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# Workforce Ageing and Economic Productivity: The Role of Supply and Demand of Labor: An Application to Austria

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## 1. Introduction

Population ageing currently receives high attention in economics, in particular with respect to its implications for the sustainability of social security systems such as the pension, health and elderly care system. In addition, population ageing will also affect other markets like the labor market, the markets for goods and services and capital markets (see e.g., Börsch-Supan, 2002). In this paper we focus on the labor market and consider the fact that population ageing will affect the quantity and the composition of the current workforce. It is now well accepted that in most industrialized countries, the economic output must be achieved by a smaller and an older labor force in the future. The question is then how this development might have an impact on the economic productivity as measured by output per worker.[2]

According to the view of many economists, an ageing population leads to negative consequences in terms of growth of output per capita for two reasons.

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[2]The recent development accounting literature (Hall and Jones, 1999) has stressed that only workers can contribute to production and therefore an understanding of differences in output per worker is more important than an understanding of differences in output per capita.

First, there is an accounting effect because a decreasing ratio of the working-age population to the total population increases the ratio of consumers to producers. This contributes negatively to growth of output per capita. Second, there might also exist behavioral effects on growth of output per worker, i.e., negative effects of an ageing population on economic productivity as measured by output per worker. It is the latter effect that we want to investigate in the current paper. In particular we shall study the sensitivity of projected economic productivity with respect to three key assumptions in the labor market. These include the projected labor force participation rates, the assumption of the age-productivity profile of workers and the degree of substitutability between labor of different ages. Hence, we focus on the supply side of the labor market and its interrelationship with the assumed labor demand function. In particular we investigate the role of the internal composition of the labor force as opposed to using only dependency ratios or broad age categories to simulate the macroeconomic implication of an ageing labor force.

Our aim is to present qualitative results and rough orders of magnitude rather than proposing detailed projections of the future development of economic productivity. We therefore follow the work of and and choose a pure labor economy as our theoretical framework to study the impact of labor force ageing on economic output. For our numerical simulations we use age-specific demographic data provided by Statistics Austria and age-specific labor market data provided by OECD.

A restrictive assumption in Blanchet (1992) is the production technology that allows for perfect substitutability between workers of different ages. Though the assumption on production technology was relaxed in Blanchet (2002) and a CES production function was applied instead, the study is restrictive since it only considers the effect of workforce ageing in a stable population. However, as is well known from recent studies in the economic growth literature relating differences of economic growth rates to changes in demographic structures (e.g. Higgins and Williamson, 1997), an analysis that restricts itself to steady states of the population distribution may be at best insufficient and at worst misleading in times of severe demographic changes. Since in many industrialized countries we will experience pronounced fluctuations of the working age population in the coming decades (caused by the baby boom generation which is expected to start retiring around 2020) a focus on transitional dynamics is essential.

We are aware of the fact that by focusing on a pure labor economy and ignoring physical capital we disregard one of the most important channels through which the negative impact of the labor force shrinkage on economic growth may be attenuated. As is well known in neoclassical growth theory, population decline increases the steady state capital labor ratio since less people have to be equipped with capital.[3] These effects are captured in general equilibrium models which

[3]As shown in Cutler et al. (1990, p.18), this „Solow effect" offsets the long-run dependency

commonly constitute the theoretical framework to study the economic consequences of population ageing. However, most of those models are restrictive with respect to the production technology which in most cases aggregates labor of all ages into one production factor. Since our aim is to introduce imperfect substitutability across age groups in the labor market and consider its implication on economic productivity during times of rapid labor force shrinkage and ageing, we regard (similarly to Lam, 1989, p.192) our assumption to concentrate on a pure labor economy as an `important departure for more complete models'.

The setup of the paper is as follows. In section 2 we go over the empirical and theoretical literature that has dealt with population~ ageing and economic productivity. Our theoretical framework is reviewed in section 3. In section 4 we present the demographic forecasts for Austria, outlining various scenarios for the size and structure of the labor supply development. Combining the labor force and demographic projections, we discuss the trends in the support ratio (the number of active to dependent population). We apply alternative assumptions about the substitutability, productivity and labor supply of workers of different ages to arrive at scenarios of economic productivity in Section~5. In Section~6 we summarize our findings.

# 2. Recent Studies on Economic Productivity and Demographics

## 2.1 Microeconomic Evidence

As evidenced in the recent literature it is a difficult task to unravel the impact of changing age composition of the workforce on aggregate productivity (Disney, 1996), Arnds and Bonin (2002, chapter 2). A common argument is that an ageing population is less entrepreneurial and ambitious and may therefore negatively affect economic productivity. On the other hand there is the argument by labor economists that a mature population embodies a greater stock of human capital and experience, measured by employment-specific acquired skills (tenure) and employment-independent experience. Testing for these competing hypotheses on the individual level is a difficult task since productivity is difficult to measure individually (see Skirbekk, 2004 and Johnson, 2002b) for a review of studies measuring individual productivity). In particular, there is the potential interaction

effect on U.S. per capita consumption in the short run. On the other hand, it can be argued that significant proportions of excess savings may be invested abroad and not in the domestic capital stock so that the positive effects of higher capital intensity are of a smaller order of magnitude.

of cohort effects, age effects and other productivity effects (including company-specific production processes and organisational structures) which complicates the uncovering of the "pure" age effect on individual productivity. The general conclusion among these studies is that "a decline in performance may be falsely attributed to age, when in fact it may be due to skill obsolescence or a burn out phenomenon which may occur at any age and can be remedied through training practices" (Auer and Fortuny, 2002, chapter 7). Moreover, the assumption of competitive labor markets where workers are paid their marginal productivity is often violated (see Laezar, 1990). It is commonly argued that older workers are more expensive than younger workers because of higher remuneration, fringe benefits and social contributions. The fear is then that the relative price of labor will rise though its quality might even decline which would reduce the competitiveness of ageing economies.

## 2.2 Macroeconomic Evidence

While the relation between age and individual productivity is less clear cut, there has been recent evidence of a significant relation between changes in the adult population and aggregate productivity. In an econometric study on the experience of 18 industrialized countries, Beaudry and Collard (2003) have shown that over the period 1960 to 1974, adult population growth (i.e., of the population aged between 15 and 64) is found to exert only a small and insignificant effect on GDP per worker, and this effect turned negative for the period 1974 to 1996. Their results imply that a country with a yearly adult population growth of one per cent greater than the average would experience poorer growth in output per worker of approximately one per cent per year which compounded over 22 years corresponds to a difference of 25 per cent in labor productivity.[4] Recalling neoclassical growth theory (which implies that economies with a lower growth rate of adult population would accumulate more capital) the authors argue that those findings could be evidence of capital biased technological change and they continue to set up a simple growth model that incorporates those considerations. The study by Beaudry and Collard (2003) relates closely to the empirical evidence which has shown that input accumulation cannot explain the majority of cross-country differences in output per worker, but that the `residual', and therefore, total factor productivity must account for the differences, see e.g. Prescott (1998). In a recent paper Feyrer (2002) has shown that the age structure of the workforce has a significant impact on aggregate productivity (where he measured productivity as the Solow residual).

[4]These results are similar to earlier findings in Cutler et al. (1990) who found in a sample of 29 countries (whose labor productivity was at least 30 per cent of U.S. labor productivity) that a 1 percentage point decrease in the annual labor force growth rate raised productivity growth by 0.62 percentage points a year from 1960 to 1985.

In particular he found that workers aged 40 to 49 have a large positive effect on productivity and he uses his findings to explain the productivity slowdown in the US in the 70s and the boom in the 90s.[5] However, Feyrer (2002) does not present a definite mechanism through which demographic change operates although he argues that technology adoption is one of the driving factors that spurs growth and this might be related to demographics. A recent study by Kögel (2004) finds a significant and negative effect of the youth dependency ratio (the population below working age divided by the population of working age) on productivity and provides a theoretical model in the style of the life cycle model where he links a lower youth dependency ratio to higher savings -- hence more capital can be spent on technology, hence productivity will increase. A key paper which presents a theoretical framework for the argument that even a dramatic decline in population growth will not lead to a long-run slowdown in productivity is Dalgaard and Kreiner (2001). The authors allow for endogenous human capital in a basic R & D driven growth model and develop a theory of scale-invariant endogenous growth where population growth is neither necessary for, nor conducive to, economic growth.

Analyses of the relation between changes to the age structure of the population and aggregate measures of performance, such as technical progress or economic growth, can also provide insight about workers' productivity. Nishimura et al. (2002) investigate the impact of age structure on technical progress and value-added growth in Japanese industries for the years 1980 to 1998. They estimate the relation between technological progress and the employees' age structure and find that the relation between the share of educated workers older than 40 years and technological progress is positive in the 1980s, but turned negative in the 1990s. This may be due to a higher rate of technological change in the 1990s which shifted the productivity peak towards younger ages.

Further studies that estimated the macroeconomic effects of the age structure of the labor force include, e.g., Lindh and Malmberg (1999) and Malmberg (1994). In both studies, demographics is assumed to influence factor accumulation, as opposite to Feyrer (2002) and Kögel (2004) who regard the effect on productivity as the more important channel. While Lindh and Malmberg (1999) find an effect of the age composition of the labor force on growth of GDP per worker in OECD countries, Malmberg (1994) finds for Sweden such age structure effects on growth of GDP, on growth of GDP per capita, on growth of TFP (Total Factor Productivity) and on aggregate savings.

