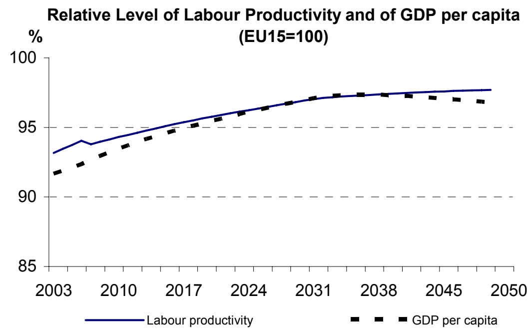
ANNEX 1: COUNTRY-SPECIFIC RESULTS

European Union (25 countries)

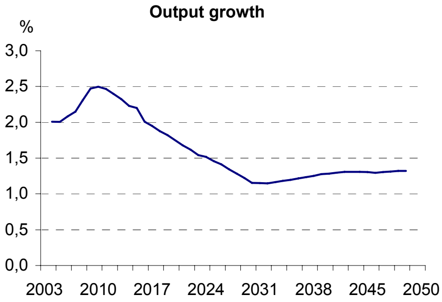


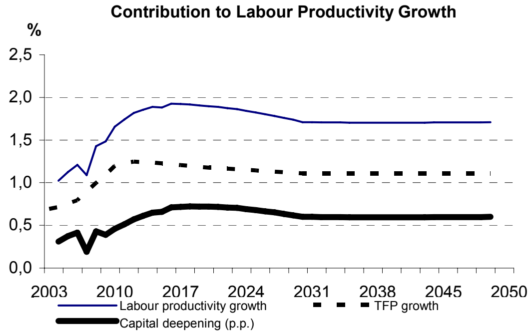


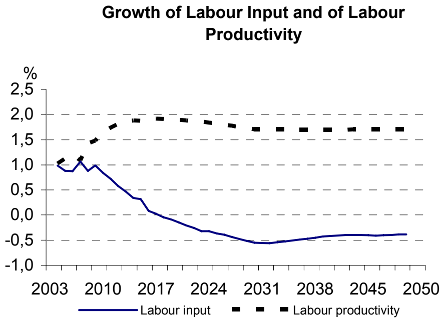


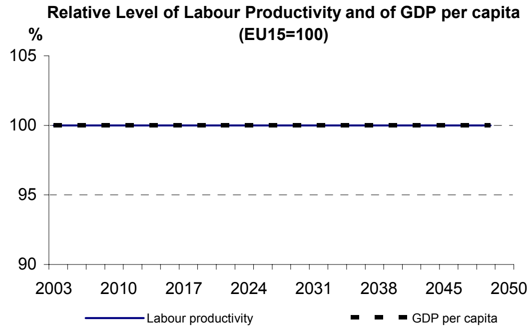


European Union (15 countries)

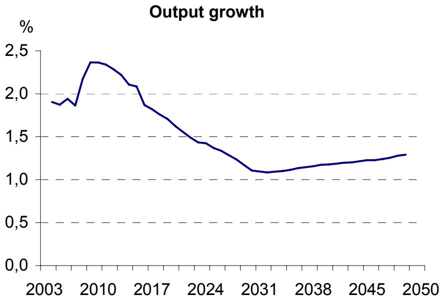


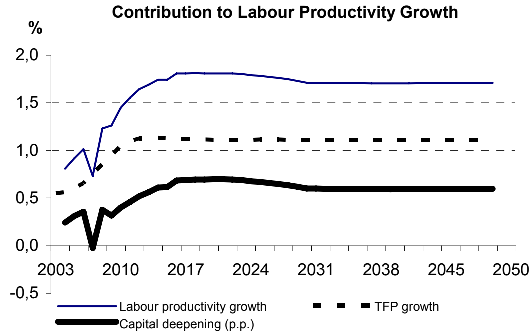


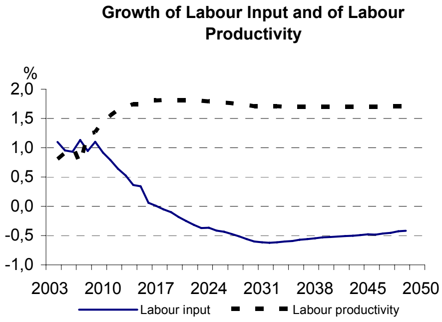


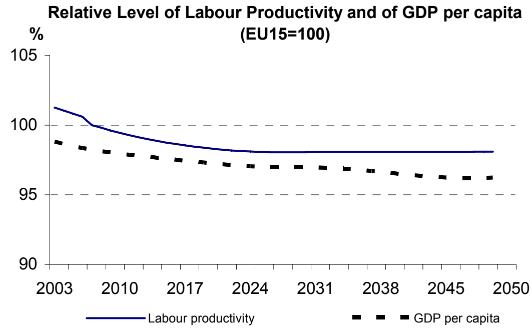


Euro-zone (12 countries)

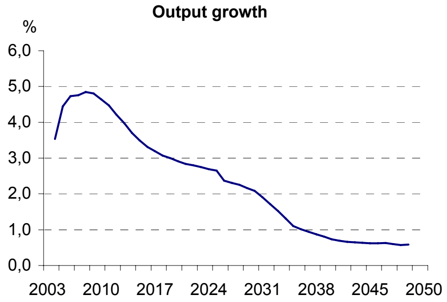


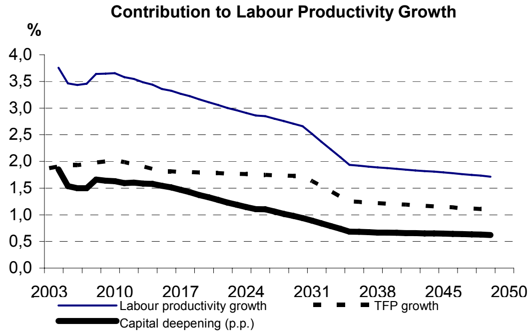


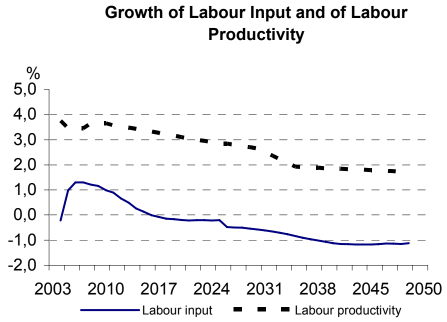


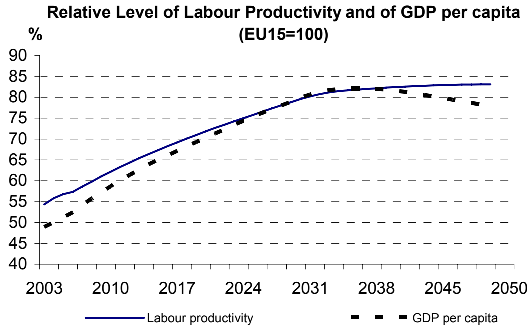


European Union (10 new Member States)









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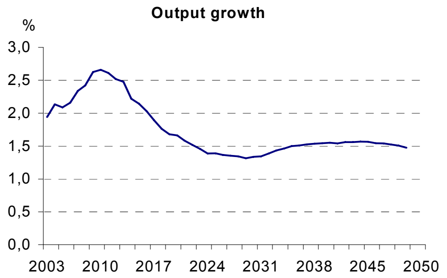
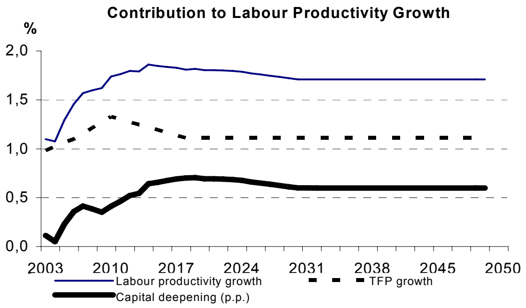
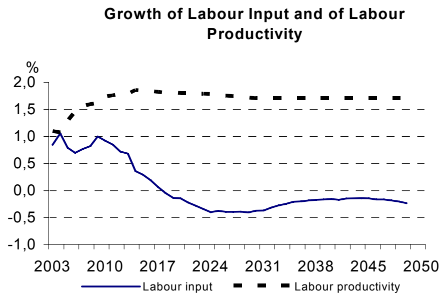
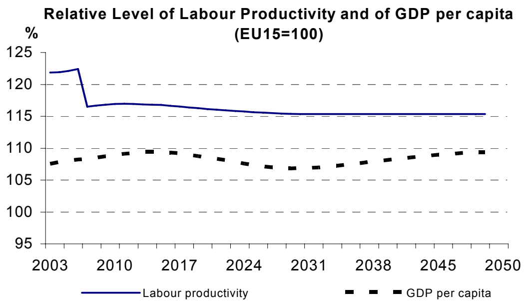


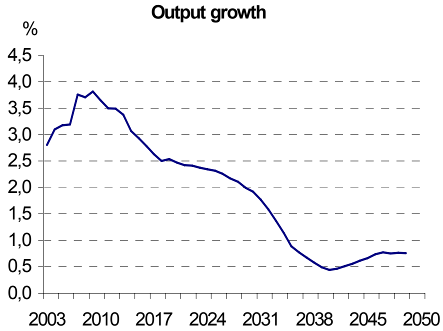




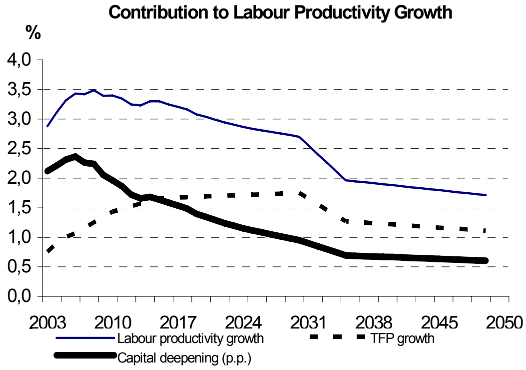


Czech Republic

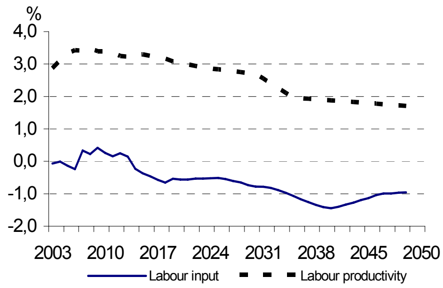
Output growth



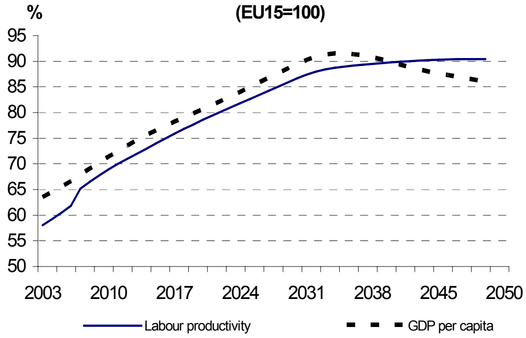
Contribution to Labour Productivity Growth



Growth of Labour Input and of Labour Productivity

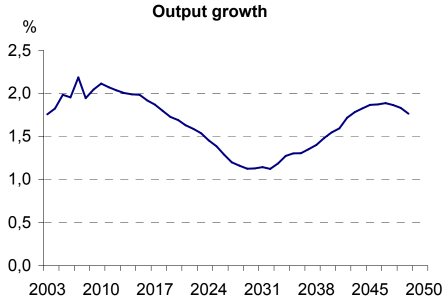


Relative Level of Labour Productivity and of GDP per capita (EU15=100)



