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MOBILITY AND THE ROLE OF EDUCATION AS A COMMITMENT DEVICE

Claudio Thum
Silke Übelmesser

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CESifo

Center for Economic Studies & Ifo Institute for Economic Research
Poschingerstr. 5, 81679 Munich, Germany

Tel.: +49 (89) 9224-1410
Fax: +49 (89) 9224-1409
e-mail: office@CESifo.de

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Abstract

European integration forces system competition within European countries. This competition has important implications for both the public pay-as-you-go pension scheme and the public education system. Without labor mobility, each generation has an incentive to invest in the human capital of the subsequent generation in order to maximize pension payments. It is a popular belief that increasing labor mobility decreases the incentives to finance the education of the subsequent generation. This paper shows that this is not true if human capital investment increases the mobility of the subsequent generation and can thus be used as a commitment device for low taxes.

JEL Classification: H52, H55.

Keywords: Education, intergenerational transfers, commitment

Claudio Thum
CESifo (University of Munich & Ifo Institute)
Poschingerstr. 5
81679 Munich
Germany

Silke Übelmesser
CESifo (University of Munich & Ifo Institute)
Poschingerstr. 5
81679 Munich
Germany
Uebelmesser@cesifo.de

Introduction

In all industrialized countries, a large fraction of government spending is used for public education. These transfers to the young amount to roughly 5 percent of GDP over all developed countries. There are significant transfers to elderly people, too. About 8 percent of GDP is redistributed via public pension schemes.[1] This paper analyzes how these transfers are affected by increased labor mobility in Europe.

In a closed economy, investment in human capital faces a hold-up problem as human capital becomes a fixed factor once the investment is made. Consequently, the optimal tax is high given the human capital investment. Boadway, Marceau and Marchand (1996) analyze the time consistency problem for a benevolent government and discuss the consequences this problem has for the incentive to invest in human capital. Increased international mobility of labor, however, changes the constraints which affect optimal education and tax policy. Kehoe (1989) points out for the case of mobile capital that mobility can solve the hold-up problem of time-consistent taxation for a benevolent government by acting as a partial commitment. In this paper, we consider the case of mobile labor and show that in a non-altruistic, gerontocratic world, investment in human capital can be interpreted as a commitment device. Each generation has an incentive to invest in the human capital of the subsequent generation if this investment increases mobility and therefore restricts taxation.

The idea of the paper is the following. Assume that the population can be divided into two generations - one young generation and one old generation. The young generation is first educated and then starts to work. The old generation, which is the owner of the fixed factor, is

[1] See e.g. OECD (1996), OECD (1999), and Thum (1999).

retired and has the power to levy a tax on the young generation.[2] Thus it receives transfers in addition to the income from the fixed factor. The taxes are set so as to extract the exact difference between the domestic wage and the wage abroad, which is the outside option for the young generation. Anticipating this behavior, taxation has an effect on the education decision of the young generation if education increases the domestic and the foreign productivity differently. If, for example, a German worker is taught German law, this country-specific knowledge would increase his labor productivity in Germany but does not affect her labor productivity in Italy. The reciprocal effect is true for foreign languages. To illustrate the effect on the education decision, assume the extreme case where education increases domestic labor productivity only (e.g. knowledge of the domestic law system). This productivity increase would be fully taxed by the old generation. Therefore, the young generation would not have any incentive to invest in human capital at all. To avoid this outcome, the old generation would like to commit itself credibly to a low taxation in the future, which would induce the young generation to invest in human capital. One feasible commitment device is to provide for skills, e.g. foreign languages, that increase the wage abroad. A necessary condition for the feasibility of this strategy, however, is the power to control the skill composition. This power can be acquired by the old generation by providing the education.