[5] More specifically, he found that a 5 per cent increase in the size of the cohort of 40 to 49 years old over a ten year period can lead to 1.7 per cent higher productivity growth in each year of the decade.

## 2.3 Projecting the Future Impact of Demographic Change on Economic Productivity

To project the future impact of an ageing labor force on macroeconomic variables, computational general equilibrium models (CGE models) are applied. In a recent study on labor market effects of population ageing, Börsch-Supan (2002) shows that about half of the decline (of 15 per cent) in per capita output that results from the decrease in the labor force until 2035 can be compensated by the induced higher capital intensity. However, as he mentions, on p. 42, *"... any possible age-structure related reduction in aggregate productivity ... would reduce the effect of higher capital intensity"*. He then concludes that an increase of productivity growth from 1.39 to 1.65 per cent would be necessary to maintain the per capita level of GDP as of 2000. Hence, strong productivity growth which in turn depends on increased capital intensity and human capital is necessary to keep up the consumption level if the labor force participation starts to decline.

A different approach -- more related to demographic accounting than applying sophisticated economic modelling -- to forecasting the effect of labor force ageing on economic productivity is taken in Blanchet (1992) and Blanchet (2002). Interacting fixed and exogenously chosen age-productivity profiles with alternative projected demographic structures and age-specific labor force participation, Blanchet (1992) shows that the effect of labor force ageing on economic productivity is moderate. To explain these results, the author refers to stable population theory which provides simple rules of thumb to assess the condition under which the average value of an age-dependent variable may be sensitive to changes in the population growth rate. In particular, he shows that a change in the population growth rate by one percentage point cannot have an aggregate impact of more than 20-25 per cent on any age-dependent phenomenon (see Appendix A where we apply the argument by Blanchet, 1992).

Aggregate economic productivity is not only determined by the change in individual-based productivity that works through a change in age composition of the workforce, but as we know from the theory of factor demand, the impact of labor force ageing and labor force shrinkage on economic productivity will depend on the substitutability of different factors of production. These include the substitution of capital for labor and the substitutability among workers of different age and education. As documented in Hamermesh (1993, chapter 3) the result of a relative decline in the supply of labor in a world consisting of homogeneous capital and labor would be declining interest rates and an increase in wage rates. However, the results are much less clear if one introduces more restrictive substitution patterns between workers disaggregated by age (Hamermesh, 1993, table 3.9).

Though Blanchet (2002) has taken up the role of imperfect substitutability of workers of different ages and its impact on economic productivity when population growth changes, his analysis is restrictive since he focused only on a stable population. However, to study the effect of imperfect substitutability between workers of different ages in times of population ageing it is necessary to focus on transitional dynamics. We therefore extend the analysis of Blanchet (1992) and investigate the time path of economic productivity in a pure labor economy where workers of different ages are not perfect substitutes. Hence, we concentrate on dynamic features of population ageing. In addition to studying the sensitivity of projected economic productivity with respect to the labor demand function we also investigate how future productivity will change depending on labor supply factors such as the individual age productivity profile and labor force participation rates.

## 3. Theoretical Framework

In the simulations presented in the following sections we want to analyse the sensitivity of the projected labor productivity with respect to alternative assumptions about future labor supply and the substitutability and productivity of the labor force at different ages. We assume that the output of a particular economy only depends on the input of labor and individuals aged 15 to 65 participate in the labor force according to the age-specific labor force participation rates given by the OECD labor market statistics.

We apply three different production functions. The first one is the *additive production function* which assumes perfect substitutability between labor at different ages. In this modelling framework the output at time $t$ is given by

$$Y(t) = \sum_{x=15}^{60} \alpha_x \, {}_5L_x(t) \sum_{x=15}^{60} \alpha_x = 1, \tag{1}$$

where $\alpha_x$ indicates the productivity of the labor force at age $x$ and ${}_5L_x$ indicates the labor force in the five year age interval $[x, x+5)$, i.e., the population at age $x$, ${}_5N_x(t)$, multiplied by the age-specific labor force participation rate ${}_x(t)$ where we distinguish between female and male labor force participation rates. Moreover, we also consider the *Cobb-Douglas production function*,

$$Y(t) = \prod_{x=15}^{60} {}_5L_x(t)^{\alpha_x} \sum_{x=15}^{60} \alpha_x = 1. \tag{2}$$

Alternatively, we assume a *constant elasticity of substitution production function* (CES) of the form

$$Y(t) = \left( \sum_{x=15}^{60} \alpha_x \, {}_5L_x(t)^{\rho} \right)^{\left(\frac{1}{\rho}\right)} \tag{3}$$

with $\sigma = \frac{1}{1-\rho}$ denoting the elasticity of substitution between labor force of different ages and $\rho \in (-\infty, 1]$. The additive and Cobb-Douglas production function are included in this general formulation and result if $\rho = 1$ and $\rho \to 0$, respectively. As already indicated in Blanchet (2002) the assumption of the CES production technology is restrictive as well. When workers from one age group are substituted by members of any other age group, the actual age difference does not matter. In reality one might assume that a person aged 25 can easily be substituted by another person aged 26 but not that easily by another person aged for instance 64. To take this into account we propose another kind of CES production function

$$\begin{aligned} Y(t) = \Bigg[ & \alpha_{15} \left( \frac{3\,{}_5L_{15}(t) + {}_5L_{20}(t)}{4} \right)^{\rho} \\ & + \sum_{x=20}^{55} \alpha_x \left( \frac{{}_5L_{x-5}(t) + 2\,{}_5L_x(t) + {}_5L_{x+5}(t)}{4} \right)^{\rho} \\ & + \alpha_{60} \left( \frac{{}_5L_{55}(t) + 3\,{}_5L_{60}(t)}{4} \right)^{\rho} \Bigg]^{\left(\frac{1}{\rho}\right)} \end{aligned} \tag{4}$$

which we will call *fuzzy CES* in the following. The above function takes into consideration that the two neighbouring age groups are better substitutes than those age groups which are further away. Instead of just having one age group within each addend of the production function -- like in formula () -- we use a weighted average of three neighbouring age groups. For example, it is assumed that the elasticity of substitution of workers of different age is higher when they belong to consecutive age groups. This idea can be extended by combining for instance five age groups instead of three which would lead to an expression like

$$\alpha_x \left( \frac{{}_5L_{x-10}(t) + 2\,{}_5L_{x-5}(t) + 4\,{}_5L_x(t) + 2\,{}_5L_{x+5}(t) + {}_5L_{x+10}(t)}{10} \right)^{\rho}.$$

# 4. Demographic and Labor Supply Forecasts for Austria

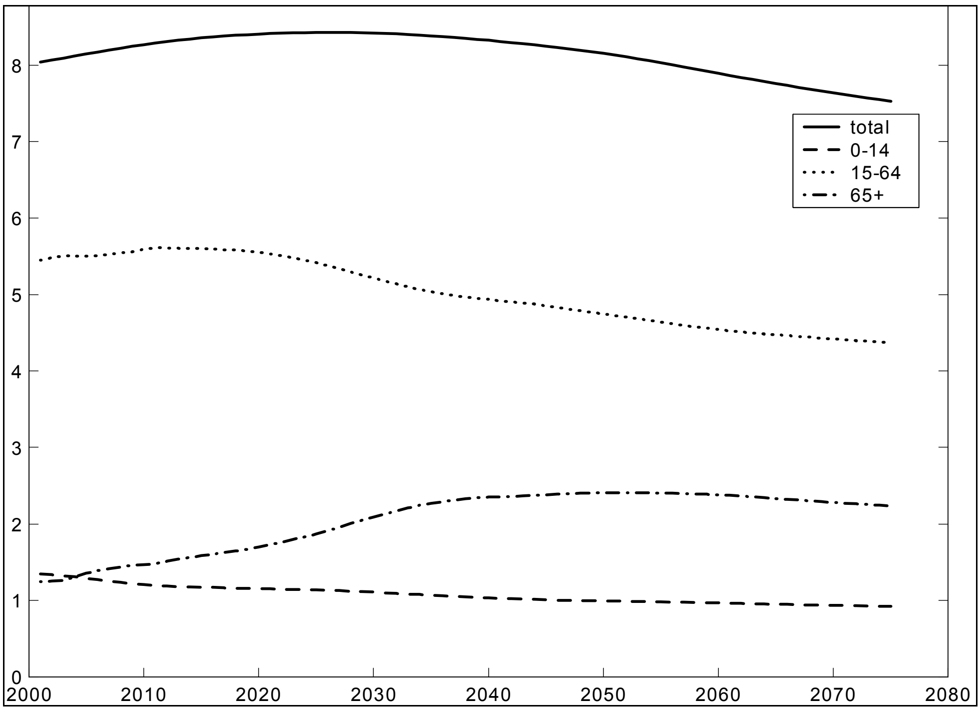
In the following we use the latest population projections released by Statistics Austria in 2003 covering the time interval from 2000 to 2075. These data contain single-year age groups and also single-year time steps.