Denmark

Output growth



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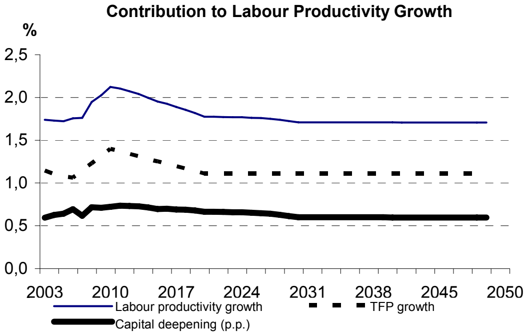
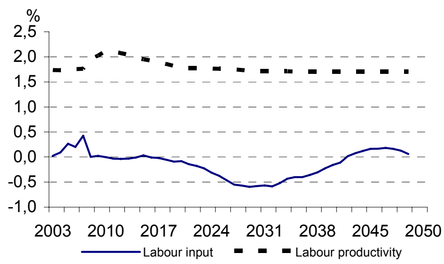


Growth of Labour Input and of Labour Productivity



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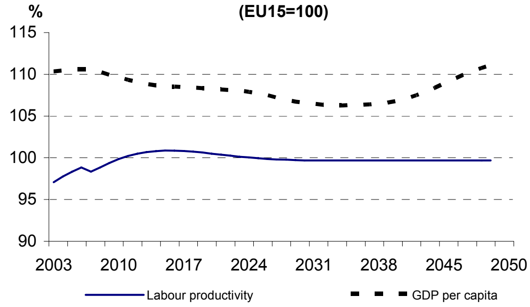
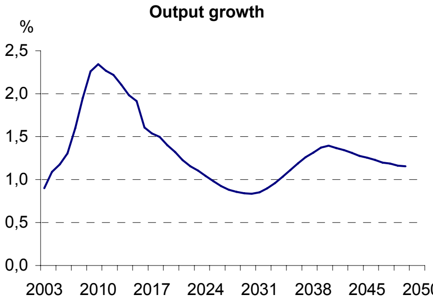
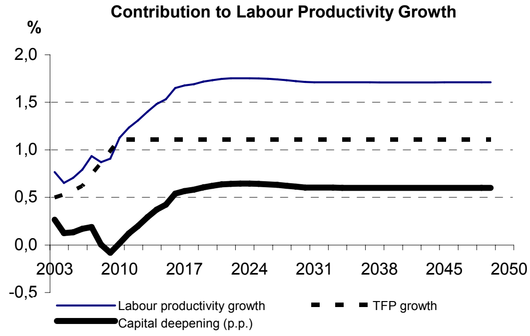
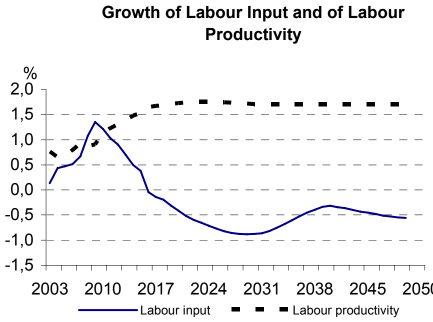
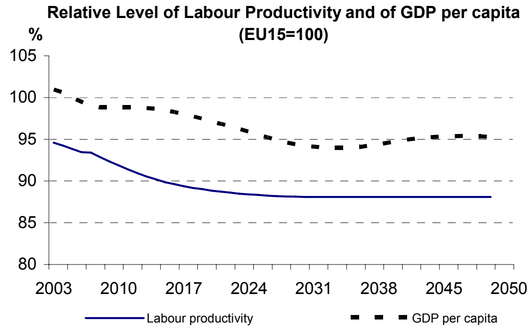


Germany









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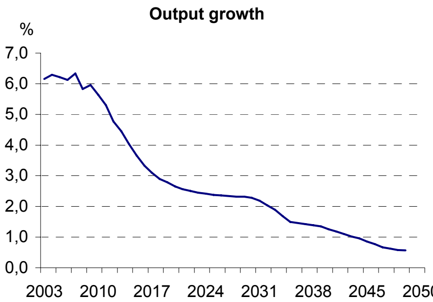

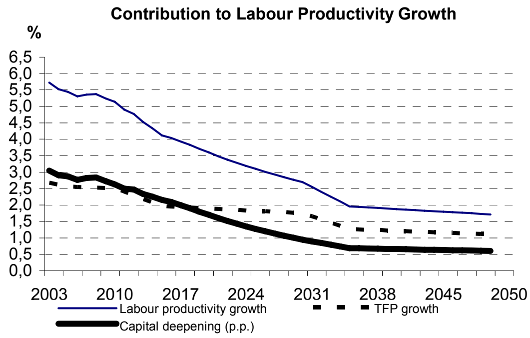

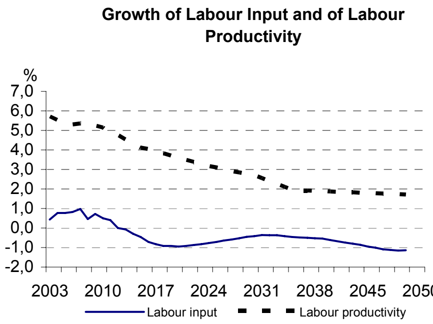

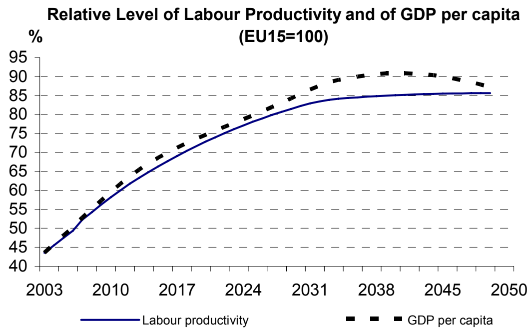

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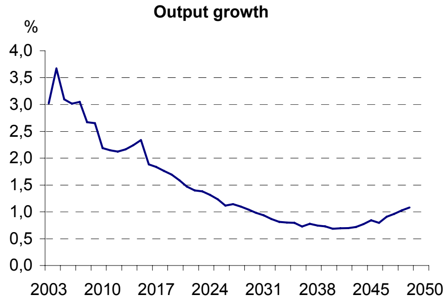
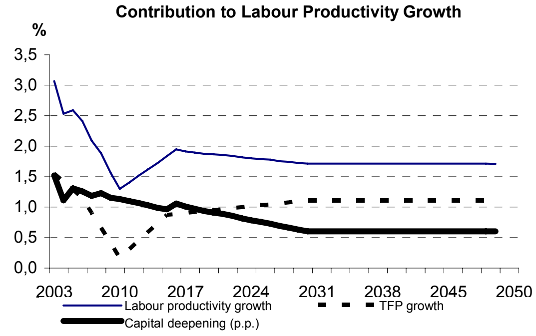
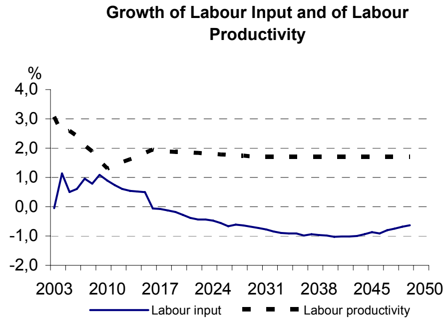
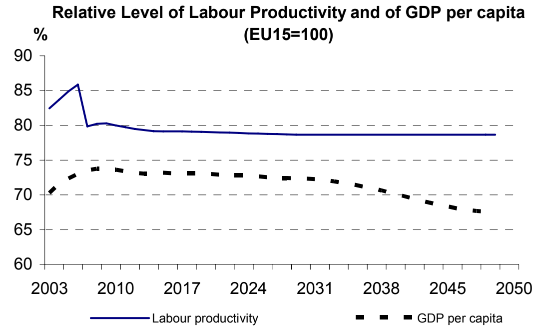
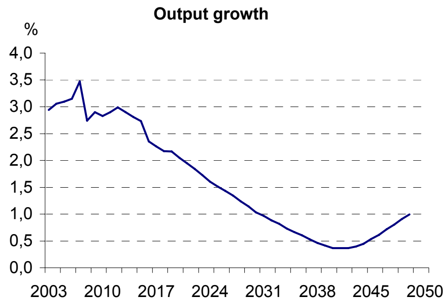


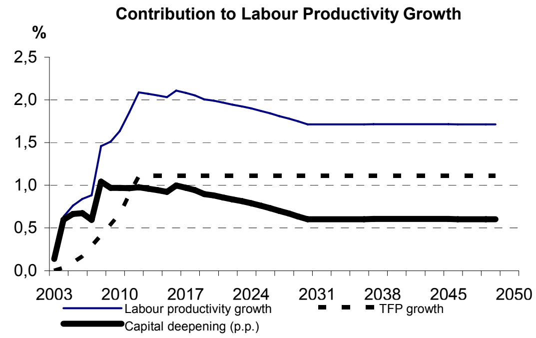


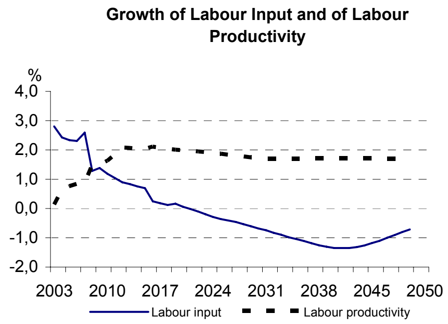


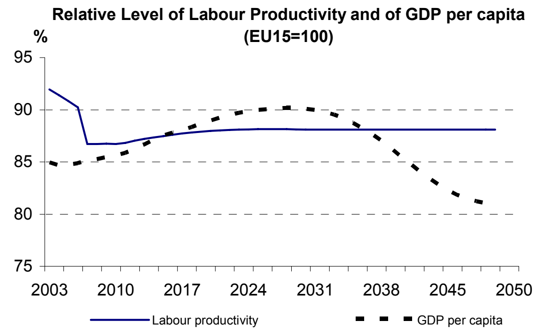


Spain



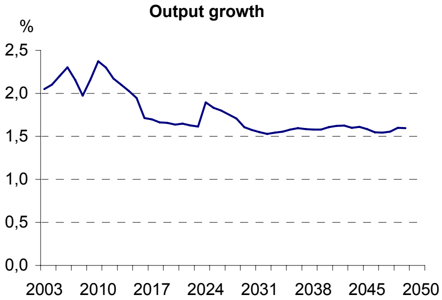




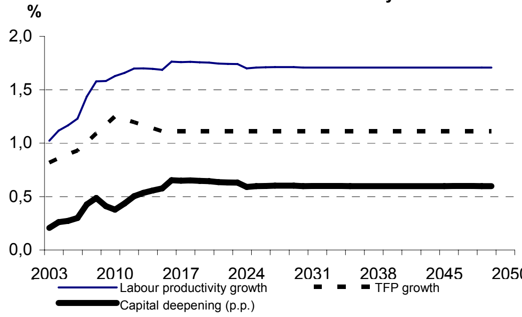


France

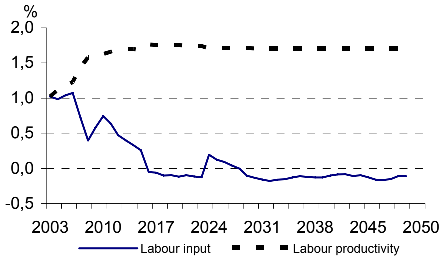
Output growth



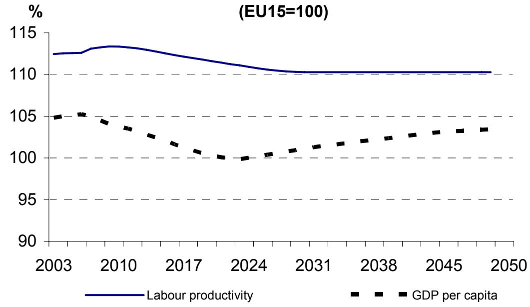
Contribution to Labour Productivity Growth



