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DISCUSSION PAPER

Demographic Change and Consumption – A Long-term Simulation Analysis

Silvia Stiller

HWWA DISCUSSION PAPER

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Demographic Change and Consumption – A Long-term Simulation Analysis

Silvia Stiller

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EUROPEAN INTEGRATION
Head: Dr. Konrad Lammers

Hamburgisches Welt-Wirtschafts-Archiv (HWWA)
Hamburg Institute of International Economics
Öffentlichkeitsarbeit
Neuer Jungfernstieg 21 - 20347 Hamburg
Telefon: 040/428 34 355
Telefax: 040/428 34 451
e-mail: hwwa@hwwa.de
Internet: http://www.hwwa.de/

Silvia Stiller
Hamburg Institute of International Economics
Neuer Jungfernstieg 21, 20347 Hamburg
Telefon: 040/428 34 452
e-mail: silvia.stiller@hwwa.de

Contents

Abstract		6
Zusammenfassung		6
1.	INTRODUCTION	7
2.	THE MODEL	8
3.	POPULATION DEVELOPMENT	12
4.	RESULTS OF THE SIMULATION MODEL	17
4.1	Solution Technique	17
4.2	Economic Reactions to Demographic Changes	18
5.	CONCLUSIONS	23
REFERENCES		26

Table 1	Migration Scenarios	13
Table 2	The Demographic Scenarios	14
Table 3	Per Capita Consumption, $\hat{c}_Q$=100	21
Figure 1	Labour Force Growth Rate	15
Figure 2	Proportion of Workers among the Population	16
Figure 3	Transition Path, “Baseline Scenario”, “Migration D” and “Fertility D”	19
Figure 4	Per Capita Consumption, Migration Scenarios (Baseline Scenario = 100)	22
Figure 5	Per Capita Consumption, Fertility Scenarios (Baseline Scenario = 100)	22
Figure 6	Per Capita Consumption, Fertility Scenarios (Migration D = 100)	23

Abstract

This study investigates the influence of the demographic ageing process in Germany on the long-term economic growth path. For this purpose a macroeconomic simulation model which combines demographic forecasts with a modified Ramsey growth model is applied. Special focus is put on the consumption effects of population ageing and the potential to counter those by rising fertility or permanent immigration. The simulation results illustrate that in the medium and in the long terms per capita consumption is among all demographic scenarios lower than without demographic changes. Permanent immigration can retard the consumption decrease. Rising fertility even reinforces the decline of consumption in the examined period of time.

Zusammenfassung

Das Diskussionpapier beschäftigt sich mit dem Einfluss der demographischen Alterung auf den langfristigen Wachstumspfad in Deutschland. Die Analyse basiert auf einem makroökonomischen Simulationsmodell, welches Bevölkerungsvorausberechnungen mit einem modifizierten Ramsey-Modell kombiniert. Die Auswertung der Simulationsergebnisse konzentriert sich erstens auf die Konsumeffekte der zukünftigen Umbrüche in der Bevölkerungsstruktur. Zweitens wird untersucht, ob steigende Fertilität oder permanente Zuwanderung den ökonomischen Effekten der demographischen Alterung entgegenwirken können. Die Ergebnisse zeigen, dass der Pro-Kopf-Konsum unter Annahme demographischer Veränderungen mittel- und langfristig geringer ist als ohne Veränderungen in der Bevölkerungsstruktur. Permanente Zuwanderung kann dem Rückgang des Pro-Kopf-Konsums entgegenwirken. Steigende Fertilität verschärft den Konsumrückgang in dem berücksichtigten Zeitraum.

JEL classification: E17, E21, J 11

Key words: Population Ageing, Consumption, Growth

1. INTRODUCTION

All industrialised countries will face an enormous population decline and an ageing process at an accelerating pace in the near future. This development is the outcome of the demographic history of those countries. First of all the fertility rates have been below replacement level for several years and still are. Furthermore life expectancy continuously rose during the past and still is expected to rise. The forthcoming changes in the population structure are expected to have far-reaching economic consequences and are crucial for the future design of the social security systems. In the following we focus on two aspects of population ageing which entail macroeconomic repercussions. Firstly, population ageing influences the relative scarcity of the production factors and their prices because of labour force decline. Secondly, as a consequence of this, demographic changes are likely to influence the inter-temporal allocation of consumption and saving and therefore the long-term growth path which determines the future standard of living. This study analyses those effects of demographic changes by a long-term macroeconomic simulation model which combines various demographic forecasts with a modified Ramsey growth model. The analysis illustrates the consequences of population ageing for the individual standard of living. Furthermore it is examined whether permanent immigration or a fertility increase can counter those effects. The comparison between the consumption effects of rising fertility and permanent immigration provides new insights concerning the economic effects of demographic changes. Those results throw – at least for the considered time period - doubt on the widely spread opinion that fertility only has to rise for compensating potential negative effects of historical demographic trends.

It is expected that Germany will experience the most pronounced ageing process among the members of the European Union (United Nations 1998). Therefore it serves in this study as an example for examining the consumption effects of population ageing. Of course the study does not aim at prognosticating the macroeconomic development in Germany. Rather it aims at illustrating the implications of population changes for the long-term economic growth path which, admittedly, is only one important aspect of the complex relationship between demographic and economic developments.

The paper is structured as follows. Section 2 outlines the link between economic and demographic development in a modified Ramsey growth model. In section 3 the population scenarios are presented and the development of the "economically relevant demographic variables" for various migration and fertility scenarios is described. Sec-

tion 4 deals with the consumption effects of demographic changes. Section 5 concludes with a summary of the main results.

2. THE MODEL

The simulations are based on a Ramsey growth model which is modified to include demographic shifts. The development of consumption and investment in the course of time is the outcome of inter-temporal allocation decisions while assuming perfect foresight. The endogenous path of the consumption and the saving behaviour depends on the future demographic development and therefore reacts to changes of the population structure.