Public education as a commitment device has already been analyzed in an altruistic world. Gradstein (2000), for example, showed that the public provision of education might reduce the threat of "aggressive" redistributive taxation in a median voter model compared to the private provision of education.[3] This leads to a higher level of human capital accumulation and, therefore, a faster growth of average income compared to a more differentiated private education system. Therefore, publicly provided education serves as a commitment device pre-

[2] Of course, the model can be interpreted in a much more general context. In fact, it is only necessary for the results to hold that the politically decisive group receives income out of an immobile factor.
[3] For the political economy of the mix of public and private provision of education see Gradstein (1996).

venting efficiency losses. In our model, a different approach will be chosen without referring to altruistic motives. Our model relies on the productivity effect of human capital investment as a link between the young and the old generation allowing for migration.[4]

The paper is organized as follows. The next section presents the basic model for a small country interacting with a large country. The second section adds the monetary costs of education to the analysis. The consequences for the welfare state in the context of an aging population are the focus of the last section, which also concludes and highlights some policy implications.

1. Education as a commitment device

How is public education affected by increased mobility? To answer this question, we introduce a simple intergenerational model with two homogeneous generations where the old generation raises a lump-sum tax that has to be paid by the young generation.[5] It is assumed that the old generation has the power to tax the young generation, i.e. there is a gerontocracy,[6] and that the old generation is the owner of the fixed factor. This assumption in this extreme version is not necessary for the result but eases the analysis significantly. Additionally, it is assumed that production Y in the domestic country is determined by a function F

$$Y = F(K, L) \tag{1}$$

[4] Konrad (1995a and 1995b) addresses the provision of education and infrastructure, however, in a somewhat different context. Konrad (1995a) focuses on how the investment incentives are affected by increased mobility with fiscal federalism; Konrad (1995b) discusses how these incentives change with population growth. Andersson and Konrad (2000a) abstract from intergenerational issues and focus on educational investment in a closed and open economy without government or with a benevolent government. Andersson and Konrad (2000b) discuss the case of a Leviathan government.

[5] In the one-generation framework of Andersson and Konrad (2000a), taxes and educational subsidies are set by a benevolent government which makes a discussion of the appropriate objective function of the government necessary. The Leviathan government in Andersson and Konrad (2000b) is therefore closer to our gerontocratic framework.

[6] See for example Konrad (1995a, 1995b) and the discussion in section 3.

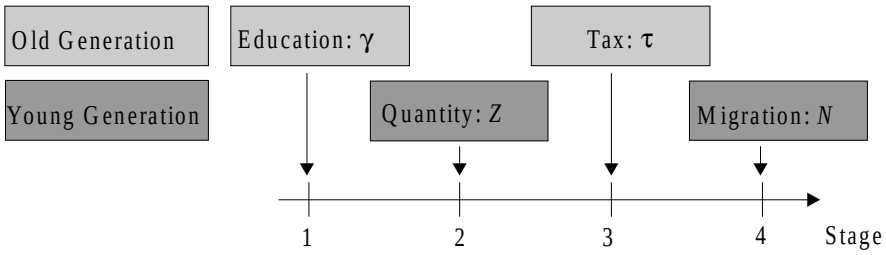
which depends on capital K and on labor expressed in efficiency units L, where L equals domestically valuable human capital investment per worker I times the number of workers N

$$L = I\,N\,. \tag{2}$$

The function $F(L)$ is assumed to be concave in the amount of efficiency units L ($\partial F/\partial L > 0$, and $\partial^2 F/\partial L^2 < 0$).

The model has the following decision structure (cf. Figure 1). In the first stage, the old generation decides about the composition of the educational program. This means that the old generation determines which skills are taught in school. It is assumed that education can be divided into one part that increases the domestic productivity (e.g. law of the domestic country) and one part that increases the productivity in the foreign country (e.g. foreign languages).[7] Let us define γ as the fraction of education that increases only the domestic productivity.

Figure 1



In the second stage, each member of the young generation chooses the amount of education Z. The amount of education Z multiplied by the part of the skills that increases domestic productivity γ can be interpreted as investment in domestic human capital I

$$I = \gamma Z\ . \tag{3}$$

[7] In reality, this separation can hardly be made, since foreign languages, for example, increase both the domestic productivity and the foreign productivity. The focus of this analysis is, however, on the relative increase, which justifies this theoretical separation. For simplicity, the part of education that increases productivity equally in the home and in the foreign country (e.g. mathematical skills) is neglected in the analysis.