Growth of Labour Input and of Labour Productivity



Relative Level of Labour Productivity and of GDP per capita (EU15=100)



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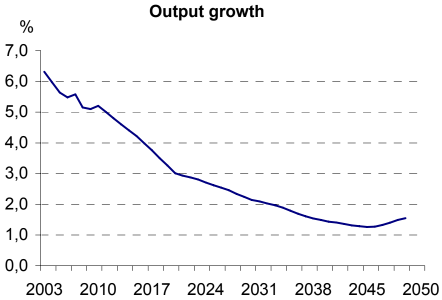
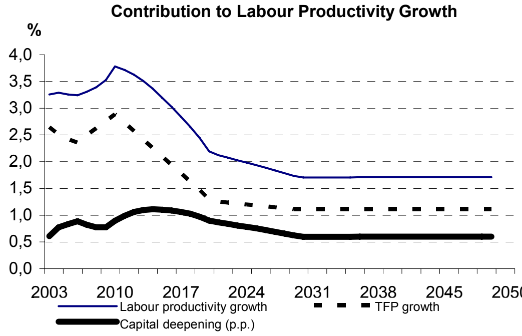
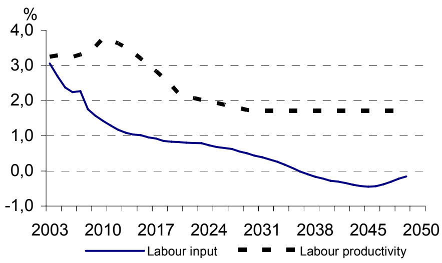
Output growth



Contribution to Labour Productivity Growth



Growth of Labour Input and of Labour Productivity



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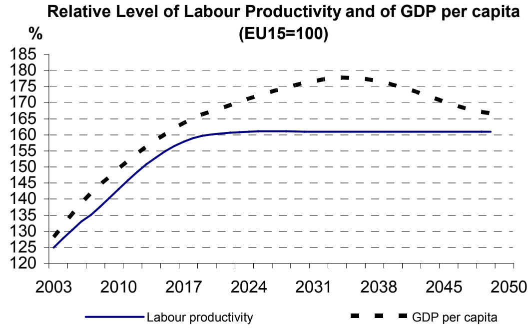

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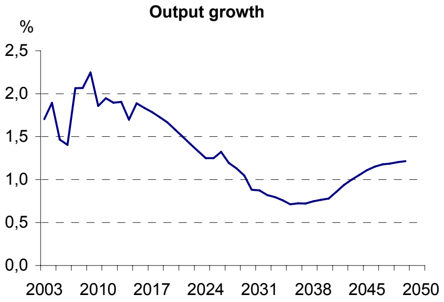

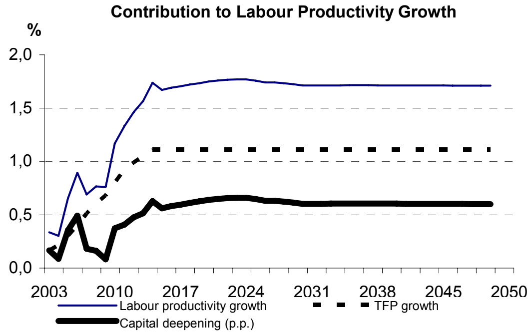

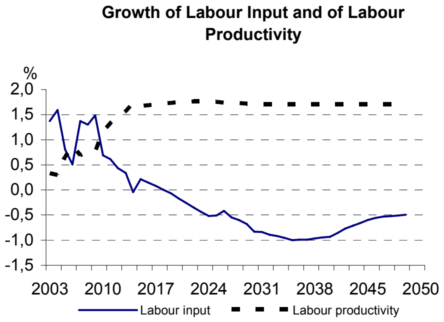

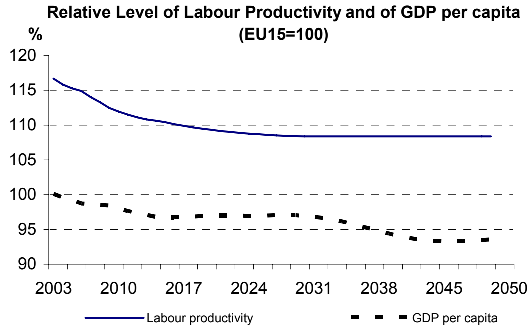

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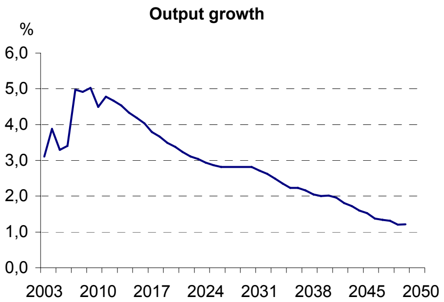
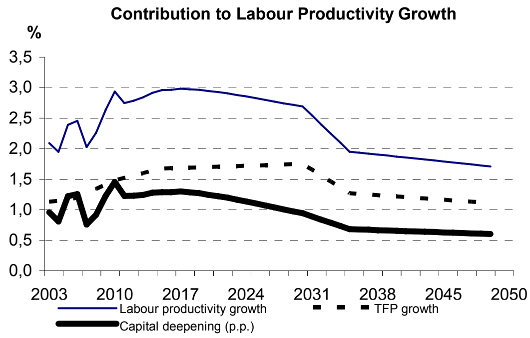
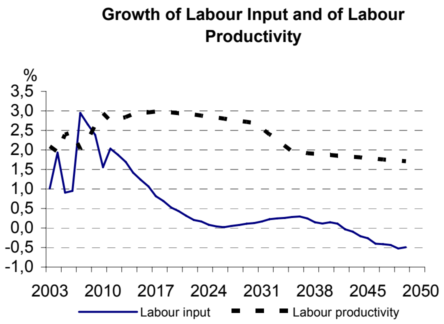
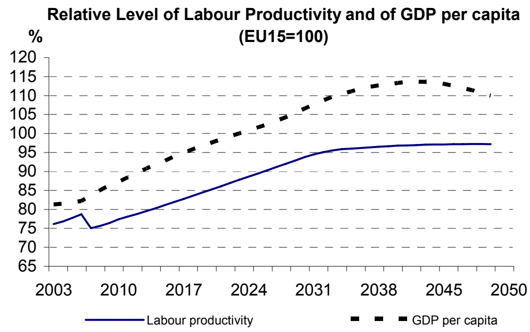
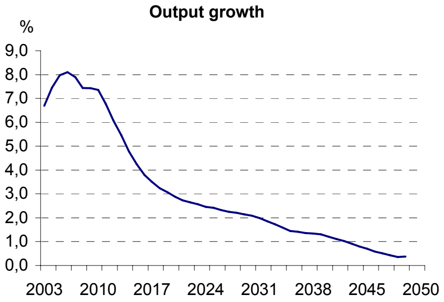


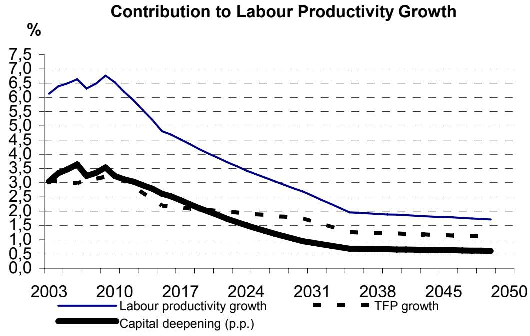


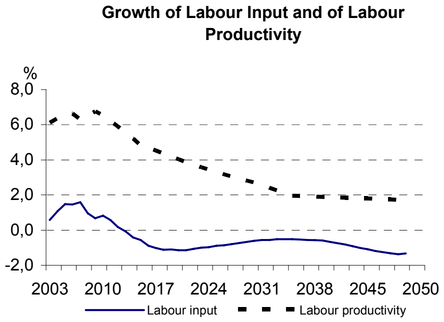


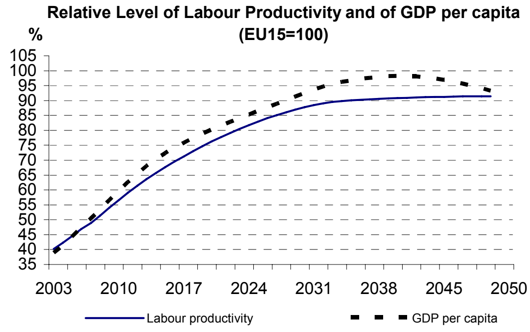


Latvia









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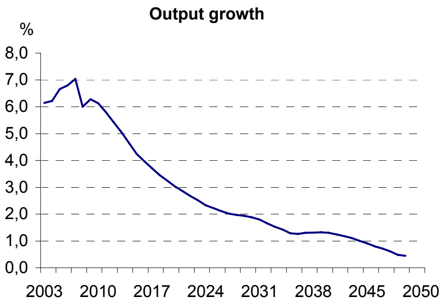
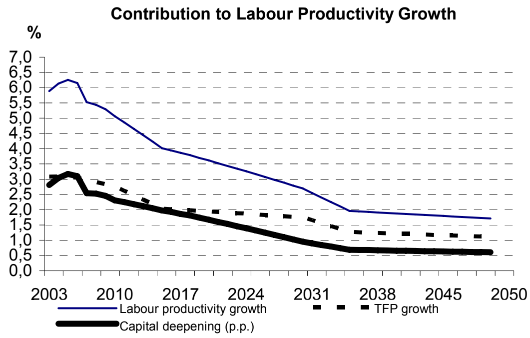
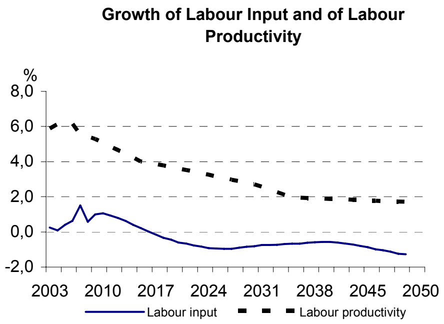
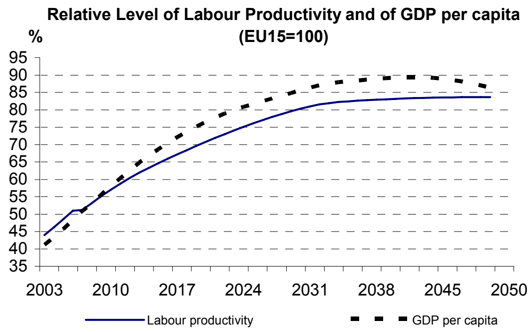


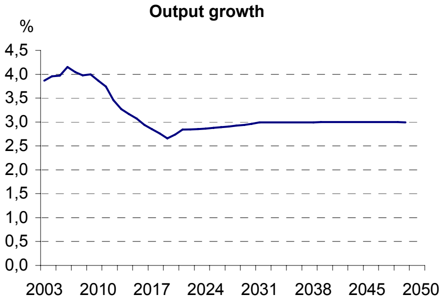




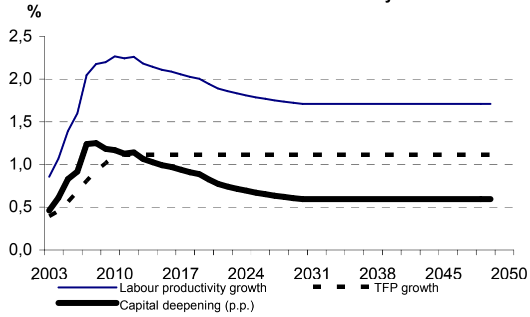


Luxembourg

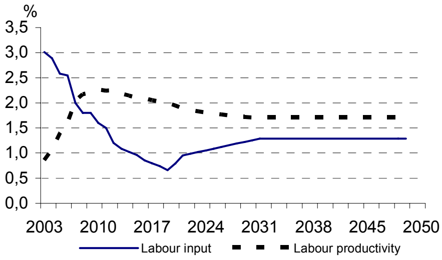
Output growth



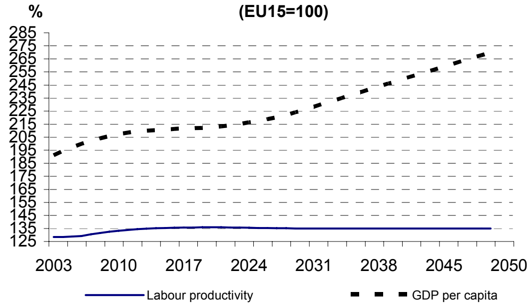
Contribution to Labour Productivity Growth