The basic model approach is in the line with Cutler et al. (1990) who applied the model in order to assess the macroeconomic impacts of population ageing for the United States. Börsch-Supan (1993, 1994, 1995 a, 1995 b) utilised the same theoretical framework for quantifying the economic effects of demographic changes - with special focus on migration scenarios – for Germany. And Schmidt/Straubhaar (1996) made use of a modified Ramsey model for a simulation concerning Switzerland. The results presented in this paper add two aspects to these previous studies and therefore provide new insight concerning the macroeconomic repercussions of demographic changes. Firstly, in addition to the consumption effects of permanent immigration those of rising fertility rates are analysed. Secondly, the economic effects of permanent immigration are compared to those of rising fertility.

The Ramsey framework is a dynamic macro model. In the remainder it is referred to the model's closed economy version since the demographic impact on the long-term growth path becomes very illustrative under this assumption.[1] Unlike in Ramsey (1928) the population (B_t) and the labour force (L_t) are of different size as we consider an explicit age structure. The labour force grows at the rate n_t and the labour force rate of the population is $\beta_t \, (= L_t / B_t)$. There is labour augmenting technical progress at a constant rate g. With A_t as the level of technology - its initial level (A_0) is normalised to one - the effective amount of labour (L_t^{eff}) at any point of time (t) is:

1 Closed economy means that Germany does not import or export capital; nevertheless Germany "imports" labour by immigration. For the open economy version of the model see Cutler et. al. (1990) and Börsch-Supan (1993).

$$L_t^{eff} = L_t \cdot A_t = L_t \cdot \exp(g \cdot t) \qquad \textbf{(1)}$$

The output (Y_t), which is either consumed (C_t) or invested (I_t), is produced using labour and capital (K_t) which are fully employed at any point in time and paid by their marginal products (see Barro/Sala-i-Martin (1995), p. 68):

$$Y_t = F(K_t, L_t, t) = F(K_t, L_t^{eff}) = C_t + I_t \qquad \textbf{(2)}$$

The production function $[F(\ldots)]$ satisfies the common neoclassical properties (see Barro/Sala-i-Martin (1995), p. 16). Equation 2 leads to the capital accumulation constraint which - measured in effective units of labour - is:

$$\frac{d\hat{k}_t}{dt} = f(\hat{k}_t) - \frac{\hat{c}_t}{\beta_t} - (n_t + d + g) \cdot \hat{k}_t \quad \text{with } \hat{k}_t = \frac{K_t}{L_t^{eff}} \qquad \textbf{(3)}$$

What is left of the production of one effective unit of labour $[f(\hat{k}_t)]$ after consumption and investment for the growing labour force $(n_t \cdot \hat{k}_t + g \cdot \hat{k}_t)$ and the replacement of depreciated capital $(d \cdot \hat{k}_t$, d denotes the depreciation rate) is added to the capital stock $(d\hat{k}_t / dt)$. Per capita consumption per effective unit of labour $(\hat{c}_t)$ weighted by β_t quantifies the consumable amount of the production of one unit of effective labour. The capital accumulation path is decisive for the optimal inter-temporal resource allocation. It is a assumed that a social planner with perfect foresight seeks to maximise[2] the social welfare (see equation 4) with regard to the inter-temporal budget constraint (see equation 2), the future demographic development and the capital intensity at the beginning of the planning period $(\hat{k}_0)$. Furthermore, capital and consumption have to be non-negative at any point in time. Additionally, the transversality condition holds for the optimal growth path (see Silberberg (1990), p. 524; Blanchard/Fischer (1989), p. 43 and Barro/Sala-i-Martin (1995), p. 65).

$$W = \int_0^\infty u(c_t) \cdot B_t \cdot \exp(-\rho \cdot t) dt \qquad \textbf{(4)}$$

2 Barro/Sala-i-Martin (1995), pp. 59-92 derive the equilibrium conditions for a decentralised economy in which the decisions of competitive households and firms lead to the optimal growth path. We prefer the planning solution for expositionary issues. Under certain assumptions concerning the form of preferences the equilibrium conditions for the centralised and decentralised economy are equal and both attain a Pareto optimum (see Barro/Sala-i-Martin (1995), p. 71).

The social welfare is the weighted sum of all future per capita utility flows. The "felicity function" [$u(...)$] measures the instantaneous per capita utility which only depends on consumption per capita (c_t) in t.[3] Discounting future flows of utility implies that the society values the consumption of different generations at a different rate. The higher the social time preference rate (ρ) the lower the contribution of future generations to the social welfare. We follow the common practice and assume a constant elasticity of inter-temporal substitution $(\sigma = 1/\theta)$ felicity function:

$$u(c_t) = \frac{c_t^{(1-\theta)} - 1}{(1-\theta)} \quad for \quad \theta \neq 1, \qquad \textbf{(5)}$$

$$= \ln c_t \qquad for \quad \theta = 1.$$

The consumption path, which entails the maximisation of the social welfare, follows the familiar Euler equation:[4]

$$\frac{dc_t / dt}{c_t} = \sigma \cdot (f'(\hat{k}_t) - d - \rho) = \sigma \cdot (r_t - \rho) \qquad \text{with } r_r = f'(\hat{k}_t) - d \qquad \textbf{(6)}$$

The difference between the net rate of return on capital (r_t) and the social time preference rate determines how consumption develops over time. The Euler equation implies rising (falling) per capita consumption as long as the net rate of return exceeds (falls short of) the social time preference rate. σ determines how sensitively per capita consumption reacts if the net rate of return and the social time preference rate deviate. The higher σ (the willingness to substitute consumption intertemporally) the steeper the inter-temporal consumption profile. Expressed in effective units of labour the Euler equation is:

$$\frac{d\hat{c}_t / dt}{\hat{c}_t} = \frac{dc_t / dt}{c_t} - g \Leftrightarrow \frac{d\hat{c}_t / dt}{\hat{c}_t} = \sigma \cdot (r_t - \rho - g / \sigma) \qquad \textbf{(7)}$$

The Euler equation and the capital accumulation path completely describe the model dynamics for given $\hat{k}_0$ and a given time path of n_t and β_t.[5] The basic condition for

3 The felicity function is increasing in c_t and concave (see Barro/Sala-i-Martin (1995), p. 65).

4 The solution technique for this type of dynamic optimisation problem is the optimal control theory (see Silberberg (1990), Chapter18; Chiang (1992), Chapter 7 and Gandolfo (1995), Chapter 22).