Then the old generation sets the tax τ in the third stage. Given this tax, the young generation decides in the last stage whether to emigrate or to stay in the home country. The solution of the model is obtained by solving the decision structure backwards.[8]

1.1. Stage 4: Migration Decision

Each member of the young generation compares the wage in the home country with the wage abroad. The domestic gross wage is given by the marginal product of labor

$$w = F_N = F_L \gamma Z \tag{4}$$

with F_L as the domestic wage per efficiency unit of labor. The foreign gross wage is

$$w^F = w^\circ \left[(1-\gamma) Z\right], \tag{5}$$

with w° as the constant foreign wage per efficiency unit of labor. It is assumed that the home country is small compared to the foreign country, thus emigration does not affect the wage abroad, i.e. the foreign marginal productivity of efficiency units of labor is constant. Symmetrical to the domestic country, a higher country-specific knowledge of the foreign country (i.e. a higher $(1-\gamma)$) implies a higher wage abroad.

If the wage net of the lump-sum tax τ in the home country is lower than the wage abroad, migration takes place until the domestic net wage is equal to the wage abroad. Hence, the equilibrium condition is given by

$$w - \tau = w^F. \tag{6}$$

The equilibrium number of members of the young generation who stay in the home country is denoted by N^*.[9] The domestic wage is determined by $F_L \gamma Z$ and the foreign wage by $w^\circ(1-\gamma) Z$. If there is human capital investment ($\gamma Z > 1$ and $(1-\gamma) Z > 1$), both wages in-

[8] For a similar set-up in a related analysis see Andersson and Konrad (2000a and 2000b).

[9] This equilibrium condition neglects the possibility that the young generation might have the opportunity to tax the subsequent generation in the future. This setting can be justified by assuming a short-time horizon for the young generation and by a singular demographic shock, i.e. a temporarily gerontocratic system (see section 3 for the demographic development in some countries).

crease. The extent of relative increase depends on the structural parameter γ. The higher γ is, the more (less) the domestic (foreign) wage shifts upwards. If the wage net of tax τ in the home country for a worker with a certain human capital investment is lower than the wage abroad, migration takes place until the domestic net wage is equal to the wage abroad. Hence, the equilibrium condition is given by equality of the net wages in both countries with $\left(\overline{N} - N^*\right)$ members of the young generation emigrating. This emigration increases the domestic net wage *w* up to the foreign wage level w^F for a given amount of education *Z* and a given composition of skills γ. If, however, the wage net of tax in the home country is higher than the wage abroad for a given lump-sum tax τ, the members of the young generation do not have an incentive to emigrate. As to immigration, we assume that immigration is not possible. This assumption can be justified by a median voter approach. If the median voter belongs to the old generation, the immigration of young people is only allowed up to the level where the old generation still has the voting power.

1.2. Stage 3: Tax Decision

The old generation maximizes its income by raising a lump-sum tax τ from the young generation taking the emigration decision into account. The income is given by the fixed factor, i.e. production minus wage payments ($Y - w N^*$), plus the tax revenue (τN^*)

$$\max_{\tau} \; Y - w N^* + \tau N^*. \tag{7}$$

The old generation taxes the difference between the domestic marginal product of labor and the foreign wage at the no-emigration level only (i.e. $N^* = \overline{N}$). The optimal tax τ^* is thus given by [10]

$$\tau^* = \overline{w} - w^F = \overline{F}_L\, \gamma Z - w^{\circ} (1-\gamma) Z\,. \tag{8}$$

[10] With $\overline{F}_L = F_L(\gamma Z\, \overline{N})$ and $\overline{w} = \overline{F}_L\, \gamma Z$.

The old generation cannot gain from raising the tax to a level that induces emigration. If the tax rate was set above τ^*, emigration would induce an excess burden of taxation that would be fully borne by the owners of the fixed factor (i.e. the old generation). Hence, taxation induces no emigration: all members of the young generation stay in the home country.