Growth of Labour Input and of Labour Productivity

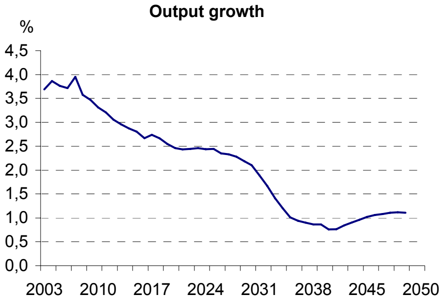


Relative Level of Labour Productivity and of GDP per capita (EU15=100)

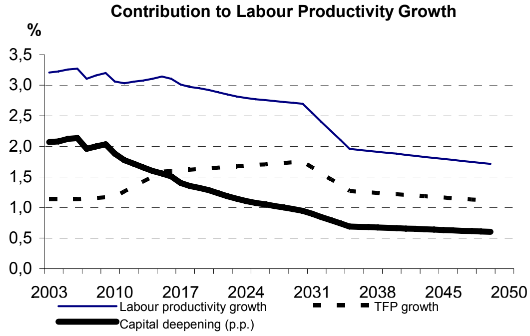


Hungary

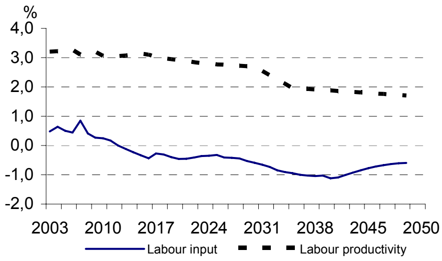
Output growth



Contribution to Labour Productivity Growth



Growth of Labour Input and of Labour Productivity



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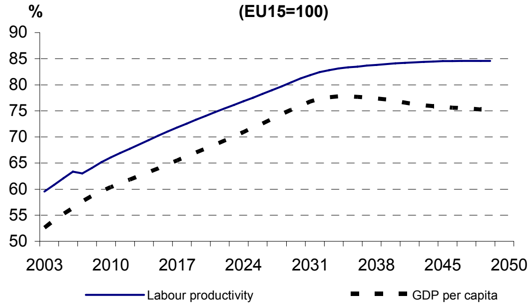
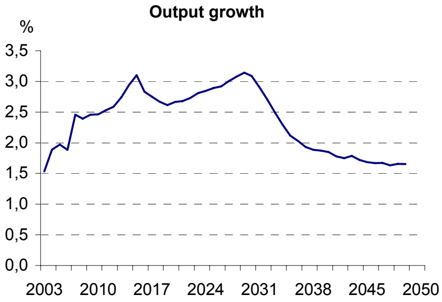
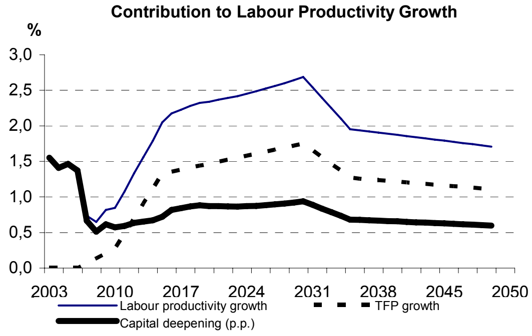
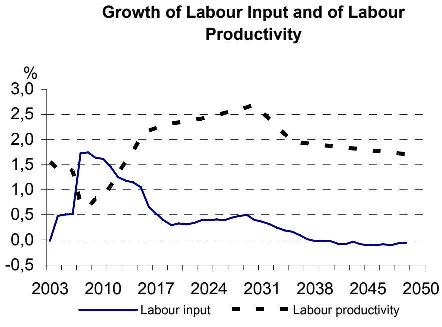
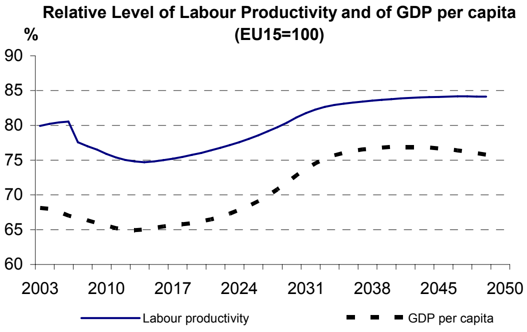


Malta

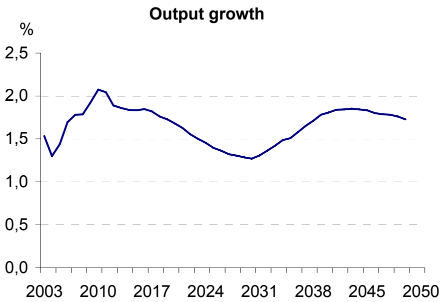


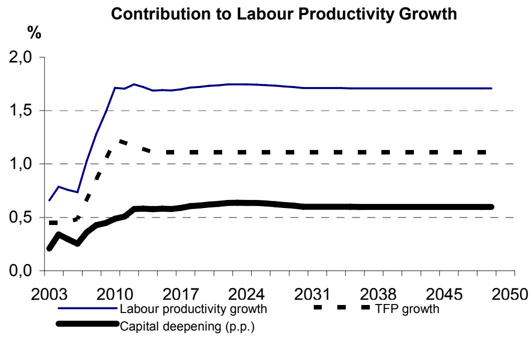


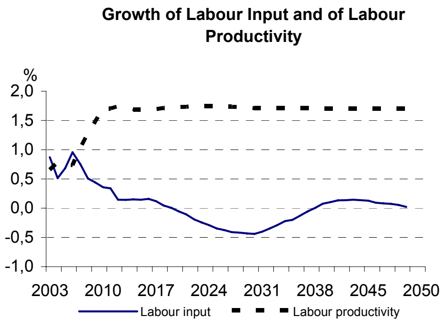


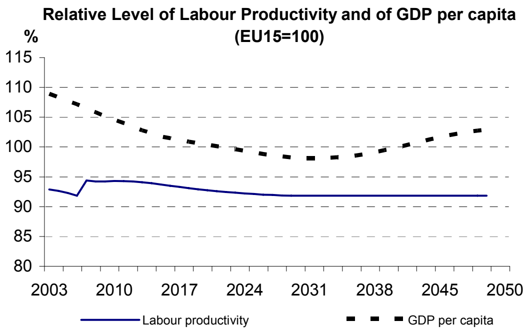


Netherlands



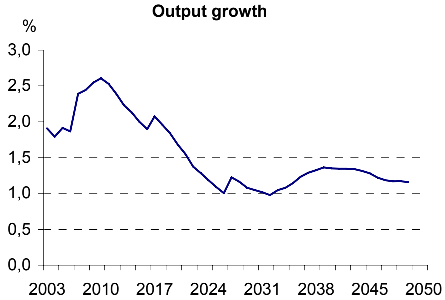




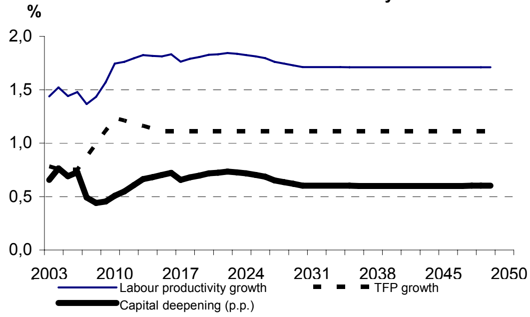


Austria

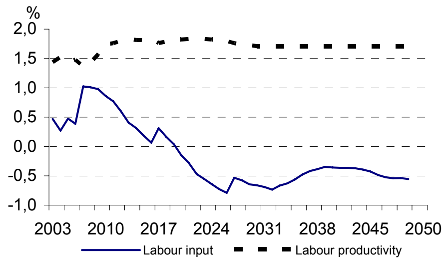
Output growth



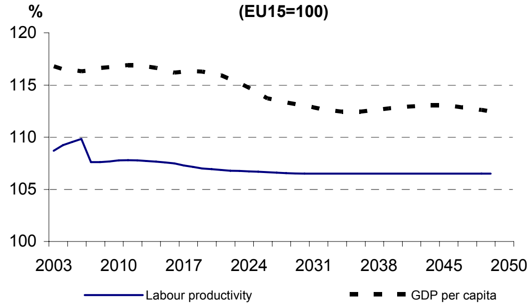
Contribution to Labour Productivity Growth



Growth of Labour Input and of Labour Productivity

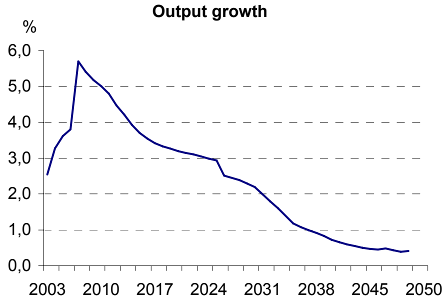


Relative Level of Labour Productivity and of GDP per capita (EU15=100)



Poland

Output growth



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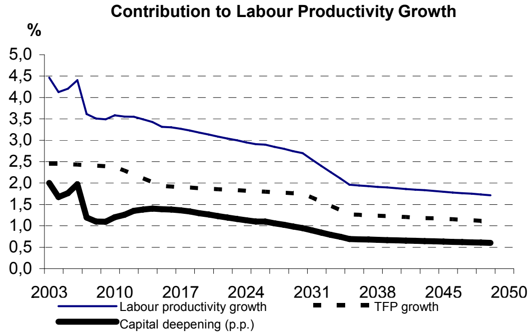
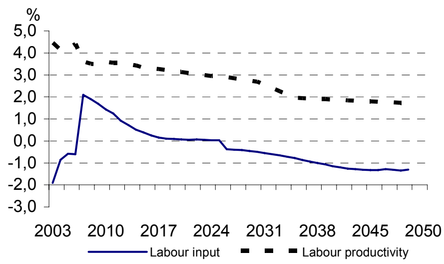
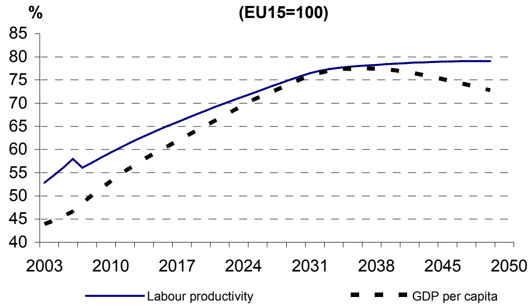


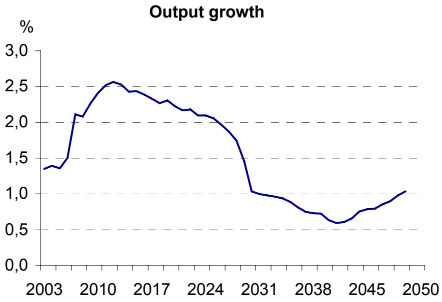
Growth of Labour Input and of Labour Productivity