5 For a detailed discussion of the transitional dynamics and the corresponding phase diagram see Barro/Sala-i-Martin (1995), pp. 74-92.

reaching a steady state are constant demographic figures. In the economic steady state $\hat{k}$ and $\hat{c}$ are also constant (see Barro/Sala-i-Martin (1995), p. 68), which implies for the steady state capital intensity (* denotes demographic and economic steady state values):

$$\frac{d\hat{c}^*}{dt} = 0 \Leftrightarrow f'(\hat{k}^*) = (d + \rho + g/\sigma) \Leftrightarrow \hat{k}^* = f'^{-1}(d, \rho, g/\sigma) \quad \textbf{(8)}$$

The capital intensity is constant in the course of time if:

$$\frac{d\hat{k}^*}{dt} = 0 \Leftrightarrow \hat{c}^* = \beta^* \cdot (f(\hat{k}^*) - (n^* + d + g) \cdot \hat{k}^*) \quad \textbf{(9)}$$

Equation (8) illustrates that k^* is independent of demographic changes. In contrast to that the population structure influences the consumption level via two channels: Per capita consumption in the steady state rises ceteris paribus if n^* decreases because the investment requirements are the lower the less people work (see equation 10). And per capita consumption decreases if the labour force rate of the population declines because the production of one unit of effective labour has to be shared among more people (see equation 11).

$$\frac{\partial \hat{c}^*}{\partial n^*} = -\hat{k}^* \cdot ß^* < 0 \quad \textbf{(10)}$$

$$\frac{\partial \hat{c}^*}{\partial ß^*} = f(\hat{k}^*) - (n^* + d + g) \cdot \hat{k}^* > 0 \quad \textbf{(11)}$$

Summarising these effects per capita consumption in the steady state is the higher the lower n is and the higher β is. Furthermore, the demographic conditions influence the capital accumulation path as well as r_t and therefore consumption development. n and β constitute the link between the demographic and the economic developments and are in the following denominated as the “economically relevant demographic variables”.

We regard per capita consumption as an indicator for the periodical standard of living. But it should be kept in mind that the consumption level is no welfare indicator in an inter-temporal context. In order to evaluate the welfare effects of demographic changes one has to go beyond merely comparing the inter-temporal consumption levels and to take regard of the assumed utility function. Nevertheless Börsch-Supan (1993, p. 8) regards the year-by-year consumption possibilities as a welfare indicator:”Welfare of society is measured in terms of consumption per capita.”. But this interpretation seems to

be wrong. As Cutler et. al. (1990, p. 54) correctly note, only looking at the per capita consumption path does not give any hint at the welfare effects of population development. Rather the theoretically correct welfare indicators in the Ramsey framework are, as Raffelhüschen (1994) points out, the Hicksian measures of relative variations.[6]

3. POPULATION DEVELOPMENT

The population model forecasts the population structure by age and sex up to the year 2050. It is based on the age and sex specific German population structure in the year 1994.[7] The demographic scenarios are constructed by combining different migration and fertility assumptions. The mortality patterns do not differ among the demographic scenarios and equal those used by the German Census Bureau forecast of 1994 (Sommer 1994). Under these assumptions the long-term life expectancy at birth of the female population will be 81.1 years and that of the male population 74.6 years.

The reason for only referring to scenarios of rising fertility and migrations gains is that the study aims at assessing the demographic potential to counter the economic impacts of population ageing. Instead decreasing fertility and migration losses would intensify population ageing and its consequences. Migration pressure directed towards the European Union and especially towards Germany for the next decades is for several reasons very probable.[8] Table 1 subsumes the considered scenarios of positive annual migration balances.

Table 1: Migration Scenarios

Scenario	Annual net immigration until 2000	Annual net immigration after 2000
Migration A	Constant migration gain of 500,000 people p.a.	Constant migration gain of 50,000 people p.a.
Migration B	Until 2000 the migration balance decreases p.a. – starting from 500,000 million people – by 50,000 people	Constant migration gain of 100,000 people p.a.
Migration C	Constant migration gain of 200,000 people p.a.	Constant migration gain of 200,000 people p.a.
Migration D	Constant migration gain of 300,000 people p.a.	Constant migration gain of 300,000 people p.a.

6 The welfare effects of demographic changes in a Ramsey framework are discussed and evaluated for different demographic scenarios in Stiller (2000 a, 2000 b).

7 Although it is not discussed here the population model takes into account the different demographic situations in East and West Germany in the base year.

8 Firstly, there is – due to labour market and demgoraphic issues - an enormous migration pressure in Eastern Europe and the Maghreb. Secondly, economic migration theory suggests futher migration pressure for Germany (see Ghatak/Levine/Price (1996), Molho (1986) und Stahl (1995)).

The assumed age and sex specific structure of the migration balance equals the immigration into Germany in 1992 (see Statistisches Bundesamt 1995 a). According to these figures 60 % of the migrants are males. The average age of immigrants is 27 years, which is roughly 10 years less than the average age of the German population in 1994.

The fertility scenarios are based on a cohort approach. In the scenario with the lowest fertility a long-term total fertility rate of on average 1.41 children per woman is assumed. In the further scenarios the fertility is 10%, 15 %, 25 % and 45 % higher than in this scenario.

The design of the demographic scenarios is firstly meant to illustrate how population ageing influences per capita consumption. Secondly, it aims at contrasting the economic effects of rising fertility on the one hand and permanent immigration on the other. Therefore it is differentiated between "migration scenarios" and "fertility scenarios" (summarised in table 2).