## 4.1 Demographic Forecasts

To investigate the sensitivity of our results with respect to alternative demographic forecasts we apply three alternative variants of the population projections by Statistics Austria (Hanika, 2004). These include the main variant which assumes a constant fertility of 1.4 children per woman and an increase of the mean age at birth from 28.6 (2001) years to 31.0 years (2050). Life expectancy is assumed to increase from 75.8 years (2002) to 83.0 years (2050) for men and from 81.7 years (2002) to 88.0 years (2050) for women. Migration is assumed to increase in the short run from 90.000 (2001) to 95.000 (2006) and will remain until 2011 at a value of 94.000 persons, afterwards a further decrease to 87.000 (2016) and consequently 80.000 (2041) is assumed. Alternatively we also apply a high fertility/high migration and a low fertility/low migration variant. In the high and low fertility variants, the total period fertility rate is assumed to be 1.70 and 1.10, respectively, starting from 2015 onwards. Hence, the high fertility variant assumes that fertility will increase in the long run to values currently observed in the northern European countries, while the low variant reflects the situation currently prevalent in southern European countries. The mean age at birth is kept similar to the main variant. For the high fertility variant, life expectancy is assumed to increase to 87.0 years for men and 91.0 years for women until 2050. In the low fertility variant, a smaller increase in life expectancy up to 79.0 years for men and 85.0 years for women is assumed. For the high migration variant, migration is assumed to be about 10.000 more persons per year, while the low migration variant assumes about 10.000 persons less.

In chart 1 we plot the forecast of total population and of broad age groups (0-14, 15-64, 65+) between 2000 and 2075 for the main variant. While population is projected to increase during the first 3 decades of the century to reach a maximum of 8.43 millions in 2026, the number of the working age population (15 - 64 years) is projected to decrease much earlier. The shrinkage of the working age population is expected to set in already in 2012.

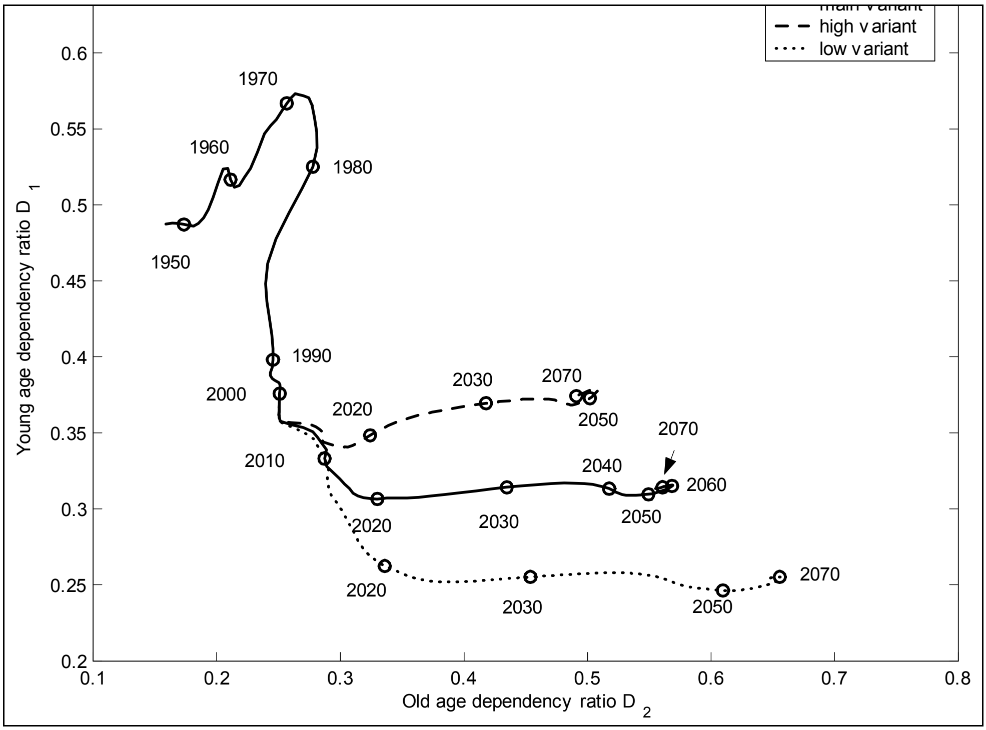
*Chart 1: Forecast of Total Population and Broad Age Groups, Main Variant*




In chart 2 we plot the historical path of old and young age dependency ratios as well as forecasts through 2070 under the main, low and high variant of the population projection.[6] Independent of the specific projection variant, Austria will experience a pronounced increase in its old age dependency ratio with the pace and the size of the increase being more pronounced in the low variant compared to the main and high variant.

[6] The young age dependency ratio is defined as the population below age 20 divided by the economically active population between ages 20 and 64, while the old age dependency ratio is defined as the population aged 65+ divided by the economically active population between ages 20 and 64.

*Chart 2: Dependency Ratios 1947–2075, Main, High and Low Variant*




## 4.2 Labor Supply Forecasts

We combine the three variants of the population projection with two variants of the labor force participation rates. In a benchmark model we assume that today's age and gender-specific labor force participation rates are kept constant over the whole projection time period. Alternatively we propose a scenario where we assume that the labor force participation rates will be adjusted to keep the size of the labor force constant at its maximum value obtained in 2012. This adjustment is made by assuming an increase in age-dependent labor force participation rates with the rates observed in northern European countries acting as an upper maximum. That means for each year we try to find a multiplier $\beta_t$ such as

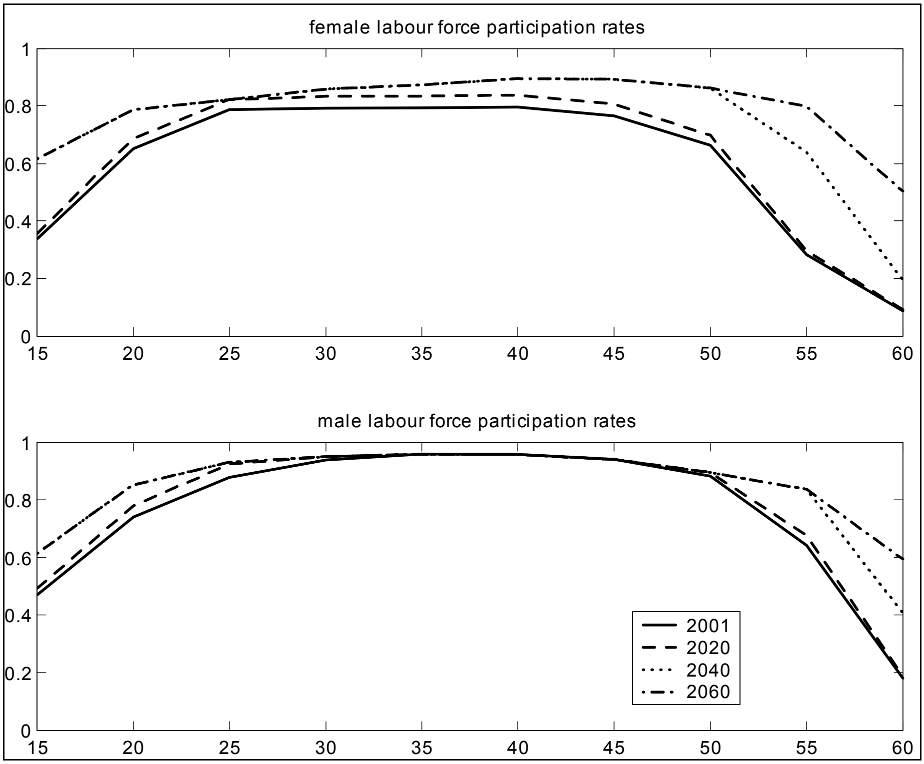
$$\sum_{x=15}^{60}\left(\min\left\{\overline{\text{lfpr}_{f,x}}, \beta_t \,\text{lfpr}_{f,x}\right\} N_{f,x}(t) + \min\left\{\overline{\text{lfpr}_{m,x}}, \beta_t \,\text{lfpr}_{m,x}\right\} N_{m,x}(t)\right)$$
$$= \sum_{x=15}^{60}\left(\text{lfpr}_{f,x}\, N_{f,x}(2012) + \text{lfpr}_{m,x}\, N_{m,x}(2012)\right), \qquad (5)$$

with $N_{f,x}(t)$ and $N_{m,x}(t)$ denoting the female and male population aged $x$ to $x+5$ . Moreover, $_{f,x}$ and $_{m,x}$ denote the current age and gender-specific labor force participation rates in Austria for women and men in 2012, and $\text{lfpr}\overline{_{f,x}}$ and $\text{lfpr}\overline{_{m,x}}$ are the maximum age and gender specific labor force participation rates observed in northern European countries. Hence, if it is not possible to find a $\beta_t$ satisfying equation (5), then we use the maximum labor force participation rate for that year.