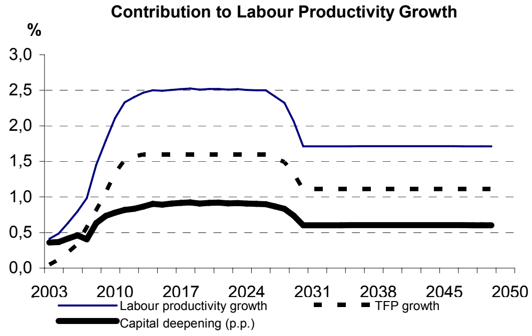


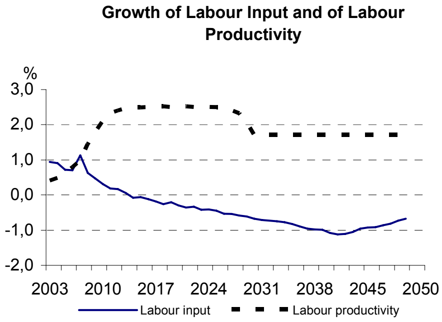
Relative Level of Labour Productivity and of GDP per capita (EU15=100)

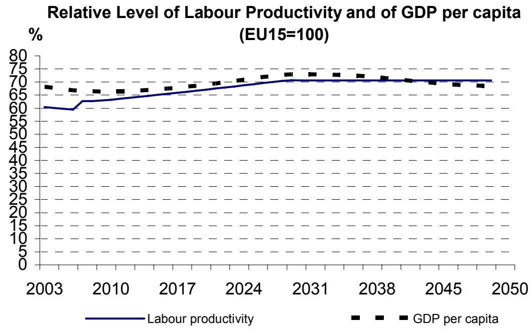


Portugal

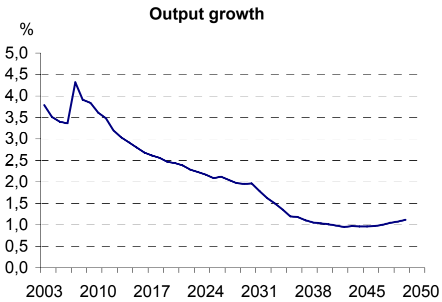


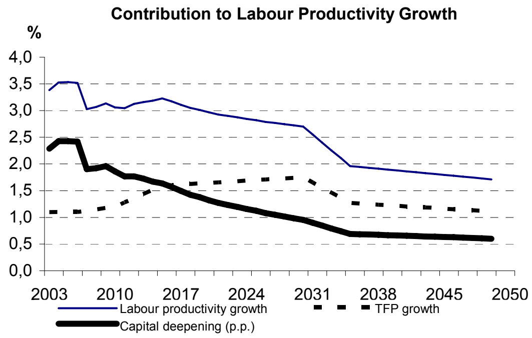


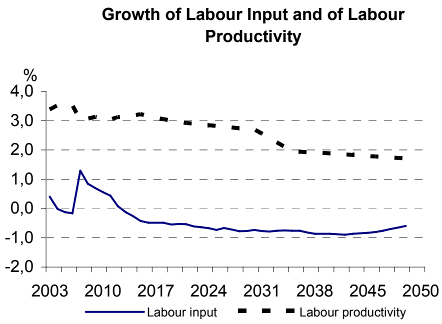


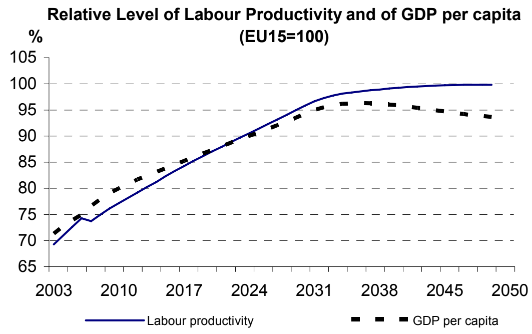


Slovenia



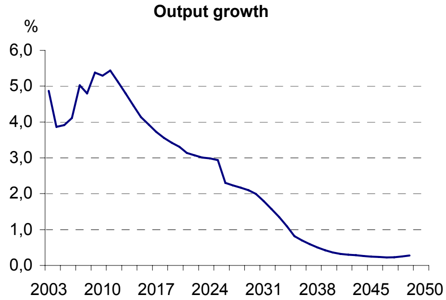




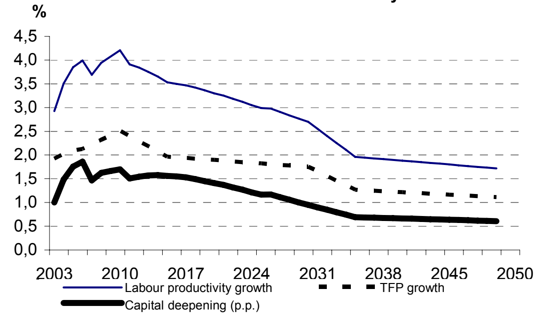


Slovak Republic

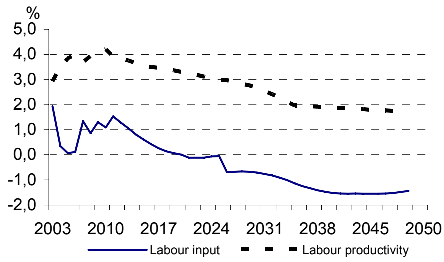
Output growth



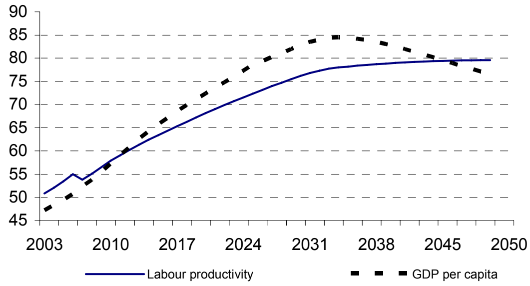
Contribution to Labour Productivity Growth



Growth of Labour Input and of Labour Productivity

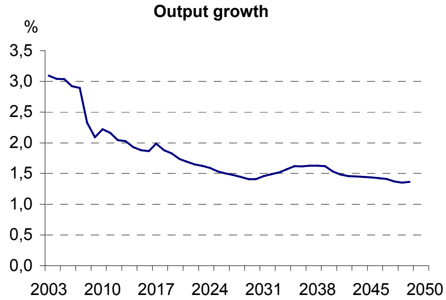


Relative Level of Labour Productivity and of GDP per capita (EU15=100)

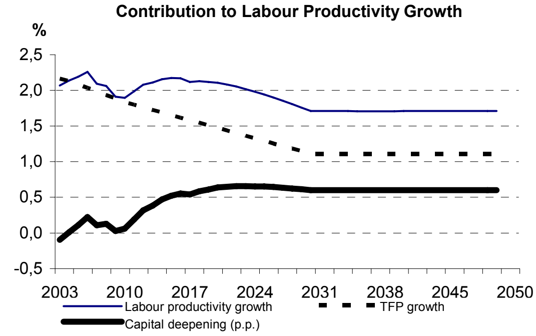


Finland

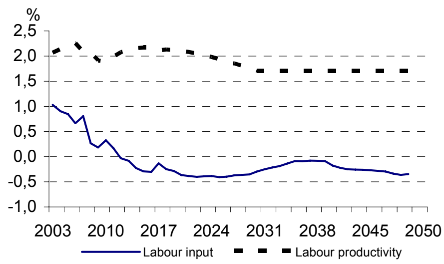
Output growth



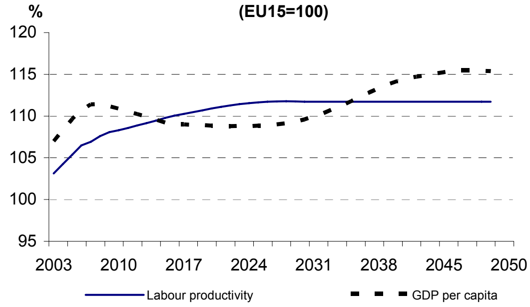
Contribution to Labour Productivity Growth



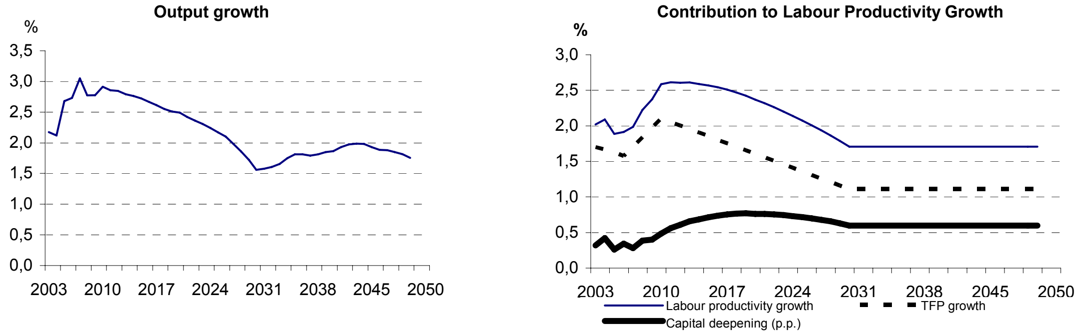
Growth of Labour Input and of Labour Productivity



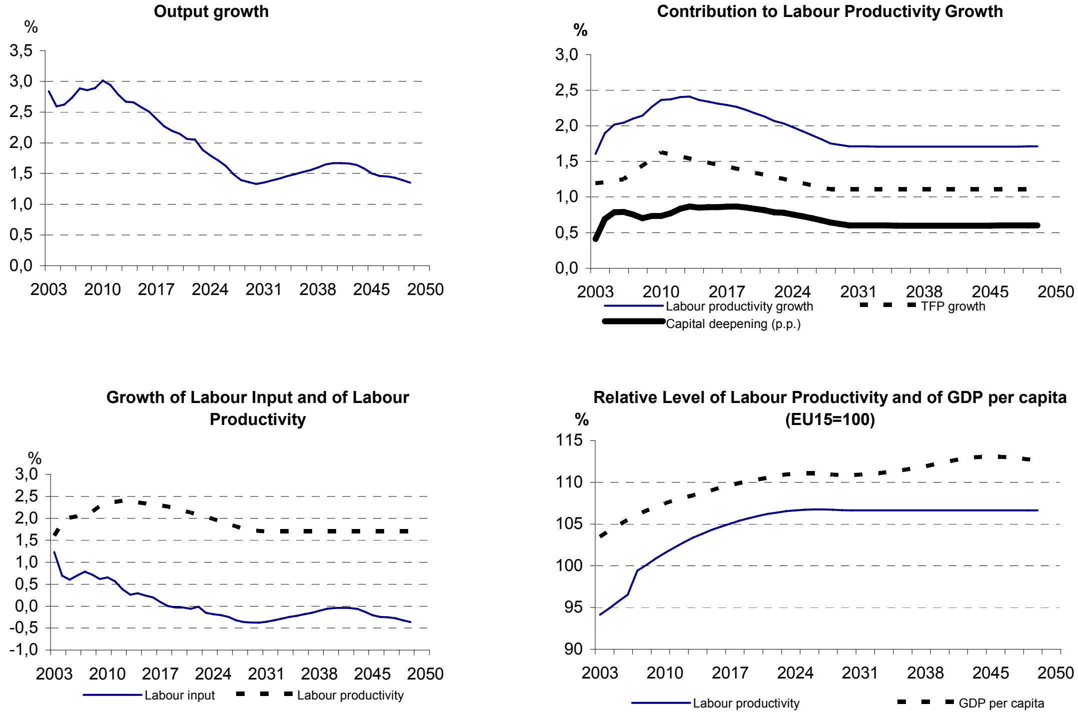
Relative Level of Labour Productivity and of GDP per capita (EU15=100)



Sweden



United Kingdom



ANNEX 2: EFFECTS OF AGEING ON LONG RUN LABOUR PRODUCTIVITY GROWTH : A THEORETICAL AND EMPIRICAL ASSESSMENT

INTRODUCTION

DG ECFIN has two broad methodologies for estimating medium to long run labour productivity trends. The first ECFIN method is largely a statistical approach based on a production function (PF) methodology, as presented in the main text of this paper. The second ECFIN method is based on an analytical framework which combines standard growth regressions with recent developments in endogenous growth theory. In essence this approach assesses the relative merits of the major hypotheses for explaining productivity growth over time – i.e. the role played by the regulatory environment (product, labour and financial markets); by the degree of openness of economies; by the efficiency of knowledge production (R&D and education); by the determinants of physical investment levels; and finally by demographics. A short overview of this second ECFIN method is given below, with a detailed description of the overall approach contained in Denis, Mc Morrow and Röger (2004 a and b).