Table 2: The Demographic Scenarios

Scenario	**Net migration gain until 2010**	**Net migration Gain until 2030**	**Net migration gain until 2050**	**Long-term total fertility rate**
Baseline scenario	0	0	0	1,41
"migration scenarios"				
Migration A	4 million	5 million	6 million	1,41
Migration B	2.9 million	4.9 million	6.9 million	1,41
Migration C	3.4 million	7.4 million	1.4 million	1,41
Migration D	5.1 million	11.1 million	17.1 million	1,41
"fertility scenarios"				
Fertility A	0	0	0	1,55
Fertility B	0	0	0	1,62
Fertility C	0	0	0	1,76
Fertility D	0	0	0	2,04

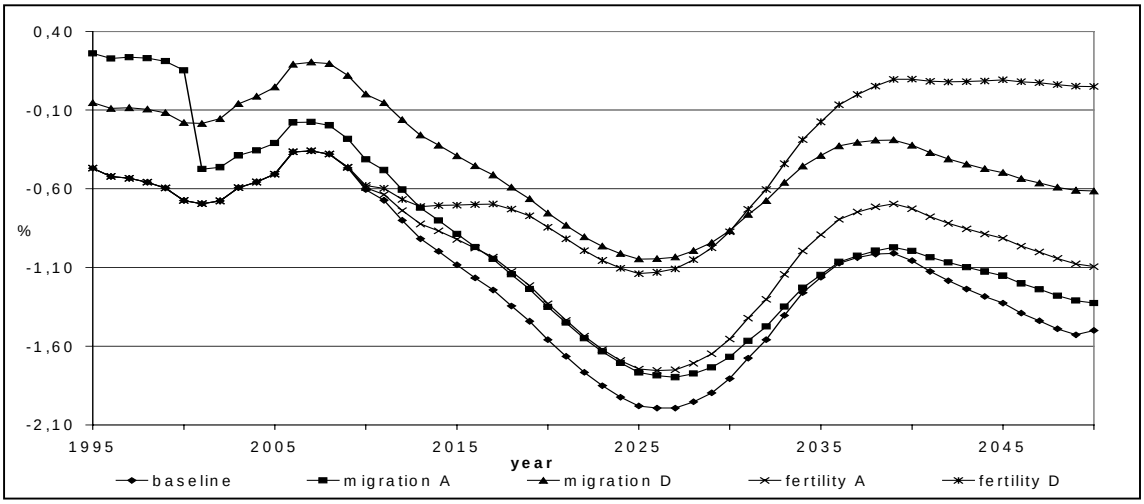
As a reference case for measuring the demographic effects of rising fertility and permanent immigration a "baseline scenario" is defined. In this scenario there exist neither fertility increase nor migration. In contrast to the "baseline scenario" the fertility scenarios assume higher fertility. The migration scenarios abstract from rising fertility but assume permanent migration gains.

The development of the economically relevant demographic figures, which depend upon the labour force participation rates, connects the population forecasts with the

economic simulation model. It is supposed that the age and gender specific labour force participation rates, which constitute the link between the demographic development and the development of the supply side of the labour market, of the year 1994 in West Germany describe the future labour supply behaviour of the foreign and the German population. According to the 1994 figures for West Germany (see Statistisches Bundesamt 1995 b) 60 % of the female and 81,8 % of the male population belonged to the labour force.

For the simulation results the labour force growth rate and the labour force rate of the population are fundamental. Figure 1 illustrates for some of the demographic scenarios exemplarily the strong fluctuations of the labour force growth rates. Within the migration scenarios and the “baseline scenario” the working force declines independently of the immigration level during the whole period of time.

Figure 1: Labour Force Growth Rate



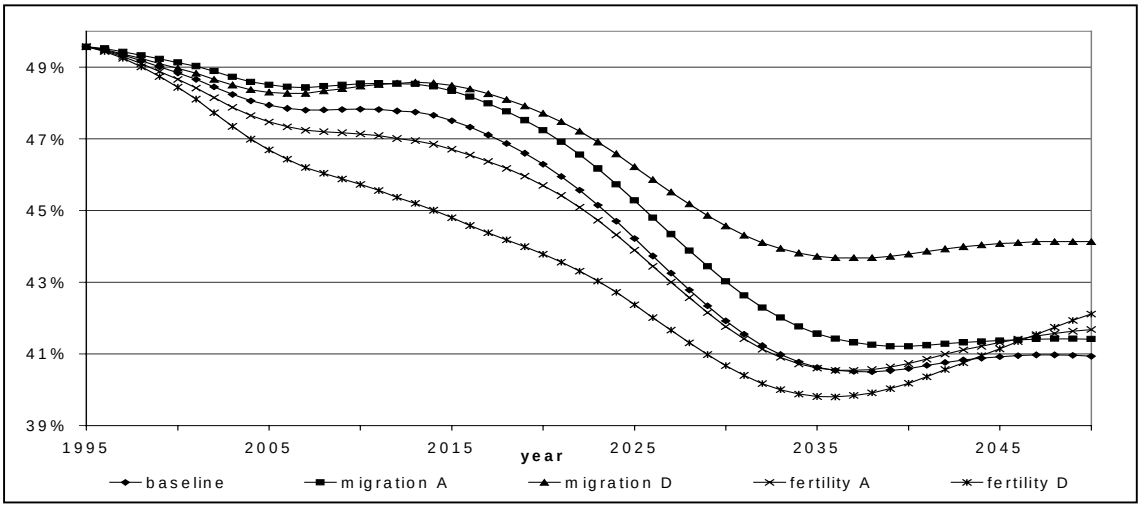
Source: Own calculations.

When assuming immigration and in the baseline case the growth rate strongly decreases after the year 2005 and reaches its minimum in the year 2025. Afterwards the labour force decline slows down. But the growth rate remains negative and does not reach its original value again. Compared to the "baseline scenario" permanent migration gains clearly retard the decline of the labour force. But despite of that permanent immigration cannot stop the shrinkage of the macroeconomic labour supply. The labour force growth rate coincides in the fertility scenarios and in the "baseline scenario" until 2010. After-

wards the “additionally” born children in the fertility scenarios strengthen the labour supply compared to the “baseline scenario“ and slow down the labour force shrinkage. Nevertheless, labour supply declines despite rising fertility almost during the whole forecast horizon. The differences between the fertility scenarios and the "baseline scenario" are the more pronounced the more strongly fertility increases. Obviously the fertility increase has to be substantial for significantly slowing down the shrinkage of the labour force in the examined period of time. Furthermore, a changing fertility behaviour influences the supply side of the labour market - of course - not before the rising number of children enters the age groups with high labour force participation rates. Therefore the improvement of the supply side of the labour market through rising fertility involves some "patience".