In chart (3) we plot the status-quo labor force participation rates (as of 2001) as well as the labor force participation rates resulting from the adjustment procedure just described and assuming the main variant of the population projection. To keep the size of the labor force constant at its maximum value obtained in 2012 requires a persistent increase in the labor force participation rate at younger and older ages for males and a persistent increase in the labor force participation rates at all ages for females.[7]

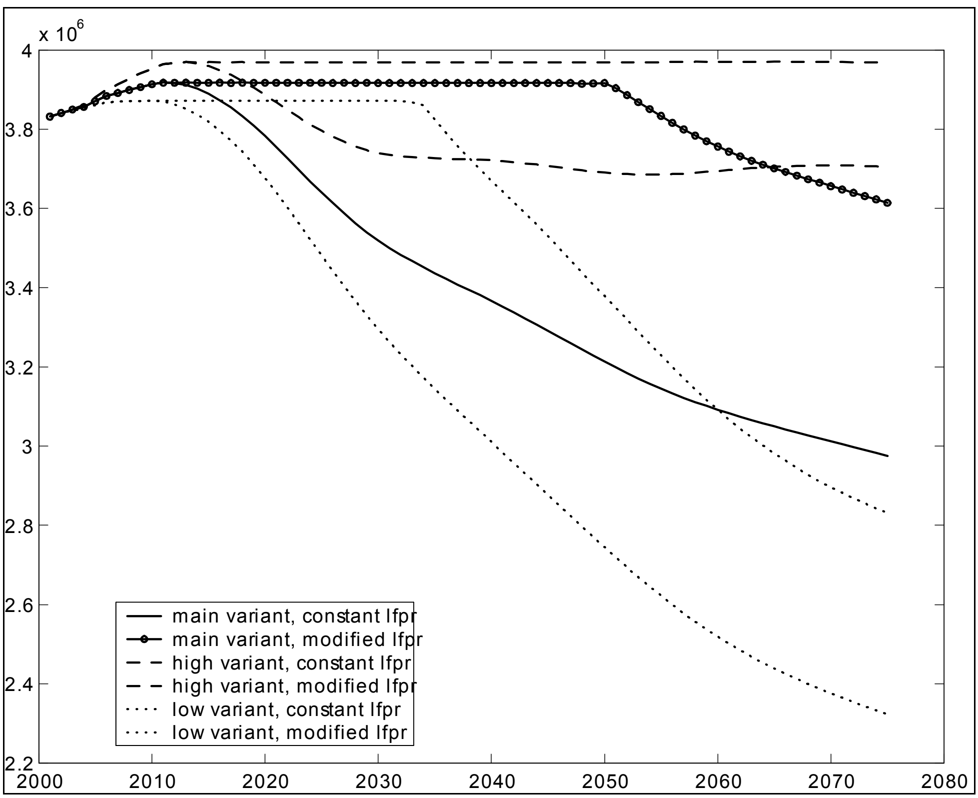
[7] Following the „lump-of-labor fallacy" it is often argued that an increase in labor force participation rates may cause additional labor market frictions (at least in the short run) since retirees are allegedly freeing jobs for others. However, the number of jobs in an economy is no fixed figure and cross-country patterns in the EU reveal no relation between employment rates of older workers and overall unemployment. On the other hand, an increase in the female labor force participation rate needs to be accompanied by family support measures, otherwise it would worsen the ageing effect since lower fertility could possibly result from the increase in female labor force participation.

*Chart 3: Age-Specific Labor Force Participation Rates, Main Variant*




We then interact the age-specific labor force participation rates with the three variants of the population projections yielding six alternative forecasts for the stock of future labor force (chart 4). Note that in the status quo scenario (and taking into consideration the main variant of the population projections) the labor force starts to shrink already in 2012. However, if we allow for an increase in labor force participation rates up to the point currently observed in northern European countries, the decline in the labor force can be held off until 2050. Thereafter such higher labor force participation rates can no longer counteract the shrinkage of the labor force that is caused by smaller cohorts entering working age. Similar dynamics also occur when the same calculations are based on the high fertility/high migration or low fertility/low migration variant. In the former case the maximum size of the labor force can even be maintained until the end of the projection period, while in the latter case adjustments of the labor force participation rates can only postpone the shrinkage of the labor force until the mid 2030s. Moreover, projections of labor force across alternative variants of population forecasting begin to diverge significantly around 2020. On the other hand, assumptions regarding the labor force participation are critical for projected labor force already in the coming decade. In summary, future projections of the quantity of the labor force are sensitive to the uncertainty in future population projections with the difference between the high and low variant (given constant labor force participation rates) being about 1.4 million workers in 2075. Only for the high population projection variant an adjustment of the labor fore participation rates towards values observed in northern European countries could counteract the shrinkage of the working population. For the median and low variant of the population projections such a scenario could not compensate for the shrinkage of the working population in the long run.

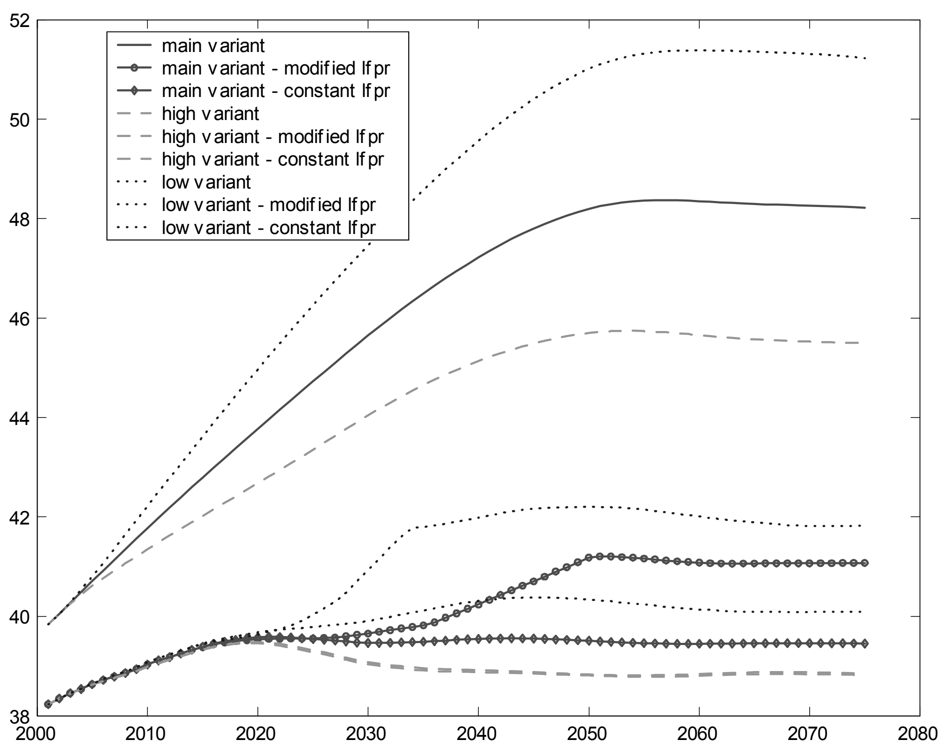
*Chart 4: Projected Total Labor Force, Mean, High and Low Variant*




In addition to a shrinking workforce, the Austrian economy will be faced with an ageing workforce. Chart 5 illustrates the mean age of the total population, the mean age of the labor force assuming that labor force participation rates are kept constant at the level of 2001, and the mean age of the labor force when labor force participation rates increase up to the maximum level of the northern European countries for the main variant, the high fertility/high migration variant, and for the low fertility/low migration variant.[8]

In case of the main variant, the mean age of the total population increases up to a value of 48.37 in 2057 before it levels off in the second half of the 21st century (chart 5), while ageing of the labor force reaches its maximum in 2021 with a mean age of the labor force of 39.6 years. Thereafter the mean age of the labor force remains nearly constant. (The slight rejuvenating effect of the labor force after 2021 can be explained by the retirement of the baby boom generation.) If age-specific labor force participation rates were increased to maintain the maximum size of the workforce as of 2012, there is a further increase of the mean age up to 41.2 years in 2051.

*Chart 5: Mean Age of Total Population and Labor Force, Mean, High and Low Variant*




[8] To compute the mean ages we assumed that the age of an individual belonging to the age-group $[x, x+n)$ is $x + n/2$.

In the high fertility/high migration variant, the mean age of the total population reaches its maximum in 2053 and always remains below 46 years. The mean age of the labor force reaches its maximum around 2020 at a level of about 39.5. Moreover, there is a clear decline in the mean age of the labor force after reaching the peak. The curves representing the two different labor force scenarios are almost identical because in case of high fertility and high migration the size of the working age population is rather big anyway. Therefore only small adjustments of the labor force participation rates are required. Finally, in the low fertility/low migration variant the mean age of the total population exceeds the previously mentioned variants. It peaks in 2060 at a level of 51.4 years. As a consequence, ageing of the labor force is also more pronounced. In case of adjusting the participation rates to maintain the size of the labor force, its mean age may rise up to 42.2 years in the year 2050.

In summary, purely demographic factors (in case of constant labor force participation rates) explain an ageing of the labor force that does not extend beyond 2021. Under constant labor force participation rates (as of 2001) the peak of workforce ageing is obtained around 2020, i.e., almost 40 years in advance of the peak of population ageing. Of course, ageing of the labor force will be more pronounced if we add to this natural ageing a process of artificial ageing due to a policy of increasing labor force participation rates at higher ages as suggested in our second scenario. An increase of the labor force participation rates towards the values observed in northern European countries would increase the age of the workforce by about 2 years until the mid 21st century.