The purpose of the present note is to show how this analytical framework can be used to provide insights for the Ageing Working Group (AWG) into the effects of ageing on long-run labour productivity trends in the EU15 and EU10 countries. While the overall framework covers much more than demographics, the present note concentrates on this latter issue given its direct relevance to the work of the AWG. Following the description of the ECFIN approach given in section 1, section 2 goes on to examine the specific risk of ageing for labour productivity over the long run, concentrating on both the theoretical and empirical issues involved. This section also provides estimates of the likely magnitude of the problem and the type of measures which could be considered to offset the negative effects which are predicted.

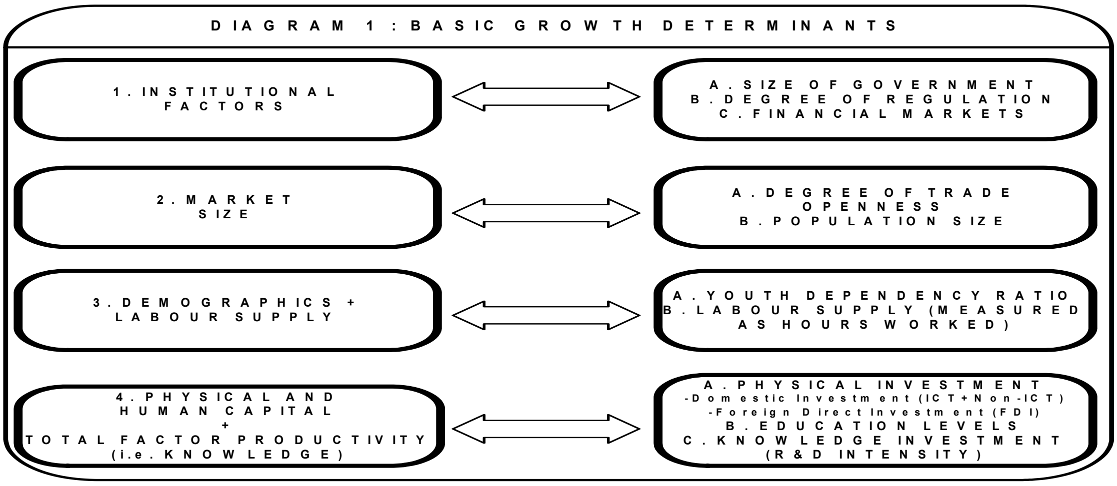
SECTION 1 : OVERVIEW OF ECFIN'S LABOUR PRODUCTIVITY MODEL

The achievement of a better understanding of the key determinants of productivity growth has been high on the research agenda of international organisations and the academic community for some decades now. ECFIN's research in this area represents an attempt to combine a detailed knowledge of these growth determinants (based on reviews of the literature and regression analysis) with the central policy concerns of European governments. It identifies five areas which are both quantitatively important for productivity and relevant in a European context i.e. the level of regulation; the structure of financial markets; the degree of product market integration; the size of knowledge investment; and the ageing of the labour force. In order to integrate all these diverse aspects into a unifying framework, growth regressions were used to draw lessons from the growth experiences of OECD member states over the last 2½ decades. On the analytical side an attempt was made to integrate recent developments in endogenous growth theory into the specification. This burgeoning growth literature combined with the distinctive nature of recent growth patterns has underlined the importance of knowledge production for productivity growth. In broad terms growth theory isolates two productivity enhancing channels, namely capital deepening and technical progress which is deemed proportional to knowledge. By looking at how these basic growth elements affect knowledge and physical capital formation, one can establish a more nuanced understanding of the channels through which they affect productivity.

As stressed in Denis et al. (2004a), when interpreting recent productivity trends in the EU and the US, two main questions arise :

- Firstly, how do the basic growth determinants (Diagram 1) affect physical investment and knowledge production (see 1.1); and

- Secondly, what is the relative importance of physical and knowledge capital formation for productivity growth (see 1.2).



1.1 HOW DO THE BASIC GROWTH DETERMINANTS AFFECT INVESTMENT AND KNOWLEDGE PRODUCTION ? At the outset, one must stress that when analysing all forms of investment one has to take into account the fact that its structure is changing over time in at least two important dimensions:

- Firstly, the growth in the importance of more knowledge intensive forms of investment (such as ICT and R&D spending); and
- Secondly, the observed increase in the international mobility of capital (FDI assets have grown from around 5% of world GDP in the mid 1980s to over 15% at the end of the 1990s).

DETERMINANTS OF PHYSICAL INVESTMENT

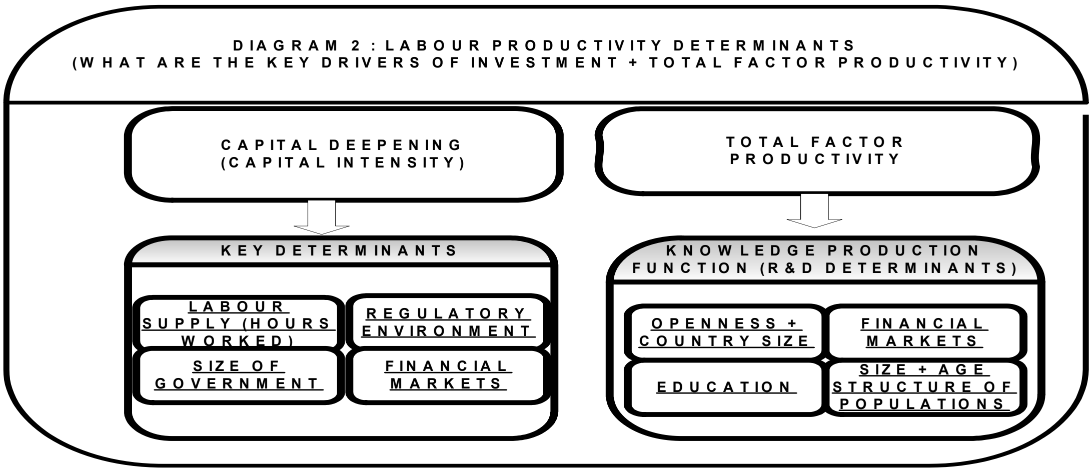
Amongst all the various growth determinants assessed in the regression analysis carried out for the 2004 study, regulation appeared to be the most important driver of investment rates. The degree of regulation plays an especially important role for foreign direct investment but it is also a crucial driver for new forms of investment such as ICT. There is also some evidence that equity based financial systems are more favourable to physical investment. Again, FDI flows are positively correlated with a more equity based structure for financial markets. Finally, education appears to be an important factor for foreign direct investment. These results suggest that in an environment characterised by increasing international capital mobility, levels of regulation, financial market conditions and human capital endowments are important determinants for the attractiveness of a country as an investment location.

DETERMINANTS OF R&D INVESTMENT

The determinants of knowledge investment are different to those of physical investment. Firstly, R&D is less affected by the regulatory environment. What seems to be more important for R&D is market size as measured by openness and population size. The lack of importance of regulation for R&D could be due to the fact that entry barriers are less significant for R&D activities which are typically concentrated amongst incumbent firms. Also, theoretically the link between regulation and research intensity is less clearcut. Given the sunk cost nature of R&D activities, the prospects of more secure rents provided by product market regulations (for example in the form of higher protection against violation of property rights from new inventions) may act as an incentive for R&D. The sunk cost nature of R&D also makes it plausible that market size matters in that firms located in more open and/or larger economies will typically engage more strongly in R&D activities. Investments in R&D are usually more risky than in physical investments and therefore the attitude of all financial institutions towards the financing of such investments is important. More market based financing mechanisms, including equity markets and venture capital funds, tend to favour riskier investments.

KNOWLEDGE PRODUCTION : THE EFFECT OF R&D, EDUCATION, MARKET SIZE AND DEMOGRAPHIC INFLUENCES

In addition to analysing the specific determinants of R&D investment, the 2004 study also assessed the role of R&D as one element in the overall knowledge production process in economies. In this context, the empirical growth literature emphasises knowledge and the creation of knowledge via the investment activities of firms, households and the government in both R&D and education as crucial for enhancing the level of technology (i.e. TFP). The empirical evidence strongly supports the view that R&D and education are significant drivers of total factor productivity. Trade openness/market size also appears to be especially important. Finally, the regression results strongly underpin the view that an ageing labour force has a negative effect on TFP. This latter result is discussed in much greater detail in Section 2 below.



1.2 : What is the relative importance of physical investment and knowledge capital formation for productivity growth ?

Section 1.1 described how the basic growth determinants affect physical capital formation and the creation of knowledge. The present section looks at the relative contribution of these two factors to labour productivity growth when they are combined with two other factors, namely the growth in the employment rate and the potential for catching-up. The neoclassical growth model makes fairly precise quantitative predictions concerning these four factors, with the estimated labour productivity growth contributions from the ECFIN model being very close to those predicted by the neoclassical model. The main results are given in Table 1 below :

Table 1 : Overview of Long Run Effects of Labour Productivity Determinants

Major Determinants	Effect on annual Labour Productivity Growth Rate (percentage points) (Level Effects in Brackets*)
Physical Investments + Regulation (Capital Deepening Effects)	
1. Physical Investment (Permanent 1 % point increase in GFCF)	0.05 (2.4)
2. Regulation (EU moving to US levels of regulation)	0.15 (4.6)
Knowledge Investments (TFP Effects)	
3. R&D (Permanent 1% point of GDP increase in R&D spending)	0.60 (17.7)
4. Education (Permanent 1 year increase in average education levels of labour force)	0.45 (12.8)
5. Ageing (Permanent 10% points decline in youth dependency ratio)	-0.25 (-6.8)**
6. Openness & Market Size (Permanent 10% points increase in intra-Euro area trade)	0.10 (3.0)
Hours Worked + Catching Up (Capital Deepening Effects)	
7. Permanent 1 % point increase in Hours Worked	-0.25 (-7.1)
8. Catching-Up	GDP per capita levels gap closed by roughly 2% on an annual average basis***

* Most of the level effects are evident after 25-30 years.

** This is the minimum TFP estimate we obtain in our regression work. This estimate excludes the positive capital deepening effects which, with a 10% points decline in the youth dependency ratio, would be equal to roughly 3%, implying therefore that the net overall effect of ageing on labour productivity would be negative (i.e. 3.8% in level terms / roughly 0.1 off the annual growth rate of labour productivity).

***This is a capital deepening effect (i.e. countries with a relatively low stock of capital tend to have higher rates of labour productivity growth) since identical TFP growth rates are assumed for the countries concerned. In addition, this speed of convergence represents the average for all of the countries in the sample, with individual country performances varying widely.

SECTION 2 : AGEING AND LABOUR PRODUCTIVITY[42]

An unavoidable consequence of declining birth rates is an ageing of the labour force. While so far there has been little research carried out on the possible consequences of ageing for productivity, nevertheless there is a widespread suspicion that an older labour force will be less adept in creating and adopting new technologies. Given the magnitude of the demographic transition in Europe, it seems appropriate to explore the possible consequences for productivity of this "greying" phenomenon.