The different development of the population on the one hand and the labour force on the other hand results in quantitative differences of the labour force rate of the population although the qualitative variations of this demographic figure are the same in all scenarios (figure 2).

Figure 2: Proportion of Workers among the Population



Source: Own calculations.

In the base year there are roughly two consumers per worker. During the whole forecast period the labour force rate of the population lies below this value and reaches its minimum in the year 2035. Between 1994 and 2035 it declines by 18 % in the “baseline scenario“ and by 12 % in the "migration D" scenario. All in all the development of the la-

bour force rate of the population is the more disadvantageous the less people immigrate. Although immigration strengthens the labour supply it cannot stop the decline of the rate of workers among the total population. When assuming rising fertility the labour force rate of the population is also during the whole forecast period lower than in the base year, and it decreases continuously until the year 2035. In the course of this development the labour force rate of the population is the lower the higher the fertility rates are. Compared to the "baseline scenario" rising fertility has a positive influence on the labour force rate of the population not before the year 2040, i. e. rising fertility initially makes the dependency problem worse and has a slightly positive effect on this demographic variable only after about four decades. The reason for this is that the consumer numbers immediately increase if fertility rises. But the amount of the working population remains the same in the “baseline scenario” and in the fertility scenarios until 2010. Therefore the number of consumers per working person is higher in the fertility scenarios than in the "baseline scenario".

The population forecasts reveal that the decline of the economically relevant demographic variables during the next decades is unavoidable. The dimension of the demographic changes to come depends on the fertility rates and the migration behaviour in the future. Immigration slows down the decline of the working force immediately due to the assumed juvenile age structure of the immigrants. In contrast to that rising fertility clearly influences the amount of the working force not before twenty years later. In all demographic scenarios the ratio between the working and the passive population declines. During this development the labour force rate of the population is the higher the higher immigration is. Instead, a fertility increase reduces the rate of people working for about four decades.

It is evident that immigration and rising fertility are no substitutes regarding the demographic development because they have different effects on the age structure of the population and on the supply side of the labour market. The results of the demographic forecasts illustrate clearly the differences of the decisive factors for the economic development when varying demographic assumptions. At the same time there are substantial changes in those indicators during the forecast horizon. Therefore qualitative and quantitative differences in the economic development under different demographic conditions are most probable.

4. RESULTS OF THE SIMULATION MODEL

4.1 Solution Technique[9]

The assumptions regarding the exogenous economic parameter of the simulation model are in accordance with those of the relevant literature.[10] Following the common practice the rate of technical progress is set equal to 1.4 %.[11] The depreciation rate is assumed to be 5 % per annum. For the time preference rate 4 % and 6 % are chosen. In order to evaluate the implication of the inter-temporal elasticity of substitution for the simulation results $\sigma = 1$ and $\sigma = 0.7$ are used alternatively. The production function is of the Cobb Douglas type. The share of capital in total income equals 30 % in the steady state which roughly corresponds to its average value in Germany during the last decades. The assumed parameter values imply an effective discount rate, which equals the real interest rate in the steady state, between 5.4 % and 8 %. The time horizon of the simulation analysis is the year 2050. It is assumed that the demographic and economic terms match their steady state values at that point in time and that they are constant afterwards. Of course, this is only a "hypothetical" steady state. But due to the turnpike property (see Blanchard/Fischer (1989) p. 101 and p. 147) of the optimal growth path the economic development until the year 2050 is only influenced at the margin if we assume that the economic and demographic terms reach their steady states later. Furthermore, capital per unit of effective labour in the base year is set to its optimal value ($\hat{k}^*$). The demographic values which influence the economic development differ between the years 1994 and 2050 according to one of the nine population scenarios (see section 3). Under these assumptions the only missing economic term for solving the model is the per capita consumption in the base year $(\hat{c}_o)$. As the model exhibits saddle path stability the per capita consumption level in the base year which will lead the economy to the steady state in 2050 is unique (see Börsch-Supan (1995 a), p. 27 and Barro/Sala-i-Martin (1995), p. 73). In order to determine the consumption level which allows the economic development according to the stable path for each demographic scenario a shooting algorithm is applied to the equations (3) and (7).

9 The solution method corresponds to Cutler et. al. (1990) and Börsch-Supan (1993).

10 See Börsch-Supan (1993), p. 34; Börsch-Supan (1994), p. 134; Börsch-Supan (1995 a), p. 224 f; Börsch-Supan (1995 b), p. 33; Cutler et.al. (1990), p. 23 and Schmidt/Straubhaar (1996), p. 403 f.

11 See Cutler et. al. (1990) and Börsch-Supan (1993).

4.2 Economic Reactions to Demographic Changes

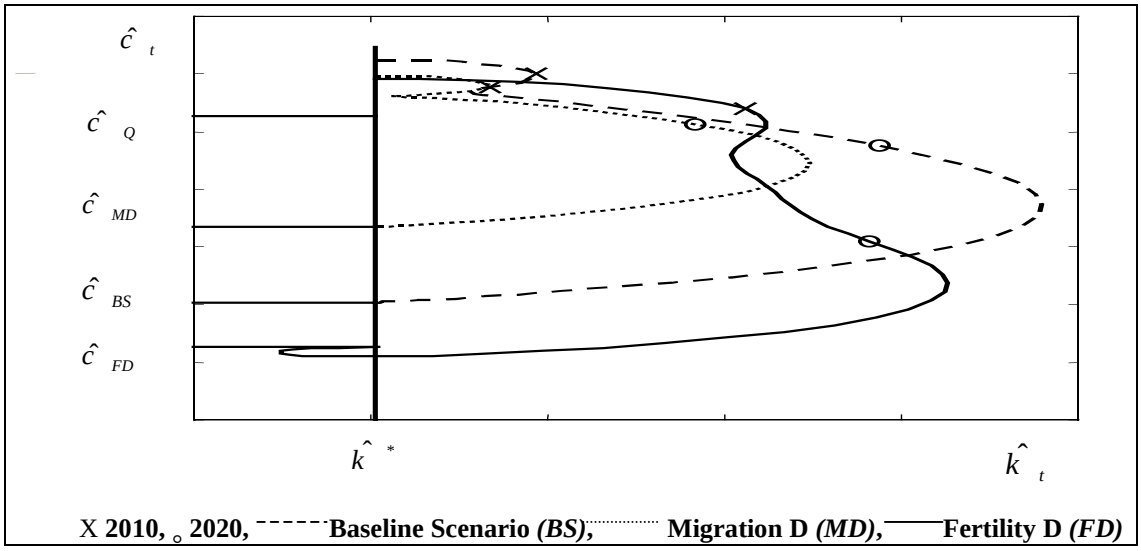
The stable path indicates the demographic impact on the development of the consumption possibilities and differs between the demographic scenarios for three reasons: *Firstly*, per capita consumption in the basic year varies among the scenarios as it depends for each population scenario on its specific future demographic terms. *Secondly*, crucial for the steady state per capita consumption in 2050 are the economically relevant demographic variables (see equations 10 and 11) which clearly differ between the demographic scenarios at that point in time. *Thirdly*, the demographic assumptions influence the growth path between 1994 and 2050 via the Euler equation and the capital accumulation path according to the scenario specific movement of the economically relevant demographic figures.