## 4.3 Support Ratio

To compare the burden of demographic change in the past and the future we calculate alternative measures of the support ratio as introduced in .Cutler et al. (1990). The benchmark definition of the support ratio $S$ relates the effective labor force $L1$ to the effective number of consumers $C1$:

$$S = L1/C1$$

where $L1 = \sum_{x=20}^{64} N_x$ and $C1 = \sum_{x=0}^{95+} N_x$ . This definition assumes that people of every age have the same consumption needs and that all people aged 20 to 64 are in the labor force.

Alternatively we can apply a needs weighted consumption measure $C2 = \sum_{x=0}^{95+} s_x N_x$ where $s_x$ indicates the weight for an individual at age $x$ . We follow Cutler et al. (1990) and assume that $s_x = 0.72$ for people under 20,

$s_x = 1$ for people aged 20 to 64 and $s_x = 1.27$ for people 65 and over. The relative consumption needs are derived by considering three components (private nonmedical expenses, public education expenses, and medical care), and represent the relative demands for consumption of different age groups. For instance, young people show less private consumption but consume more education services whereas older people consume more health services.

For the labor force we consider one alternative measure in addition to $L1$. Similar to Cutler et al. (1990) we propose a measure $L2$ that takes variation of labor force participation and wages by age into account. We use the sex and age-specific labor force participation rates $\text{lpfr}_{f,x}, \text{lpfr}_{m,x}$ of 2001 (chart 3) and sex and age-specific mean earnings $w_{f,x}, w_{m,x}$ of 2001 (table 1) to estimate $L2 = \sum_{x=15}^{60} [w_{f,x} \text{lpfr}_{f,x}\ {}_5N_{f,x} + w_{m,x} \text{lpfr}_{m,x}\ {}_5N_{m,x}]$. This definition considers the fact that the earnings capacity of a society will differ depending on the underlying age distribution of the labor force.

*Table 1: Gross Earnings of Employed Persons in Euro per Year in 2001*

| age group | 15 – 19 | 20 – 29 | 30 – 39 | 40 – 49 | 50 – 59 | 60+ |
|---|---|---|---|---|---|---|
| female | 9889 | 16279 | 16324 | 19086 | 20077 | 13259 |
| male | 12175 | 21992 | 27752 | 30291 | 32427 | 41626 |

Out of these two alternative consumption and labor force measures we construct four alternative support ratios as plotted in chart 6. (All projections are based on the main variant of the population projection.) The general conclusion we may draw from these figures is the projection of a long-run decline in the support ratio which is caused by the decline of the labor force as compared to the total population. Note that we are currently at the beginning of this decline which will only come to a halt by the middle of the century. Ignoring the labor force participation rates and differences in consumption needs by age (i.e., applying the definition $L1/C1$ ) we observe a slight increase in the support ratio until 2010 due to the baby boom generation still being in its working ages while the old age dependency has not yet set in. The decline in the support ratio during the coming decades is not exceptional; the support ratio declined markedly in the late 1940s and 1950s before it recovered when the baby boom generation entered the labor market. However, the decline of the support ratio we expect in the future is indeed unique in terms of its persistence and magnitude. From chart 6 we may draw two further conclusions. First, the projected support ratio is more sensitive to alternative measures of the consumption measure than to alternative measures of the labor force. When we assume equal consumption needs for all people (C1), the support ratio drops by $14.1\%$ ( $16.3\%$ ) for L1 (L2) between 2001 and 2050. When adjusting for consumption needs, the respective declines are much more pronounced: $18.6\%$ ( $20.8\%$ ) for L1 (L2). Secondly, while the support ratio that considers needs weighted consumption falls below the corresponding ratios where we neglect those weights for the future, the opposite was true in the past. This reflects the fact of an increasing old age dependency burden as compared to the youth dependency burden we observed during the baby boom years.

In summary, in the worst scenario ( $L2/C2$ ) the support ratio drops between 2001 and 2050 by $20.8\%$ . This means that in 2050 the working population will need to be almost $21\%$ more productive than in the year 2001 in order to keep per capita output the same. Put differently, this would require an annual productivity growth rate of about $0.4$ percentage points between 2001 and 2050. Referring to estimates for long-term real productivity growth of about $1.4\%$ (Börsch-Supan, 2002, p. 8) about one third of this growth rate would be taken up by the decrease in the labor force. In fact, the decline of the support ratio is steepest already in the first three decades between 2001 and 2035 implying that the productivity increase would need to be even bigger to preserve the 2001 level of output per capita during this period.

As our simulations indicate, the demographic burden -- as a consequence of workforce shrinkage and increased old age dependency -- is expected to rise during the next decades. It is therefore of interest to understand the potential of economic productivity (output per worker) to increase depending on the underlying labor demand function and labor supply conditions.

## 5. Economic Productivity Forecasts

To forecast economic productivity we multiply the age-dependent productivity schedule $\alpha_x$ with the distribution of the work force by age and divide by the total size of the labor force. In a first step we investigate the sensitivity of those projections if we assume equal productivity schedules across ages, i.e., $\alpha_x = \frac{1}{10}$ , but vary the elasticity of substitution across age groups. We base this first set of simulations on the main variant of the population projection and the constant labor force participation scenario as of 2001. Next, we allow for alternative shapes of the age-productivity schedules and labor force participation to study the sensitivity with respect to labor supply as opposed to the labor demand function.

Applying equal productivity levels by age together with perfect substitutability of workers of different ages (i.e., an additive production function, $\rho = 1$ ) implies that output per worker will be independent of the projected changes in the size and composition of the labor force (chart 7). If we relax the assumption of perfect substitutability between workers of different ages, the change in the size and composition of the workforce will no longer be neutral for forecasts of output per worker. The lower the elasticity of substitution between workers of different ages (i.e., the lower the value of $\rho$ ), the more pronounced fluctuations of output per worker are to be expected. For instance, in case of $\rho = -1$ , i.e., an elasticity of substitution of $0.5$ , the change in the size and composition of the workforce would result in an increase of about 15 per cent of output per worker between 2000 and 2025.

The results are intuitive since output maximization for a CES type production function with equal productivity for all ages is achieved if the age distribution is uniform (see Appendix~B where we review the argument brought forward by Lam (1989, section 3.) As shown in Appendix C, the age distribution of the labor force is less uniform during the first decades of the century and then becomes more uniform as the baby boom generation moves through the ages of high labor force participation rates. Obviously, the sensitivity of the output with respect to the age distribution of the labor force is higher in case of a lower elasticity of substitution.

*Chart 6: Actual and Projected Support Ratios (Relative to 2001). Four Alternative Measures, Main Variant of Population Projection*

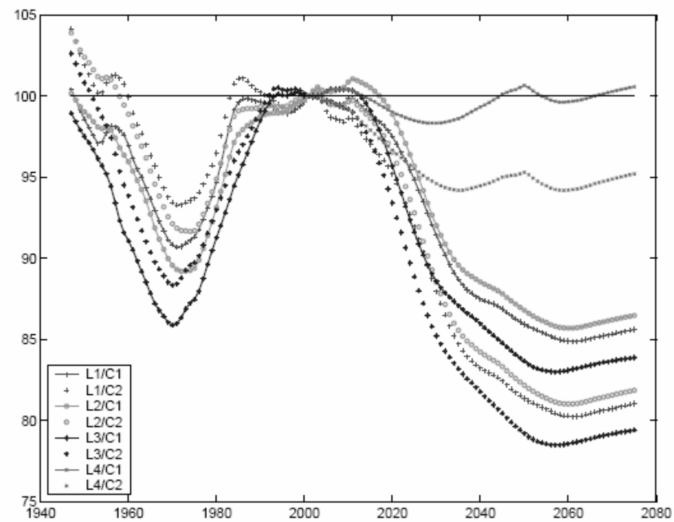
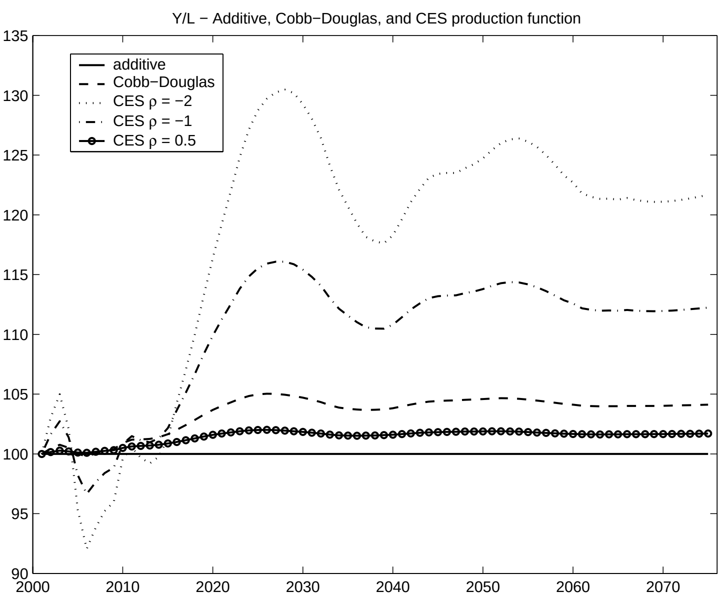
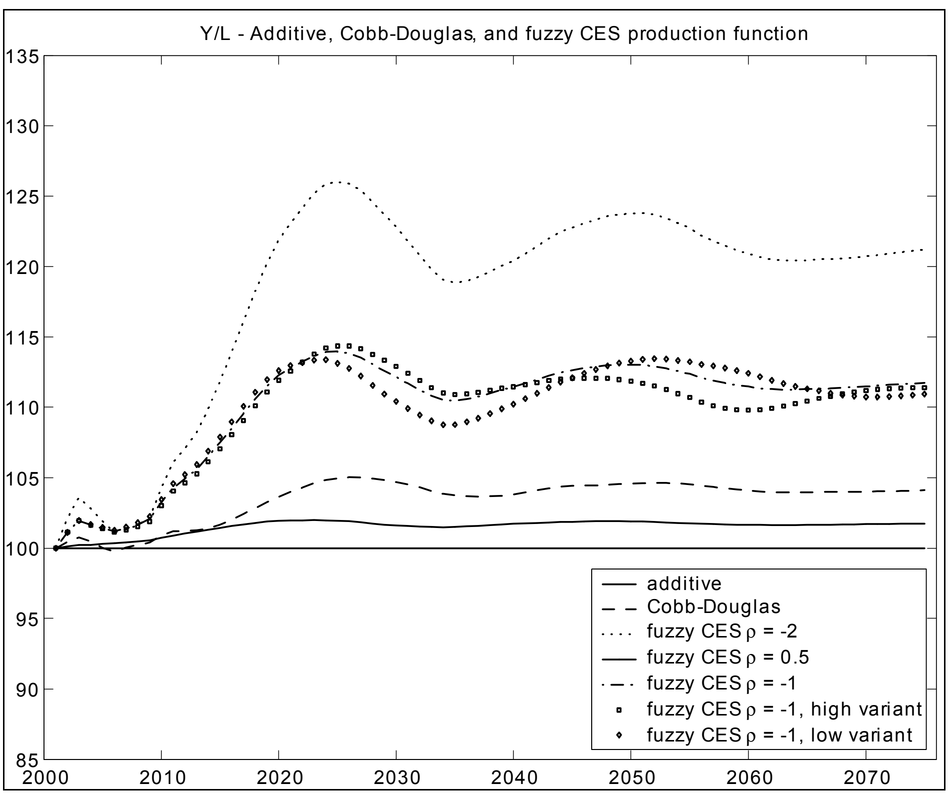