GOING BEYOND THE CONVENTIONAL NEOCLASSICAL GROWTH MODEL FOR ANALYSING THE EFFECTS OF POPULATION GROWTH ON PRODUCTIVITY

The framework used in DG ECFIN's medium term analysis is basically a conventional neoclassical growth model consisting of a production function with constant returns to scale and exogenous technical progress and a simple investment rule where investment/saving is proportional to GDP. In earlier work we showed how the investment rule could be modified in order to become consistent with long term population trends. This present paper deals with attempts to endogenise TFP within this framework. This represents an additional issue of relevance in the context of long term demographic scenarios for two reasons :

- Firstly, changes in the birth rate and the implied age structure of the labour force could have effects on the efficiency of labour and the rate of technical progress; and

- Secondly, one might be interested in quantitatively analysing certain policy measures in order to stimulate the rate of technical progress such as to compensate for the income losses associated with ageing.

This section is organised as follows. Firstly, we briefly state the standard neoclassical growth model and present the predictions of this model concerning the long term level and growth rate effects of changes in the population growth rate. In a second step we look at two possible extensions of this model aimed at endogenising TFP. The first extension is in the spirit of Mankiw, Romer and Weil (1992) and basically consists of adding measures of human capital to the production function. This allows for endogenous level shifts of TFP but leaves the long run growth rate of TFP unaffected and not to be explained within the model. Such a modification has consequences in a demographic context to the extent that the efficiency of labour is cohort specific. A second extension is more radical and is based on the new endogenous growth literature which tries to model the long run growth rate of TFP as a function of human capital investment. In these models demographic factors are even more pertinent since population growth is tied in closely with the rate of knowledge production. The empirical results presented in this paper draw heavily on two sources, firstly the results presented in the EU Economy Review 2003 study and on recent results from Jones (2002). This latter paper, to the best of our knowledge, represents

[42] References for Section 2 include: European Commission (2003); Jones, C. I. (2002); Mankiw, N. Romer, D. and D. Weil (1992);. Solow, R. M. (1956); Temple, J. (1999).

one of the very few attempts made by researchers to confront endogenous growth models with data (in this case data for the US).

2.1 : THE SOLOW MODEL

The Solow model consists of four relationships :

A. DESCRIPTION OF THE TECHNOLOGY : neoclassical production function (constant returns to scale, exogenous TFP, with growth rate *g*) :

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

B. AN EQUILIBRIUM CONDITION FOR THE GOODS MARKET :

(2) $Y_t = C_t + I_t$

C. A BEHAVIOURAL RULE FOR INVESTMENT (or alternatively consumption) :

(3) $I_t = s(.)Y_t$

D. AN ACCOUNTING IDENTITY, LINKING THE CAPITAL STOCK TO INVESTMENT :

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

Employment is exogenous to the model but a labour market can easily be added as is done in DG ECFIN's medium term growth model, where the employment trend is determined by the medium term participation rate and the NAIRU. The growth rate of the population of working age (*n*) is exogenous.

This model makes two well known predictions on the impact of population growth on labour productivity :

1. The (balanced) growth rate of labour productivity is equal to the rate of labour augmenting technical progress and therefore independent of the growth rate of population.

2. The long run level of productivity is a negative function of the population growth rate. This means that, over a transition period, economies with lower population/labour force growth rates enjoy higher labour productivity growth.

This second effect is generated via an increase in the capital / labour ratio. This occurs because with the same investment rate more capital deepening is possible since fewer entrants to the labour force have to be equipped with capital. The long run productivity level (*Y/L*) effect of a change in population growth (*n*), the investment rate (*s*) or the growth rate of TFP (*g*) can be calculated easily from the following expression :

$$(5) \qquad \ln\left(\frac{Y_t}{L_t}\right) = gt + \frac{\alpha}{1-\alpha}\ln s(.) - \frac{\alpha}{1-\alpha}\ln(n+g+\delta)$$

With standard parameter values and the growth rates observed for OECD countries, this expression predicts that a 1% decline in the working age population growth rate (equivalent to a 20% points decline in the youth dependency ratio) raises the level of labour productivity by about 6% in the long run.

These effects have some support from empirical growth regressions. The rate of population growth usually enters negatively in growth regressions (see for example Mankiw et al. but also DG ECFIN (2003)). Also Temple (1999), in a recent survey of the empirical growth literature, concludes that empirical studies tend to find a (weak) negative correlation between population growth and per capita income[43].

Obviously a major shortcoming of this model is the fact that it only explains a small fraction of the variation in productivity growth, namely the part that is due to capital deepening and leaves unexplained the medium to long term movements of TFP. Also, in the context of demographic scenarios, one can ask the question whether the predictions made by this model on the effects of ageing on productivity are realistic since it excludes the possibly adverse effects of an ageing labour force on the rate of technical progress (e.g. ageing may lead to a slowdown in the creation and adoption of new ideas and techniques).

In the following paragraphs two possible extensions of the standard framework are presented which could provide another channel linking population ageing to productivity growth. Also the quantitative magnitude of these effects is assessed. The first model is a simple extension of the Solow model by adding human capital. The human capital extension of the standard growth model has been found to be more successful in replicating growth patterns in the empirical growth literature (see Mankiw et al.). The Mankiw et al formulation retains the assumption that the long run TFP trend is exogenous – see discussion under 'Extension I'. The recent endogenous growth literature goes one step further and endogenises TFP itself by postulating ideas or knowledge production functions. We call this variant 'Extension II'.

2.2 : Extension I : Human Capital Accumulation

Mankiw et al. assume that society devotes a certain fraction of current output to the accumulation of human capital in the form of spending on education. Their human capital accumulation equation is similar to the formulation used in the case of physical capital :

$$(6) \qquad H_t = s_h(.)Y + (1-\delta)H_{t-1}$$

Human capital investment is a constant share of total GDP and it depreciates at a rate equal to physical capital. Although this formulation conveys the idea that human capital is subject to depreciation, in the same way as physical capital (and therefore a

[43] Temple offers endogeneity problems as a possible explanation.

change in the age structure of the labour force could potentially have an effect on the average level of efficiency of workers), demographic effects do not come into play in this formulation since human capital investment is not proportional to the youth population but proportional to GDP. In other words this formulation implicitly assumes that when the share of the youth population is declining, education spending per student increases. One should not necessarily assume that this will be the case automatically but one should try to separate out both effects conceptually. In the empirical analysis conducted for the 2003 Review, ECFIN made an attempt in that direction by introducing a dynamic relationship for the average human capital endowment which is based on the concept of human capital investment per person. (see Appendix at the end of this annex for a more detailed derivation).

$$(7) \qquad h_t^w = (1 - \lambda^w - dh - gw)h_{t-1}^w + \lambda^y h_{t-1}^y Ydeprat_{t-1}$$

In this formulation the average human capital stock of the labour force can be expressed as a function of the education level at entry into the labour force (h^y); the youth dependency ratio (*ydeprat*); and the rate of depreciation of human capital (*dh*). This formulation suggests that to the extent that human capital depreciates, the youth dependency ratio should enter a TFP regression positively. Obviously this effect can be counteracted by increasing the human capital endowment of the labour force and therefore measures of the level of education would be expected to play a role as well. The TFP regression that was estimated had the following general form :

$$(8) \qquad \ln(TFP_t) = a_1 \ln(TFP_{t-1}) + a_2\left(\frac{R\,\&\,D_t}{Y_t}\right) + a_3 EDU_t + a_4 Ydeprat_t + \sum_{j=1}^{k} bX_{t,j}$$

As shown in the Review (2003), the youth dependency ratio is significant in this regression and has a positive sign. The first question to ask is whether this effect can potentially overturn the positive effect of population ageing on productivity as predicted by the conventional model ? The answer is yes. According to current estimates, the youth dependency ratio has declined from around 0.4 to 0.25 in 2000. A further small decline is forecast over the coming decades. This additional decline will be accompanied by a reduction in the growth rate of the working age population by about 1% in some Member States. According to our estimates, without compensating educational measures, the overall decline of about 0.2 in the youth dependency ratio leads to a decline in TFP of around 14 ½% in the long run. However, this is based on "old" demographic assumptions, which are much more pessimistic than the recent Eurostat demographic scenario released in 2005 (EUROPOP2004 and the AWG variant). We know from earlier that the capital deepening effect of a 1% decline in the growth rate of the labour force is of the order of magnitude of +6%. Consequently, the net effect (TFP + capital deepening) of a decline in the birth rate on the level of labour productivity is of the order of magnitude of -8 ½% in the long run (i.e. roughly 0.2 off the labour productivity growth rate)[44]. Again, it should be borne in mind that this figure is only illustrative, as the demographic assumptions are not consistent with the most recent ones used in

[44] While the overall effect of ageing on labour productivity is negative, it is difficult due to the complex dynamics involved to predict how the effect will be distributed over time i.e. how much has already been realised and how much remains still to be experienced is an empirical issue which demands additional analysis.

the main text. Indeed, scenario 3 in section 6.1.2, based on the same elasticity of TFP growth to youth dependency ratio (table1 above) shows that the negative impact of decreasing youth dependency should be significantly lower. The second question to ask is : are these results plausible ? One possibility to check this is to retrieve the implied human capital depreciation figure which would be consistent with the estimated effect of the youth dependency ratio on TFP. This is done by simulating the theoretical model with a shock that corresponds to the decline in the growth rate of the youth population of 1%, which generates the projected decline of the youth dependency ratio of 20% points (0.4 to 0.2) in the long run for a whole range of alternative human capital depreciation rates.

The following table provides results on the effect of a decline in the population growth rate of 1% on TFP, capital intensity and labour productivity under alternative assumptions on the rate of depreciation of human capital.

TABLE 2 : EFFECTS OF DEPRECIATION OF HUMAN CAPITAL

Year	1970 0	1980 10	2000 30	2020 50	2050 80	2100 130	2500 500
δ =0.0, Human Capital after 40 years: 100%							
YL_PCER	0.01	0.55	2.31	3.78	5.14	6.09	6.54
HW_PCER	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TFPADJ_PCER	0.00	0.00	0.00	0.00	0.00	0.00	0.00
KL_PCER	0.03	1.60	6.74	11.18	15.40	18.42	19.86
δ =0.0025, Human Capital after 40 years: 90%							
YL_PCER	0.01	0.47	1.80	2.72	3.32	3.44	3.21
HW_PCER	0.00	-0.10	-0.60	-1.15	-1.86	-2.57	-3.12
TFPADJ_PCER	0.00	-0.07	-0.39	-0.75	-1.21	-1.68	-2.04
KL_PCER	0.03	1.57	6.43	10.35	13.70	15.63	16.12
δ =0.005, Human Capital after 40 years: 82%							
YL_PCER	0.01	0.40	1.32	1.74	1.69	1.15	0.49
HW_PCER	0.00	-0.21	-1.17	-2.23	-3.53	-4.79	-5.68
TFPADJ_PCER	0.00	-0.13	-0.76	-1.45	-2.30	-3.14	-3.73
KL_PCER	0.03	1.55	6.14	9.57	12.15	13.21	13.05
δ =0.01, Human Capital after 40 years: 67%							
YL_PCER	0.01	0.25	0.42	-0.02	-1.12	-2.57	-3.69
HW_PCER	0.00	-0.42	-2.24	-4.16	-6.38	-8.38	-9.61
TFPADJ_PCER	0.00	-0.27	-1.46	-2.73	-4.19	-5.53	-6.36
KL_PCER	0.03	1.50	5.58	8.15	9.45	9.22	8.33
δ =0.02, Human Capital after 40 years: 45%							
YL_PCER	0.01	-0.04	-1.16	-2.93	-5.36	-7.72	-9.12
HW_PCER	0.00	-0.81	-4.12	-7.31	-10.64	-13.31	-14.70
TFPADJ_PCER	0.00	-0.53	-2.70	-4.81	-7.05	-8.86	-9.82
KL_PCER	0.03	1.41	4.57	5.75	5.28	3.62	2.23
δ =0.03, Human Capital after 40 years: 30%							
YL_PCER	0.01	-0.31	-2.51	-5.18	-8.35	-11.04	-12.48
HW_PCER	0.00	-1.18	-5.70	-9.71	-13.60	-16.46	-17.85
TFPADJ_PCER	0.00	-0.77	-3.74	-6.42	-9.07	-11.03	-12.00
KL_PCER	0.03	1.32	3.69	3.83	2.26	-0.04	-1.54
δ =0.04, Human Capital after 40 years: 20%							
YL_PCER	0.01	-0.57	-3.65	-6.96	-10.53	-13.34	-14.76
HW_PCER	0.00	-1.53	-7.03	-11.58	-15.74	-18.63	-20.00
TFPADJ_PCER	0.00	-1.00	-4.62	-7.69	-10.53	-12.54	-13.50
KL_PCER	0.03	1.24	2.92	2.27	0.00	-2.59	-4.10
δ =0.05, Human Capital after 40 years: 13%							
YL_PCER	0.01	-0.81	-4.63	-8.37	-12.17	-15.01	-16.41
HW_PCER	0.00	-1.86	-8.15	-13.06	-17.33	-20.20	-21.55
TFPADJ_PCER	0.00	-1.21	-5.38	-8.69	-11.63	-13.64	-14.59
KL_PCER	0.03	1.16	2.25	1.00	-1.71	-4.46	-5.96