Of course, due to labour-augmenting technical progress, per capita consumption grows in the course of time despite of population ageing. In the following we do not figure out the growth effects merely caused by technical progress. As the analysis aims at illustrating the consumption effects of population ageing it focuses on the relative consumption effects compared to a situation of a constant demography. As a reference case serves a scenario in which we hold the age structure of 1994 constant. For this scenario the economy is supposed to be in steady state with the corresponding economically relevant demographic variables. This particularly means that $\hat{k}$ and $\hat{c}$ will not vary any more. The steady state consumption level for this scenario is denominated as $\hat{c}_Q$. A closer look at the development path of $\hat{k}$ and $\hat{c}$ clarifies the economic reactions to demographic changes in the Ramsey framework. Assuming $\sigma = 0{,}7$ and $\rho = 4\,\%$ [12] figure 3 shows the movements of per capita consumption and capital exemplarily for the "baseline scenario", "migration D" and "fertility D".

Capital per effective unit of labour initially rises and decreases afterwards but it exceeds its steady state value in all scenarios almost during the whole simulation period. This indicates that, due to the labour force shrinkage, capital is the relatively abundant factor along the transition path. Therefore the real interest rate is lower and the wage rate is higher than in the steady state.

12 As the simulation results for the other parameter choices are analogous we are allowed to renounce the discussion of the results of those scenarios.

Figure 3: Transition Path, "Baseline Scenario", "Migration D" and "Fertility D"



Source: Own calculations.

As long as this is valid the Euler equation implies measured in efficiency units declining per capita consumption (like for the scenarios in figure 3) along the stable path:

$$\hat{k}_t > \hat{k}^* \Rightarrow f'(\hat{k}_t) < f'(\hat{k}^*) = (\rho + d + g/\sigma) \Rightarrow \frac{d\hat{c}_t / dt}{\hat{c}_t} < 0 \qquad \textbf{(12)}$$

Although per capita consumption in all demographic scenarios is, apart from some points in time, continuously decreasing it initially lies for two reasons above $\hat{c}_Q$. *Firstly*, production per effective worker is higher than in the steady state as long as $\hat{k}_t$ exceeds $\hat{k}^*$. *Secondly*, the required investment per effective worker declines because of the labour force decrease. We describe the sum of those effects as the "investment effect:

$$(f(\hat{k}_t) - (n_t + d + g) \cdot \hat{k}_t) \uparrow \quad \text{(investment effect)} \qquad \textbf{(13)}$$

If these were the only economic repercussions of demographic changes, per capita consumption could increase. But against this consumption effect works the shrinking labour force rate of the population due to which the production per effective worker has to be shared among more people than without demographic ageing. This consumption effect of population ageing is considered to be the "burden effect":

$$\beta \downarrow \cdot (f(\hat{k}_t) - (n_t + d + g) \cdot \hat{k}_t) \quad \text{(burden effect)} \qquad \textbf{(14)}$$

The effective movement of the per capita consumption depends on the relative importance of the counteracting consumption effects which obviously changes in the course of the ageing process (see figure 3). Initially population ageing and shrinking is in favour of per capita consumption and less investment allows a higher consumption level than $\hat{c}_Q$. But this "consumption dividend"[13] is only temporary. As demographic ageing proceeds consumption falls below $\hat{c}_Q$. Simultaneously the capital intensity declines. During that period of time the "burden effect" outweighs the "investment effect" due to the accelerating labour force decrease. Per capita consumption decreases in the "baseline scenario" and in "migration D" during the whole forecasting period while the capital intensity exceeds its optimal value. Except for the end of the simulation period this is also true for "fertility D". But in this scenario capital is due to the labour force increase after 2040 (see figure 1), which requires higher investment, temporarily the relatively scarce production factor. In this case the capital intensity is lower than $\hat{k}^*$ and per capita consumption rises according to the Euler equation:

$$\hat{k}_t < \hat{k}^* \Rightarrow f'(\hat{k}_t) > f'(\hat{k}^*) = (\rho + d + g/\sigma) \Rightarrow \frac{d\hat{c}_t / dt}{\hat{c}_t} > 0 \qquad \textbf{(15)}$$

The "burden effect" overtakes the "investment effect" dependent on the development of the economically relevant demographic terms at different points in time. Per capita consumption falls below $\hat{c}_Q$ in the year 2025 with "migration D" and in the year 2022 in the "baseline scenario". Assuming "fertility D" the proportion of workers among the population decreases more strongly than in the other scenarios because of the rising number of children. Therefore already in the year 2007 the consumption level in this scenario is lower than $\hat{c}_Q$. According to our assumptions the economy reaches a steady state in the year 2050 and the demographic figures will not fluctuate afterwards any more. The steady state consumption level is 94 % of $\hat{c}_Q$ when assuming "migration D" and 90 % of $\hat{c}_Q$ in the "baseline scenario". At the end of the simulation horizon consumption is the lowest with "fertility D". In that scenario consumers achieve only 87 % of the consumption level which is possible without demographic changes.