1.3. Stage 2: Education Quantity Decision

In the second stage, each member of the young generation decides on the amount of education by maximizing the gross wage *w* minus the tax payments τ^* and the disutility from education. For tractability, the disutility is assumed to be a quadratic function of the amount of education Z

$$\max_Z \ \overline{w} - \tau^* - Z^2. \tag{9}$$

This yields the optimal amount of education Z^*

$$Z^* = \frac{1}{2} w^* (1-\gamma). \tag{10}$$

Equation (10) shows that there is a negative relationship between the education level *Z* and the skill composition parameter γ. A higher value for γ, i.e. a more domestically oriented educational structure, decreases the outside option of the young generation. This allows the old generation to extract a larger part of the productivity gain without having to fear emigration. The prospect of higher future taxes, however, decreases the incentives for the young generation to invest in *Z*. The old generation cannot influence the chosen amount of education *Z* directly; all it can do is to choose a certain structure γ.

1.4. Stage 1: Education Structure Decision

In the first stage, the old generation maximizes its income from the fixed factor and the tax

revenue by choosing the educational structure γ [11]

$$\max_{\gamma} \; Y - \overline{w}\,\overline{N} + \tau^{*}\,\overline{N}\,. \tag{11}$$

The first order condition is given by

$$w^{\blacksquare}\,\overline{F}_{L}\left(\frac{1}{2}-\gamma\right) = -(w^{\blacksquare})^{2}\,(1-\gamma). \tag{12}$$

The left-hand side shows two opposing effects on the income of the old generation from a marginal increase in γ, which can be seen by rewriting this expression as

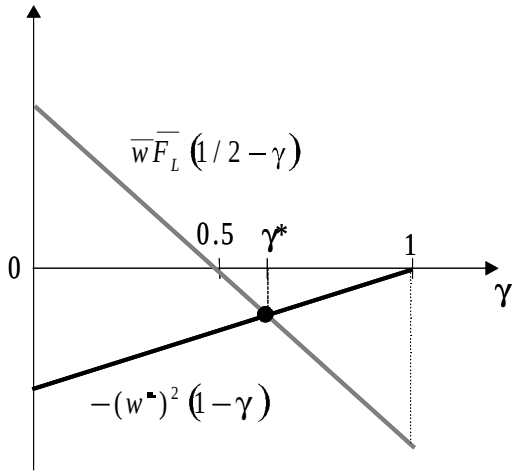
$$\overline{F}_{L}\,Z^{*} + \overline{F}_{L}\,\gamma\frac{\partial Z^{*}}{\partial\gamma} = \overline{w}\,\overline{F}_{L}\left(\frac{1}{2}-\gamma\right). \tag{13}$$

First, the output increases for a given Z^{*}. This effect is equal to $\overline{F}_{L}Z^{*}$. Second, the young generation decreases the chosen quantity Z of education. This effect is equal to $\overline{F}_{L}\,\gamma\,\partial Z^{*}/\partial\gamma$. The sum of both effects $w^{\circ}\overline{F}_{L}\,(1/2-\gamma)$ is the first term of equation (12). For $\gamma<1/2$, this term is positive; then a marginal increase of γ increases this advantage for the old generation. The right-hand side of equation (12) shows how a marginal increase of γ influences the migration decision of the young generation. Increasing γ means that the migration option becomes less attractive, which increases the taxation possibilities for the old generation.[12] Differentiation of the foreign income of the young generation w^{F} with respect to γ yields $-(w^{\blacksquare})^{2}\,(1-\gamma)$. For $\gamma<1$, this term is negative. For the optimum, the term on the left-hand side has to be negative, too. Hence, the optimal fraction γ has to be greater than $1/2$ (cf. Figure 2). This is optimal because the outside option of the young generation becomes less attractive. The difference between the domestic wage rate and the foreign wage rate increases, thus raising the tax income for the old generation.

[11] Note that Y and τ^{*} are functions of γ.

[12] As we know from above, the optimal lump sum τ^{*} is set equal to the difference between the wage rate in the home country and the foreign wage rate to avoid emigration.