*Chart 7: Projected Relative Output per Worker for Equal Productivity Schedule by Age and CES Type Labor Demand Functions, Main Variant and Constant Labor Force Participation Scenerio*



As already noted in Blanchet (2002), the assumption of a CES type labor demand function may be unrealistic as well. We therefore introduce a fuzzy CES type production function as described in section 3. By allowing neighbouring age groups to be better substitutes than distant age groups the pattern of output per worker is smoothed (chart 8) and the peak of output per worker occurs about 3 years earlier and is slightly attenuated compared to chart 7. For the CES type labor demand function with $\rho = -1$ we also plot the projected output per worker if we apply the high and low variant of the population projections in addition to the main variant. The results are less sensitive to alternative demographic projections compared to alternative assumptions on the degree of substitutability between workers of different ages.

*Chart 8: Projected Relative Output per Worker for Equal Productivity Schedule by Age and Fuzzy CES Type Labor Demand Functions, Main Variant and Constant Labor Participation Scenario*



Up to now our results seem very optimistic. Though the labor force is projected to age and shrink, the relative output per worker is projected to increase. However, these results will depend on age-specific productivity schedules. We therefore alternatively assume a decreasing and a hump shaped pattern of age-specific productivity (chart 9). The qualitative shape of the age-productivity profiles is chosen to present two rather extreme scenarios but should also reflect some of the empirical findings. For instance, a hump shaped profile has been found in many empirical studies (see e.g. Börsch-Supan, 2002). We interact those age-productivity profiles with our forecasts of the age composition of the labor force given the main variant of the population projections and constant labor force participation rates and assuming different labor demand functions. In chart 10 we plot output per worker if we apply these alternative (rather extreme) age productivity profiles and assume either an additive or fuzzy CES production function with $\rho = -1$ . From chart 10 we may draw the following three conclusions. Firstly, allowing productivity to vary by age the projected changes in the size and composition of the labor will have an effect on output per worker also in case of an additive production function that assumes perfect substitutability between workers of different ages. Combined with an ageing labor force, the assumption of decreasing productivity by age will lead to lower output per worker compared to a scenario with age-independent productivity.[9] Secondly, given a CES production function with an elasticity of substitution of $0.5$ , the difference between the most optimistic (constant age-productivity profile) and most pessimistic (monotonically decreasing productivity) scenario is pretty constant over time at about $10\%$ . Thirdly, the results are more sensitive to variations in age-specific productivity compared to alternative variants of the population projections.

[9]For the additive production function and assuming age-varying productivity, the optimal age structure, i.e., the age distribution that optimises output, is achieved if all workers are in the age group with the highest productivity. However, the concentration of the population distribution towards these ages (age 35–39 in case of the hump-shaped productivity profile and age 15–19 in case of the decreasing age productivity profile) declines over the next few decades.

*Chart 9: Age Productivity Schedules*

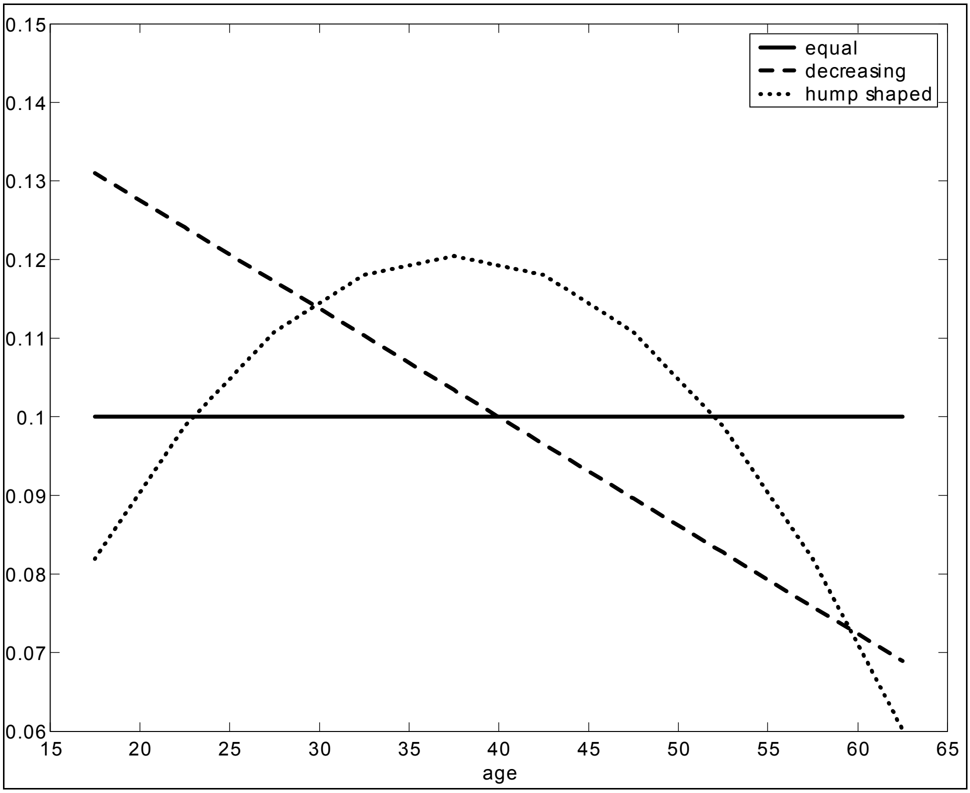
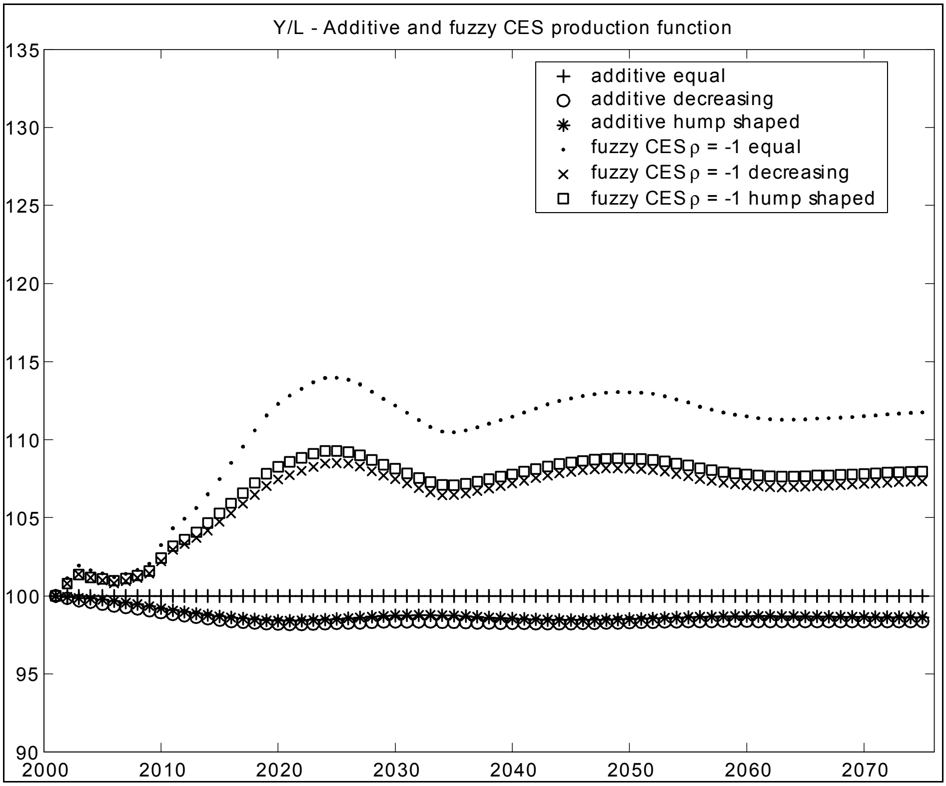
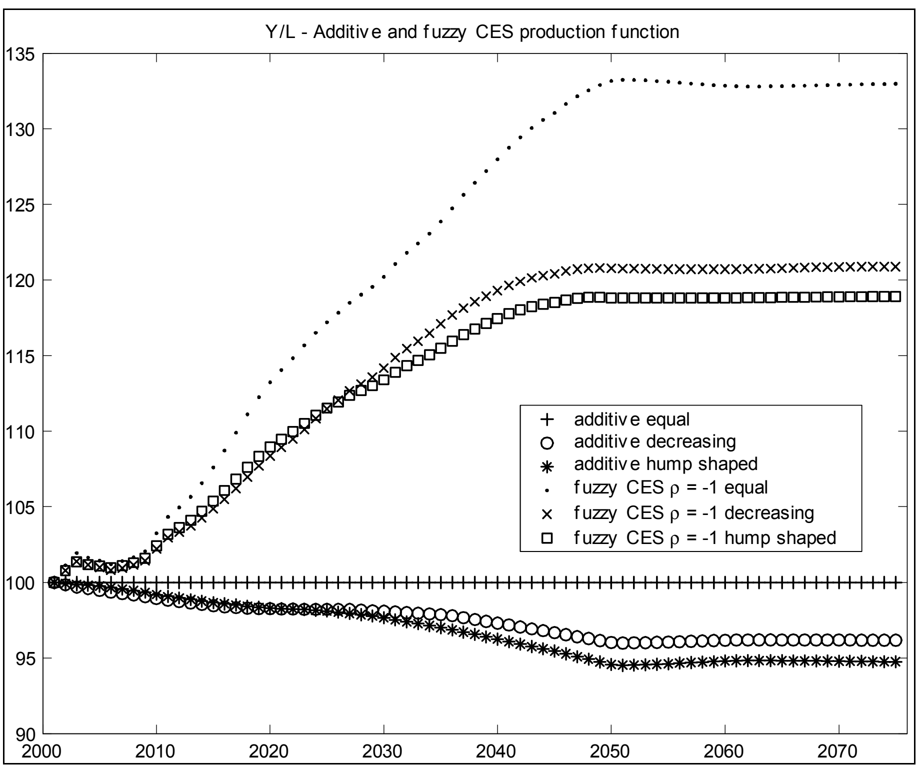