Despite the similar qualitative development in all demographic scenarios (see table 3) there are quantitative differences regarding per capita consumption. At first consumption in the "baseline scenario" is higher than in the migration scenarios since the required investment is less if less people immigrate. But after 2017 the standard of living

13 See Cutler et al. (1990), p. 107.

is without any exception higher with permanent immigration than without immigration. Nevertheless immigration, even if it has a very significant effect on the development of the working force, cannot stop the consumption possibilities from falling below $\hat{c}_Q$.

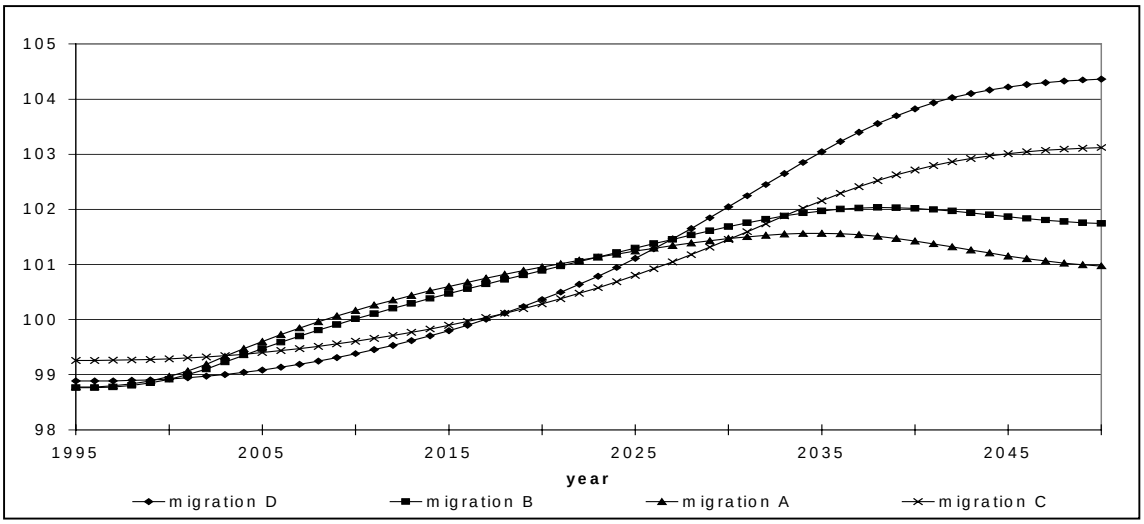
Table 3: Per Capita Consumption, $\hat{c}_Q$=100

	1995	2000	2010	2020	2030	2040	2050
Migration A	102,6	102,6	102,4	101,3	96,9	92,4	91,3
Migration B	102,6	102,5	102,3	101,3	97,1	93,0	92,0
Migration C	103,0	102,8	101,8	100,7	96,9	93,7	93,2
Migration D	102,6	102,4	101,6	100,8	97,6	94,8	94,3
Baseline	103,8	103,5	102,2	100,3	95,4	91,2	90,4
Fertility A	103,3	102,9	100,9	98,7	94,2	90,4	90,0
Fertility B	103,0	102,6	100,4	98,0	93,6	90,0	89,7
Fertility C	102,8	102,4	99,8	96,9	92,4	88,9	88,7
Fertility D	102,3	101,6	98,3	94,6	90,0	86,8	86,8

In contrast to immigration rising fertility is not suited to counter the negative consumption effects of population ageing. Though initially per capita consumption with rising fertility is higher than $\hat{c}_Q$ because the “investment effect” - like in the migration scenarios - temporarily dominates the “burden effect”. Per capita consumption in the base year and along the transition path is the higher the less fertility increases, which can be explained by two aspects. On the one hand the rising number of children strengthens the burden the working population has to carry. On the other hand in the medium and in the long run the required investment is the higher the higher the fertility rate is. Both effects impair the consumption possibilities compared to a scenario of constant fertility behaviour. After falling below $\hat{c}_Q$ the standard of living continues to fall in all demographic scenarios until 2040.

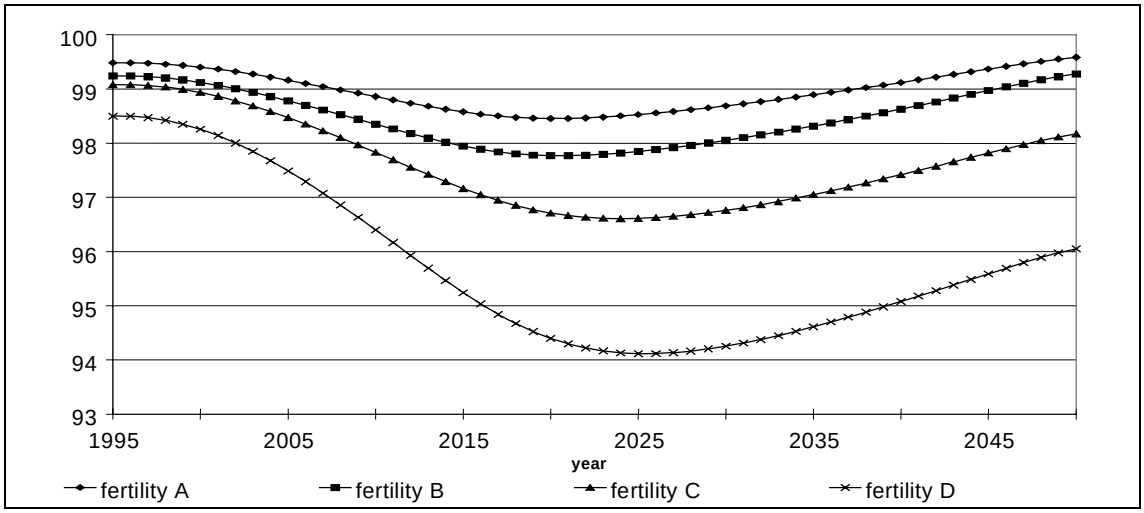
Figures 4 to 6 compare the per capita consumption between the demographic scenarios. This comparison is especially suited for stressing the merits of the demographic scenarios regarding the year-by-year consumption possibilities. Figure 4 illustrates that compared to the “baseline scenario” the positive impact of immigration on per capita consumption strongly depends on the amount of the annual migration gains. For example assuming a yearly net immigration of 50.000 people results in a consumption level in the medium and in the long terms that is approximately only 1 % higher than in the "baseline scenario". Assuming instead a yearly net immigration of 300.000 people the periodical per capita consumption with migration deviates from that without migration up to 4.5 %.