Figure 2



Rewriting equation (12) gives the optimal structure of education γ^*

$$\gamma^* = 1 - \frac{1}{2}\frac{\overline{F}_L}{(\overline{F}_L + w^{\blacksquare})}. \tag{14}$$

This equation shows once again that $0.5 < \gamma^* < 1$.[13]

> ***Proposition 1*****:** *The old generation has an incentive to set up an educational system which increases foreign skills (i.e.* $\gamma^* < 1$*) in order to restrict future taxation. Education is used as a commitment device by the old generation.*

The social planner, who wants to obtain the social optimum for the domestic individuals independently of where they live and work, chooses the γ, Z combination that maximizes the income of the fixed factor for the old generation and the domestic and foreign income of labor for the young generation minus the disutility from education

$$\max_{\gamma,Z} \; Y + (\overline{N} - N)\, w^{\circ}(1-\gamma)\, Z - \overline{N}\, Z^2. \tag{15}$$

[13] This result is very different to that of Andersson and Konrad (2000b). There, the Leviathan government has an incentive to tax or to prohibit education for the case of an open economy with zero migration costs where the highly productive individuals are mobile and the individuals with low productivity are immobile.

The optimal structure of education γ depends only on the relation between the total wage per efficiency unit for the emigrated individuals and the total wage per efficiency unit for the individuals at home.[14] It follows from the Kuhn-Tucker conditions that for all γ the optimal amount of education Z is positive. For $\gamma = 1$ and $\gamma = 0$, it can be optimal that no one emigrates or that everybody leaves the country respectively. $0 < \gamma < 1$ leads to partial migration of the domestic individuals, in contrast to the no-migration case for which the optimal choice of γ of the old generation without an intergenerational contract is derived.[15]

These general results also carry over to a more specific case. Suppose that the domestic social planner thinks in terms of the domestic country and not in terms of the domestic individuals, i.e. she is only interested in maximizing domestic output Y minus the disutility from education ($\overline{N} Z^2$)

$$\max_I \; Y - \overline{N} Z^2 . \tag{16}$$

As she does not need to commit herself to a certain policy and as she only thinks of the domestic country, she invests exclusively in domestically valuable skills ($\gamma = 1$). Therefore, equation (3) simplifies to $Z = I$. Rewriting the first order condition determines the socially optimal investment in human capital I_S^*

$$I_S^* = \frac{1}{2} \overline{F}_L .^{16} \tag{17}$$

Without the feasibility of an intergenerational contract, however, there is a negative relationship between γ and Z (see equation (10)). The higher the value for γ, i.e. the closer γ gets to the socially optimal level, the less attractive the investment in human capital becomes for the young generation. Hence, the old generation has to choose a skill composition which can at

[14] See appendix 1.
[15] See appendix 1.
[16] This result can also be reached for the more general approach in equation (A1) in the appendix by setting $\overline{N} = N$.

least partly increase productivity in the foreign country (i.e. $\gamma < 1$) in order to induce the young generation to invest in human capital. From a social planner's point of view, the members of the young generation learn too many skills which only increase foreign productivity. The socially optimal value for the human capital investment I_s^* cannot be reached. This can easily be seen by comparing the amount of domestically valuable human capital $Z^*\gamma^*$ with the socially optimal level I_s^*.[17]

In the first best, all education is used to increase domestic productivity ($\gamma = 1$), whereas in the second best, γ is below 1. Due to the distorted skill composition and the distorted education decision of the young generation, there is too little investment in human capital. These results can be summarized in the following proposition.

> ***Proposition 2:*** *Without the feasibility of intergenerational contracts, human capital investment is below the social optimum. There are two sources of inefficiencies. (1) The structure γ of education is distorted towards too many skills that increase only the foreign productivity. (2) The level of education Z is below the social optimum.*

2. Costs of education

To single out the effects of the intergenerational setting, we have so far neglected any monetary costs of education. This section analyses the case where monetary costs *C* per unit of education *Z* are completely borne by the old generation.[18]

[17] See appendix 2.
[18] The young generation is assumed to bear costs of education only in the form of disutility.