*Chart 10: Projected Relative Output per Worker for Alternative Productivity Schedules by Age and Various Labor Demand Functions, Main Variant and Constant Labor Participation Scenario*




To prevent labor productivity from falling when the shrinkage of the working age population sets in around 2020, we apply the labor force scenario introduced in section 4.2 assuming the main variant of the population projections. Similar to chart 10 we assume an additive or fuzzy CES labor demand function with $\rho = -1$ As illustrated in chart 11, if labor force participation rates are adjusted to approach the values observed in northern European countries, economic productivity can be sustained at its high level even after 2020 in case of the fuzzy CES type labor demand function. By increasing labor force participation rates at lower and older ages (cf. chart 3) we reduce the dissimilarity between the projected age distribution and the uniform age distribution, thereby increasing the level of output per worker in case of equal age-specific productivity levels (compare chart 14, Appendix C). Though a uniform age distribution does no longer constitute the maximizing age distribution if we allow for the hump-shaped or declining age productivity profiles (cf. Appendix B), the increase in the labor force participation rate at higher and lower ages reduces the dissimilarity between the projected and optimal age distribution in those latter two cases as well. The increase in economic productivity amounts to more than 30 per cent in case of the fuzzy CES production function with age-independent productivity levels, while the increase in the labor force participation rates does not change the negative impact of workforce ageing for the declining and hump-shaped age productivity profile in case of the additive production function.

*Chart 11: Projected Relative Output per Worker for Alternative Productivity Schedules by Age and Various Labor Demand Functions, Main Variant and Modified Labor Force Participation Rate*




## 6. Conclusion

The computational findings presented in this paper are based on the population projections released by Statistics Austria and on the labor force participation rates provided by the OECD labor market statistics. We combine three different variants of the population projections (main variant, high fertility/high migration, and low fertility/low migration), two different scenarios with respect to the labor force participation rates (retaining the participation rates of 2001 vs. smoothly converging to the maximum participation rates of the northern European countries), production functions with different elasticities of substitution among age-groups within the workforce, and three different age-productivity profiles. The international comparison reveals that at present, exploitation of the potential labor force is rather low in Austria. This high potential of workers offers an opportunity to compensate for the expected shrinkage of the labor force due to population ageing.[10] Nevertheless, an increased exploitation of the available labor force also intensifies ageing of the labor force. Whether this is advantageous in terms of output per worker depends on the underlying age-productivity profile and on the substitutability of workers of different age. However, investment in education of older workers may help to soften the negative impact of population ageing on labor productivity.

Our simulation results indicate that the degree of substitutability between workers at different ages markedly determines the projected relative productivity. In particular we show that in a pure labor economy, the assumption of imperfect substitution of workers at different ages implies an increase in relative economic productivity during the next two decades compared to a constant or declining economic productivity that results in case of the commonly applied additive labor demand function found in the literature. Given those results, it is surprising that most studies on the economics of ageing assume perfect substitutability of workers at different ages without discussing alternative labor demand functions. We may even conclude that given imperfect substitutability of workers at different ages the next two decades will offer both opportunity and challenge in terms of economic productivity. Of course, future work needs to verify the robustness of those results with respect to the inclusion of non-labor factors in the production function. Most importantly, future work needs to put more focus on estimating the elasticity of substitution between workers at different ages and possibly on how it may change over time as technological progress advances.

[10] As noted in Johnson (2002a), those behavioral factors, and in particular the rise in female employment, have dominated the purely demographic influence on the size of the workforce in post-war Europe as well.

# A The Effect of Labor Force Ageing on Economic Productivity in a Stable Population

The average value of an age-specific variable $x(a)$ over ages $a_1$ to $a_2$ in a stable population that grows at rate $n$ and has a survivorship function $s(a)$ can be written as:

$$\bar{x} = \frac{\int_{a_1}^{a_2} x(a)s(a)e^{-na}da}{\int_{a_1}^{a_2} s(a)e^{-na}da} \tag{7}$$

The logarithmic derivative of $\bar{x}$ is then equal to

$$dlog\bar{x} = \frac{d\bar{x}}{\bar{x}} = (-A_x + A)dn \tag{8}$$

where $A$ is the mean age of the population and $A_x$ is the mean age associated with the characteristic $x(a)$. If one limits the labor force participation to ages $[\alpha, \beta]$ it follows that $A - A_x$ is bounded in absolute values by $(\beta - \alpha)/2$, i.e., about 20 to 25 ages. Hence, a change of the population growth rate by 1 percentage point cannot have an aggregate impact of more than $20 - 25\%$.

# B Output Maximization with CES Technology

Lam (1989, section 3) considers a CES production function $Y = [\alpha L_1^\rho + (1-\alpha)L_2^\rho]^{1/\rho}$ which can be rewritten as $Y = L[\alpha\pi^\rho + (1-\alpha)(1-\pi)^\rho]^{1/\rho}$ with $\pi$ denoting the proportion of the labor force in the young age group. It can be shown that for given values of $\rho$ and $\alpha$ there exists a unique value of the share of the labor force in the young age group $\pi$ that maximizes the value of total output, i.e., which equates the marginal products of the two ages of workers. More specifically, output per period attains a maximum when

$$\frac{\pi}{1-\pi} = \left[\frac{\alpha}{1-\alpha}\right]^{\sigma} \tag{9}$$

with $\sigma = 1/(1-\rho)$ denoting the elasticity of substitution between the young and old labor force age groups. From (9) it follows that if the two types of workers have equal productivity ( $\alpha = 0.5$ ) output will be maximized when $\pi = 0.5$ , i.e., when the age distribution of the labor force is uniform. If $\alpha \neq 0.5$ , however, the elasticity of substitution will determine the division of labor that maximizes output. For instance, if $\alpha < 0.5$ the optimal value of $\pi$ will be less than 0.5 since a greater proportion of older workers will be required to equate the marginal products of the two age groups. As the degree of substitutability increases, a higher ratio of older workers to younger workers is required to equilibrate their marginal products and the output maximizing value of $\pi$ will decrease.