Figure 4: Per Capita Consumption, Migration Scenarios (Baseline Scenario = 100)



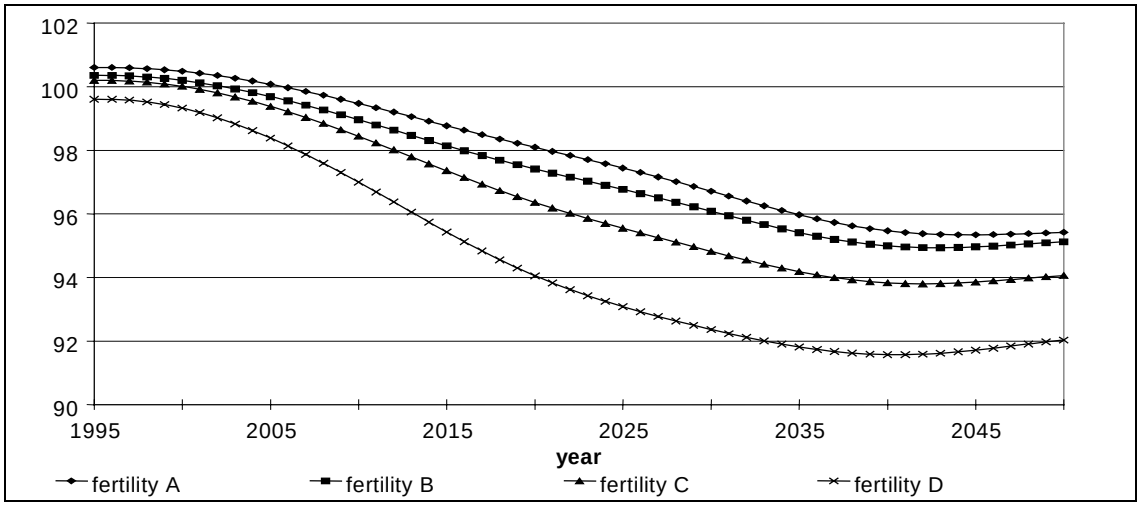
Higher fertility than in the “baseline scenario” has a distinctly negative effect on the consumption level (see figure 5). The difference of the per capita consumption in the “baseline scenario” and in fertility scenarios rises continuously up to the year 2025. Until then it amounts to 6 % between the "baseline scenario" and "fertility D" and decreases afterwards. But at the end of the forecast horizon it is still between 0,5 % and 4% between the fertility and the baseline scenarios.

Figure 5: Per Capita Consumption, Fertility Scenarios (Baseline Scenario = 100)



The most obvious difference in the consumption level can be found between "migration D" and "fertility D" (see figure 6). Permanent net immigration of 300.000 people has – compared to rising fertility - without any exception a positive effect on the consumption development. For example the consumption level with "fertility D" falls for some points in time about 8 % short of that in the "migration D" scenario. Furthermore the differences between the other fertility scenarios and "migration D" are distinct.

Figure 6: Per Capita Consumption, Fertility Scenarios (Migration D = 100)



5. CONCLUSIONS

Summarising my results one can draw some general conclusions regarding the demographic effects on the growth path of the modified Ramsey model. Due to the demographic ageing physical capital becomes - compared to the labour supply - the relatively abundant production factor. Therefore the capital intensity rises along the transition path. This affects the factor prices and the consumption and saving decisions of the society compared to a situation with a constant population structure.

Due to the population ageing per capita consumption decreases in the course of time. Permanent immigration can retard the consumption decrease since it has, due to the assumed juvenile age structure of the immigrants, a positive influence on the labour supply.[14] Rising fertility even reinforces the decline of consumption for more than four

14 The same results can be found in Cutler et al. (1990) and. Börsch-Supan (1993, 1994, 1995 a, 1995 b). But those studies do not offer results concerning the economic effects of changing fertility rates.

decades since transitions from low to high fertility entail a corresponding period of high dependency.[15] The reason for this is that consumer numbers rise immediately as a consequence of higher fertility rates while the amount of the labour force is not influenced by higher fertility rates but two decades later. So we draw – at least for the examined period of time - the conclusion that "less children allow more consumption".

Needless to say that the simulation model and its results are subject to many limitations as the model only includes a limited number of economically relevant feedbacks of population ageing. Among others a restrictive assumption are time invariant labour force participation rates. If instead the labour supply reacted to rising wages this could reduce the economic repercussions of population ageing. This is also true if we allow for capital export from Germany to countries which do not face population ageing. But the possibility of reducing the negative impact of population change by exporting capital to relative labour abundant countries seems to be problematic. The countries Germany mainly invests in – which are the member states of the European Union and the United States – have to cope with population ageing themselves. Also some might argue that a calibrated overlapping generations model, within which the aggregate outcome is the result of individual decisions, should be preferred to a Ramsey framework. But when arguing like this one should keep in mind that "...overlapping generations models with more than two generations tend to be analytically intractable."[16]. Furthermore the disaggregated analysis of an overlapping generation model and the Ramsey growth model lead, for certain assumptions concerning the preference structure, to identical solutions.[17]

Altogether the approach followed in this analysis has the advantage of being analytically easy to solve on the one hand and including key relations between the demographic and economic development on the other. All in all the set of issues captured by this study supposes that immigration is adequate for and rising fertility is opposed to reducing the negative effects of the prospective demographic changes for the standard of living. However, as the analysis is highly aggregated, it is difficult to judge about policy options on the basis of the simulation results.

15 Weil (1999) draws the same conclusion concerning the connection between average per capita consumption and rising fertility but he does not use an explicit model approach.
16 See Blanchard/Fischer (1989), p. 115.
17 See Börsch-Supan (1995), p. 31 and Blanchard/Fischer (1989), p. 106.

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