Only stage 1 of the analysis above is affected. The optimal skill composition γ_c^* is given by[19]

$$\gamma_c^* = 1 - \frac{1}{2}\frac{\left(\overline{F}_L - C\right)}{(\overline{F}_L + w^*)}. \tag{18}$$

Taking the costs into account does not change the qualitative results of the analysis. Quantitatively, however, the costs lead to a higher optimal value for γ_c^*

$$\gamma_c^* > \gamma^*. \tag{19}$$

This is intuitively clear when thinking about the following mechanism: a higher γ induces the young generation to choose less education Z_c^* because the outside option is less attractive. This reduces the costs of providing for Z_c^* for the old generation. The disadvantage of a higher γ in the form of a lower Z is therefore partially compensated by the advantage of lower costs. It can be shown that the total investment in human capital $\gamma_c^* Z_c^*$ is again below the socially optimal level $I_{s,c}{}^*$ from the point of view of a social planner who is only interested in the domestic country

$$I_{s,c}{}^* = \frac{1}{2}\left(\overline{F}_L - C\right). \tag{20}$$

> ***Proposition 3:*** *Each generation has an incentive to invest in the human capital of the subsequent generation, even if the monetary costs are fully borne by the old generation. The human capital investment, however, is again below the social optimum.*

[19] See appendix 3 for all derivations of this section.

3. Consequences for the welfare state

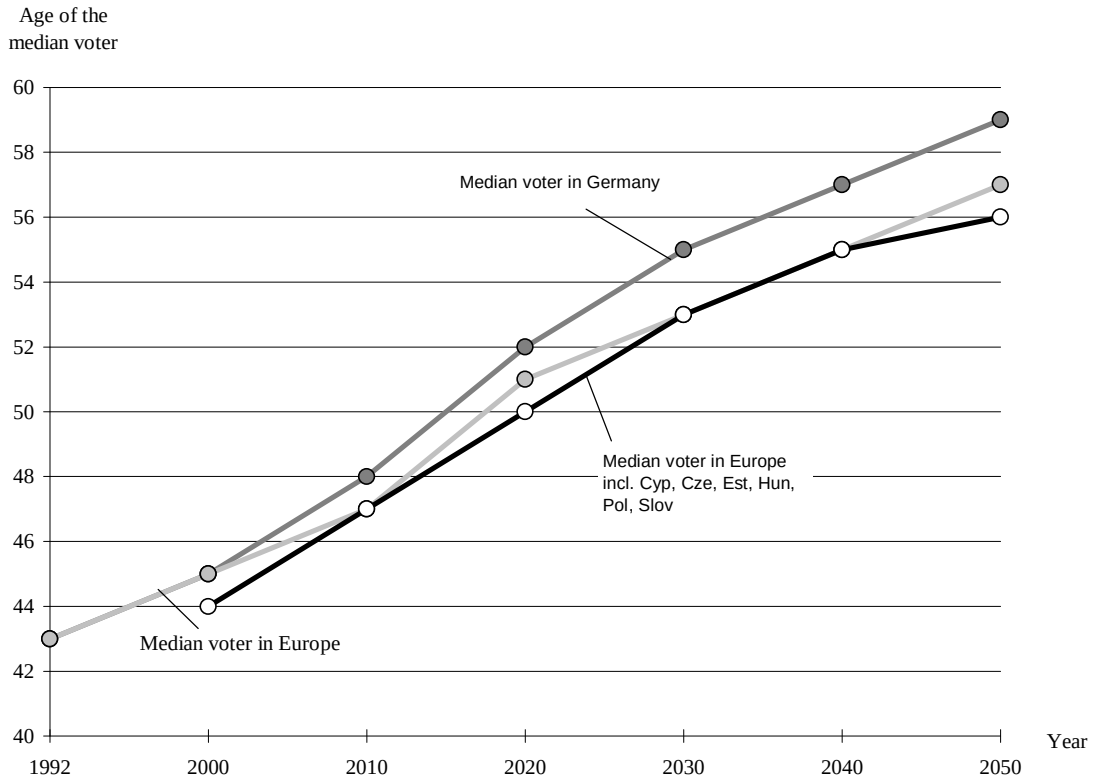
We have seen that in a mobile, non-altruistic world, increasing the mobility of the young generation enables the old generation to commit itself credibly to lower tax level in the future. But what can be concluded in general as to the question: Will there be an erosion of the welfare state? Thinking about Europe, there are some conclusions to be drawn for redistributive taxation and public pensions. In an economy with wage taxation and mobility of labor, a redistributive system cannot survive. The only stable equilibrium is one with no taxation and consequently no redistribution, as Sinn (1997) shows. However, there are some arguments in favor of a less pessimistic view. Mobility costs allow a tax up to these costs without inducing emigration.[20] As these costs are not necessarily exogenous, the government or the old generation respectively might have an interest in increasing these mobility costs by offering an educational program with a clear focus on domestically valuable skills. This would increase the scope for redistributive taxation if, and only if, the young generation was not able to react. In the model above, however, the young generation can and will react. Consequently, a necessary condition for the survival of a moderate redistributive system in favor of the old generation is that there is a credible commitment that prevents excessive redistribution.