The above considerations can be applied to the labor demand function as given in (). Denoting by $\pi_x$ and $\pi_y$ the share of the labor force in age group $x$ and $y$ , the output maximization condition is:

$$\frac{\pi_x}{\pi_y} = \left[\frac{\alpha_x}{\alpha_y}\right]^{\sigma}. \tag{10}$$

For an age-independent productivity schedule $\alpha_x = \alpha_y$ we obtain that $\pi_x = \pi_y$ for any pair of ages $x,y$ . In other words, a uniform age distribution within the labor force ensures maximum output per worker.

In case of age-dependent productivity - for instance decreasing or hump-shaped the optimal age distribution of the workforce will differ from the uniform age distribution. Formula (10) indicates that an optimal age-structure requires a higher share of those age-groups with higher productivity and a lower share of those with lower productivity. Thus the profile of the optimal age-structure looks similar to the chosen productivity profile (see charts 12 and 13). Moreover, the optimal age structure also depends on the elasticity of substitution. In both figures the curves representing a high elasticity are steeper than those for low elasticity. Therefore, in the latter case the share of workers with an average low age-specific productivity is relatively high because it is difficult to substitute them with workers from other age groups.

*Chart 12: Optimal Age Structure – Decreasing Productivity*

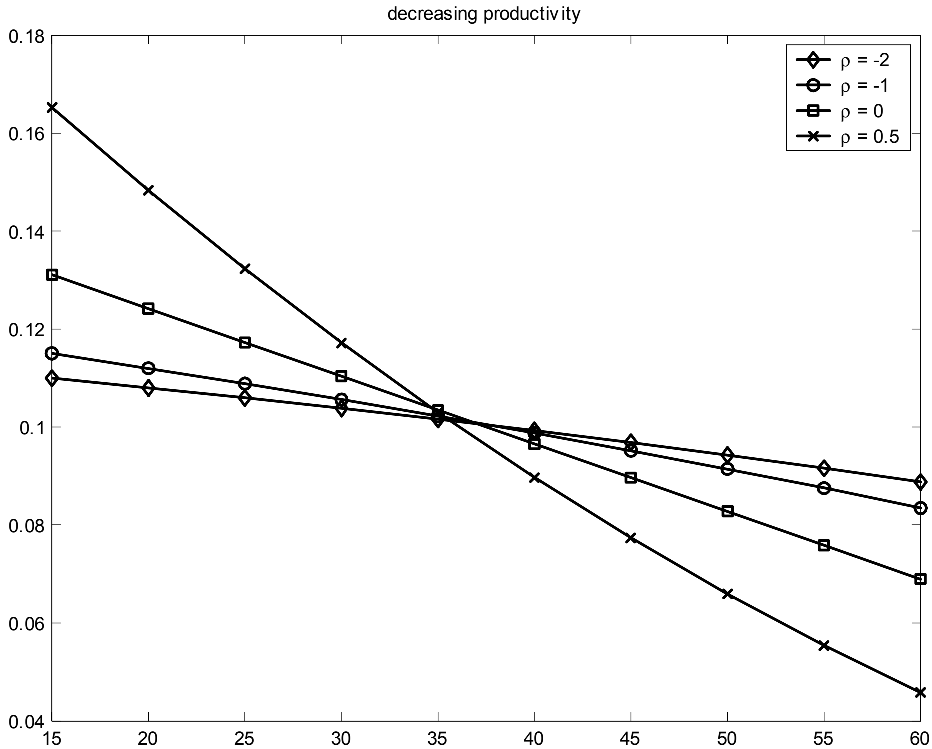
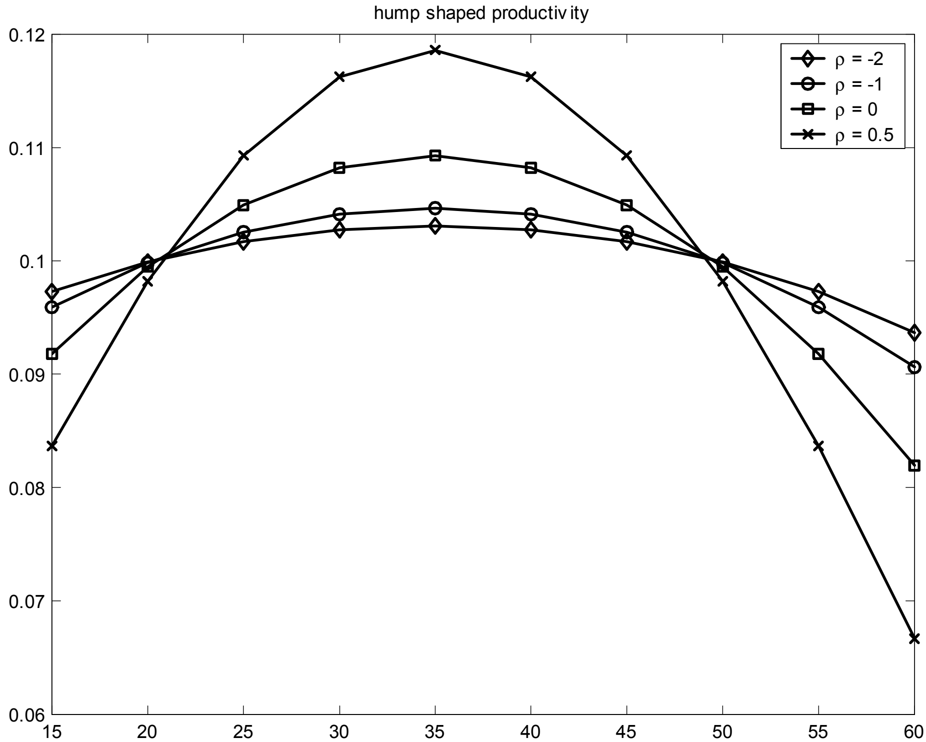


*Chart 13: Optimal Age Structure – Hump Shaped Productivity*



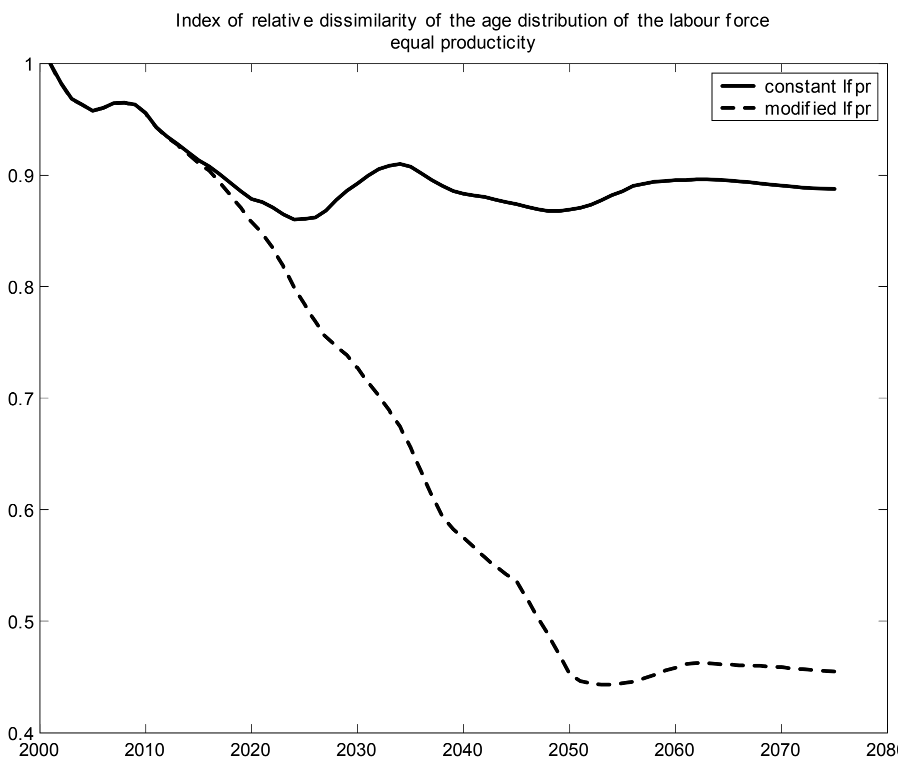

# C Index of Dissimilarity of the Age Distribution of the Labor Force

As a measure of the dissimilarity between the uniform and the projected age distribution we calculate the index

$$0.5 \sum_x |\tilde{\pi}_x - \pi_x| \tag{11}$$

where $\tilde{\pi}_x$ denotes the actually observed share and $\pi_x$ the optimal share of the five-year age groups of the labor force. The index of dissimilarity will result in a measure between 0 and 1, being closer to 1 the more dissimilar the projected age distribution is from the optimal age distribution. In the following we will use the relative dissimilarity which means that we multiply all dissimilarity values with a constant multiplier such that the index in year 2001 is always equal to 1. As shown in figure~ for an equal age-specific productivity, assuming constant labor force participation rates, the age distribution is more dissimilar to the uniform age distribution during the first decade of the 21st century whereafter the dissimilarity decreases and reaches its minimum value around 2025 which also corresponds to the peak in output per worker in figure~. If the labor force participation rates are increased to maintain the size of the labor force, the index of dissimilarity decreases even further until around 2055. Again, this perfectly corresponds to the increase in output per worker illustrated in chart 11.

*Chart 14: Projected Index of Dissimiliarity between the Projected and Uniform Age Distribution of the Labor Force, Mean Variant*

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