YL = Labour Productivity **HW** = Efficiency of Labour
TFPADJ = TFP adjusted for labour efficiency **KL** = Capital intensity

With zero human capital depreciation, the model replicates the effect of the standard neoclassical (Solow) growth model. Population growth has a positive effect on labour productivity which is equal to the theoretical prediction. It should be noted that this is generated by an increase in capital intensity of 18%. With assumptions of human capital depreciation, there is a negative TFP effect which starts to dominate the capital deepening effect for depreciation rates in a range larger than 0.5% per year. In order to obtain a long run productivity effect of the order of magnitude estimated in the present note, namely a reduction in labour productivity of about 14 ½% (from a decline in the youth dependency ratio from .4 to .2) one has to assume a rate of depreciation of between 3% to 4 %. As can be seen from the table, this would imply that the average worker, at the end of his career, would have an efficiency level which is 20% to 30% compared to the level at entry into the labour force. These depreciation rates appear large. Two observations should be added when interpreting these numbers. The estimates could potentially be biased upwards. The youth dependency ratio may capture some sectoral changes in the economy, possibly related to the expected shift in demand to low productivity growth service sectors, associated with the shifting demand patterns of an ageing society. Secondly, these estimates could reflect certain features of the innovation process such as, for example, resource constraints in the form of (young) researchers and entrepreneurs capable of generating and implementing new ideas (instead of refining existing ideas), a factor stressed in the endogenous growth literature surveyed in the next section.

2.3 : Extension II : Endogenizing TFP Growth (Knowledge Production Function)

The results presented above suggest that a decline in the birth rate will eventually lead to a lower level of TFP and labour productivity (relative to their long term trends). New growth theory arrives at a more pessimistic view on the relationship between population ageing and productivity. The effect is intrinsic to the way in which the creation of knowledge is seen in these models. The argument basically goes as follows. Starting from the conventional neoclassical production function where TFP is exogenous, the new growth theory regards TFP as being proportional to the stock of knowledge accumulated by conscious efforts. Knowledge must be produced just like other goods, using especially human resources. Typically the following type of knowledge production function is postulated :

(9) $$\Delta TFP_t = \chi L_{A,t}^{\lambda} TFP_{t-1}^{\phi}$$

Where $L_{A,t}$ is the amount of labour devoted to R&D activities. Total labour must be allocated between the research and the production sector. Just like in the conventional growth model there exists a balanced growth path with a constant investment share and a constant share of workers in the two sectors for any growth rate of the labour force. Notice that the long run growth of labour productivity is still equal to the growth rate of TFP. But from (9) one can now determine the growth rate of TFP as a function of the growth rate of the population :

(10) $$g_{TFP} = \gamma g_{L_A} \; with \;\; \gamma = \frac{\lambda}{1-\phi}$$

and g_{L_A} equal to population growth under a balanced growth assumption. And even more importantly, population growth is the only source of TFP growth in the long run. The central messages from these types of models in the context of population ageing are:

1. The growth rate of TFP declines proportionally to the growth rate of the population[45].

2. TFP growth can only be prevented from declining by an ever increasing share of workers allocated to R&D activities.

This view is expressed forcefully by Jones (2002) by giving an alternative interpretation to the long term growth process of the US economy. With standard growth accounting assumptions (based on the basic neoclassical growth model) the US economy is often portrayed as growing along a balanced growth path, namely along a fairly constant growth rate of TFP (which may have increased in recent years), with constant investment rates and stable employment rates (stable NAIRU and stable trend participation rates). A growth accounting exercise which is based on endogenous growth models arrives at different conclusions. Firstly, the balanced growth path, as determined by the growth rate of the population, is in fact very small and lies at 1/3 of a per cent for the US. The actual growth rate of labour productivity, averaging about 2% in the US (from 1950 to 1993) was generated via the (permanent) shift of resources into knowledge (R&D) activities. According to Jones two factors have been responsible for sustaining these 2% growth rates, namely rising educational attainment levels and rising R&D spending shares. In this context, the annual average growth rate of human capital over this period (educational attainment) was equal to 0.63% while the growth rate of the R&D labour force was estimated to be 4.8% per annum (note : without these human capital and R&D growth rates, US labour productivity growth would have averaged only 1/3 of a % over this period). The effect of physical capital on growth is relatively small[46].

2.4 : Quantification of Effects

As emphasised above, the more recent endogenous growth models have a radically different view on the determinants of long term (balanced) growth. While the 'Extension I' models regard the same variables to be important for growth as 'Extension II' models, the former emphasise long term level effects while the latter emphasise growth rate effects. It is interesting to ask whether the quantitative predictions concerning population, investment and knowledge are very different when one calculates level multipliers over very long time horizons. This is attempted in table 3, where we compare standardized shocks between the Jones model and DG ECFIN's Review estimates.

Interestingly the level implications of the results based on the two approaches are similar when calculated over longer term horizons. This is true for both the effects of population ageing on labour productivity as well as for the effect of possible compensating measures. The most important result from the point of view of demographic scenarios is the sign difference for the effect of population growth on labour productivity between the standard Solow model and both the extension I and

[45] While this refers to the global population growth rate, it is not clear under what conditions countries would benefit or lose from these trends.

[46] This effect cannot be directly compared to the effect of capital deepening in conventional growth accounting exercises. In Jones the capital effect is based on the capital / output ratio while in traditional exercises the effect is based on the capital / labour ratio. Obviously the latter increases more than the former.

extension II models. The standard Solow model predicts a positive effect from a fall in the population growth rate (due to the capital deepening effects), while the two alternatives predict a negative response ranging from 0.2 (Extension 1) to 0.3 (Extension 2) off the growth rate of labour productivity. Given that the labour productivity forecasts included in the main text already allow for the positive capital deepening effects of ageing, this would imply that these forecasts would have to be revised downwards by the full TFP effects. Given the projected declines over the coming decades in the EU15 (-0.5%) and EU10 (-1%) populations of working age, this would imply that the labour productivity projections for these aggregates may need to be reduced by between a ¼-½ a % point if one accepts that ageing is negative for TFP.

TABLE 3 : LONG RUN LABOUR PRODUCTIVITY MULTIPLIERS FROM EXTENSION'S I AND II (LEVEL EFFECTS AFTER 50 YEARS*)

	Jones(1)	**ECFIN**(2)
PHYSICAL INVESTMENT SHARE (Increasing by 1% point)	2.1%(1a)	2.4%
YEARS OF EDUCATION (Increase by 1 year)	7%(1b)	12.8%
R&D SHARE (Increase by 1% point of GDP***)	16%(1c)	17.7%
WORKING AGE POPULATION GROWTH (1% reduction of growth rate**)	(-2.5%, -16%)(1d)	-8.7% (2a)

(1) Results reported in this column are own calculations on the basis of information provided in Jones (2002). The results from Jones, as with the ECFIN results, include the net effect of the positive capital deepening and negative TFP effects of changes to the population of working age.
(1a) Calculation is based on information provided in Jones (2002), Tables 1 and 2.
(1b) Based on information given in the Jones text on page 227.
(1c) Based on information provided in footnote 20 of Jones text.
(1d) Jones cannot pin down a precise estimate of the parameter γ but gives values in the range between .05 and .33.
(2) Results are taken from Tables A4 and A5 of chapter 2, EU Economy Review 2003.
(2a) Figure gives the net effect of the fall in TFP (-14.7) and the rise in capital intensity (+6.0).
* Most of the level effects are evident after 25-30 years.
* *Equivalent to a 20% points decline in the youth dependency ratio.
*** A 1% point of GDP increase in R&D would represent an increase of at least 50% on current EU levels.

Finally, it must be stressed that although the results reported in Table 3 contradict the results of the standard growth model, this is not a fundamental contradiction. The contradiction occurs because extensions I and II both model TFP whilst it is exogenous in the standard model. All three models make very similar predictions concerning the effects of a change in the investment rate, a change in population growth on capital deepening and the effects of a change in TFP. This point is stressed in Table A3 of the Review study.

CONCLUDING REMARKS

To conclude, this annex should be seen as an alternative approach for looking at the possibly negative effects of ageing on TFP and labour productivity. It is clear that the complex dynamics surrounding this issue, allied to age-related sectoral shifts and modelling difficulties, cast a large degree of uncertainty over the estimates given at the end of section 2. However, on the basis of the present analysis, it would appear that ageing has the potential to substantially reduce long run labour productivity growth rates in the existing and new Member States, especially the latter.

To offset the potentially negative effects of ageing on TFP growth, it appears reasonable to conclude that many countries will have no option but to embark on a sustained, and extensive process, of human capital and R&D investments.

APPENDIX TO ANNEX 2 : HUMAN CAPITAL, AGEING AND GROWTH

Model : Neoclassical production function:

(1) $Y = AK^{1-\alpha}(h^w N^w)^\alpha$

Y: output
K: capital
h^w : average human capital of working age population
N^w: working age population

Demographics : Youth Population

(2) $N_t^y = (1+gy)N_{t-1}^y$

Youth population (N^y) grows with exogenous rate g_y .

Population of working age:

(2) $N_t^w = (1-\lambda^w)N_{t-1}^w + \lambda^y N_{t-1}^y$

λ^w : exit-rate of N^w
λ^y : exit-rate from N^y

Investment:

(4) $I_t = s_t^i Y_t$

Investment is a constant share of GDP.

Capital:
(5) $K_t = I_t + (1-dk)K_{t-1}$

Human capital : Human capital of a (survivor) in the working age population evolves according to :

(6) $h_t^w = (1-dh)h_{t-1}^w$

i.e. it depreciates at rate *dh*. Therefore total human capital evolves as follows:

(7) $h_t^w N_t^w = (1-\lambda^w)(1-dh)h_{t-1}^w N_{t-1}^w + \lambda^y h_{t-1}^y N_{t-1}^y$

or

(7b) $h_t^w = (1-\lambda^w)(1-dh)/(1+gw)h_{t-1}^w + \lambda^y h_{t-1}^y/(1+gw)(1/nwy_{t-1})$