This paper shows that education can be used as such a commitment device. Each generation – even if it is not altruistic – has an incentive to increase the mobility of the subsequent generation in order to commit itself to a low future tax level. This commitment prevents emigration. However, this commitment is expensive. There is a loss due to investments that increase the foreign productivity but not the domestic one. Is there an alternative instrument allowing commitment with lower costs?

[20] Mobility costs can be of different kinds, comprising language barriers as well as asymmetric information as to local customs, laws, regulations and not completely harmonized social security systems (Andersson and Konrad, 2000a and 2000b).

An intergenerational contract seems to be a solution of this problem at first sight. On closer analysis, however, it becomes clear that the old generation always has the power to use alternative instruments in order to enforce redistribution in the case of a gerontocracy. But do we really – or will we in the near future – live in a gerontocratic system? The fact that the median voter is still clearly younger than the retirement age does not have to be a fundamental criticism of the assumed gerontocracy, as the following two arguments show.

Figure 3



Own calculations. The graphs show the age of the median voter in Germany, in Europe, and in an enlarged Europe. The calculation is based on the population predictions of the U.S. Bureau of the Census (2000).

Source: U.S. Bureau of the Census (2000): *International Database*, http://www.census.gov.

First, the forecasts for the demographic development show that the median voter will get older and older in the years to come. In Germany, for example, the median voter is today 45 years old (see Figure 3). Within the next decades, the age of the median voter will increase signifi-cantly. Second, it is not necessary that the age of the median voter is equal to or higher than

the retirement age in order to be able to speak of a gerontocracy. It is not unrealistic to assume that individuals close to the retirement age have similar interests to the retired.

It becomes clear that if we do not yet live in a gerontocracy, we certainly will pretty soon. So what can be done? In the context of European integration, an intergenerational contract might be feasible if taxation power is shifted from the national level to the European level. Demographic predictions show (cf. Figure 3) that the age of the median voter increases particularly fast in Germany between 2000 and 2050 compared to the European average. In the European Union, it increases to 57 years, and in an European Union enlarged by eastern countries that have a more favorable demographic structure it increases to 56 years in the same period. Hence, an intergenerational contract on the European level might be credible for a longer period of time compared to one on the German level.

European integration thus has two countervailing effects. On the one hand, the increased mobility of labor presents a danger for the welfare state by eroding the basis for redistributive taxation if there is no common tax policy. On the other hand, it also offers new possibilities to overcome this problem by implementing a common tax and welfare policy. This common policy might mitigate the intergenerational problem and might allow for a more credible commitment.

Appendix 1

Solving equation (A1) for γ, Z yields

$$\left\{\begin{array}{l}\gamma=1\\ 0<\gamma<1\\ \gamma=0\end{array}\right\} \Leftrightarrow (\overline{N}-N)w^{\circ} \left\{\begin{array}{l}<\\ =\\ >\end{array}\right\} F_L N \Leftrightarrow Z=\left\{\begin{array}{l}\frac{F_L N}{2\overline{N}}>\frac{(\overline{N}-N)w^{\circ}}{2\overline{N}}\\ \frac{F_L N}{2\overline{N}}=\frac{(\overline{N}-N)w^{\circ}}{2\overline{N}}\\ \frac{(\overline{N}-N)w^{\circ}}{2\overline{N}}>\frac{F_L N}{2\overline{N}}\end{array}\right\}. \qquad \text{(A1)}$$

By assuming that $w^{\circ} > 0$ and $F_L > 0$, we get the following intervals for the extent of migration

$$\left\{\begin{array}{l}\gamma = 1\\ 0 < \gamma < 1\\ \gamma = 0\end{array}\right\} \Leftrightarrow \left\{\begin{array}{l}0 < N \le \overline{N}\\ 0 < N < \overline{N}\\ 0 \le N < \overline{N}\end{array}\right\}. \tag{A2}$$

Appendix 2

The socially optimal education level is given by (cf. equation 17)

$$I_S^* = \frac{1}{2}\overline{F}_L. \tag{A3}$$

Comparing the socially optimal amount of human capital to the amount realized without a social planner, we get for $0{,}5 < \gamma^* \le 1$

$$\gamma^* Z^* < I_S^* \;\Leftrightarrow\; \gamma^* w^{\blacksquare}(1-\gamma^*) < \overline{F}_L. \tag{A4}$$

This can easily be verified by using equation (14).

Appendix 3

If the monetary costs of C per unit of education Z are completely borne by the old generation, only stage 1 of the analysis above is affected. Equation (12) thus becomes

$$\max_{\gamma}\; Y + \tau\overline{N} - \overline{w}\,\overline{N} - C\,Z\,\overline{N}, \tag{A5}$$

with the first order condition

$$w^{\blacksquare}\overline{F}_L\left(\frac{1}{2} - \gamma\right) = -(w^{\blacksquare})^2(1-\gamma) - w^{\blacksquare}\frac{C}{2}. \tag{A6}$$

The interpretation of this equation is identical to the second section with the exception that there is an additional disadvantageous term on the right-hand side caused by the costs of education. Rearranging this equation yields the optimal educational structure γ_c^*

$$\gamma_c^* = 1 - \frac{1}{2}\frac{\left(\overline{F}_L - C\right)}{(\overline{F}_L + w^{\blacksquare})}. \tag{A7}$$

It can again be seen that $0.5 < \gamma_c^* < 1$ (for $\overline{F}_L - C > 0$). Thus, taking the costs into account does not change the qualitative results of the analysis. Quantitatively, however, the costs lead to a higher optimal value for γ than without monetary costs *C*.

In order to obtain the social optimum for this case, a social planner has to take the production and the costs of education, i.e. the disutility of education as well as the monetary costs, into account:

$$\max_I \; Y - C\,\overline{N}\,I - \overline{N}\,I^2. \tag{A8}$$

Rewriting the first order condition yields the socially optimal investment in human capital

$$I_{s,c}{}^* = \frac{1}{2}\overline{F}_L - \frac{1}{2}C. \tag{A9}$$

In order to show that $Z_c^*\gamma_c^* < I_{s,c}^*$, one has to take into account that $C \in [0; \overline{F}_L]$ as $\gamma^* \in \left[\frac{1}{2}; 1\right]$ and that

$$Z_c^* = \frac{1}{4}w^{\blacksquare}\frac{(\overline{F}_L - C)}{(\overline{F}_L + w^{\blacksquare})}. \tag{A10}$$

For $C = 0$, it has already been shown that $Z_c^*\,\gamma_c^* \le I_{s,c}^*$.[21] And for $C = \overline{F}_L$, it is easy to show that $Z_c^*\,\gamma_c^* = I_{s,c}^* = 0$.

Therefore, it remains to check

[21] See the argumentation on p.10-11.

$$Z_c^* \gamma_c^* \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} I_{s,c}^* \quad \Leftrightarrow \quad \bar{w} \left(1 - \gamma_c^*\right) \gamma_c^* \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} \bar{F}_L - C \,. \tag{A11}$$

We define $Q \equiv \bar{w} \left(1 - \gamma_c^*\right) \gamma_c^*$ and differentiate Q with respect to C

$$\frac{\partial Q}{\partial C} = \bar{w} \frac{\partial \gamma_c^*}{\partial C} \left(1 - 2\gamma_c^*\right) \tag{A12}$$

where

$$\frac{\partial \gamma_c^*}{\partial C} = \frac{1}{2(\bar{F}_L + \bar{w})} \,. \tag{A13}$$

With (A12) and (A13), one gets

$$\frac{\partial Q}{\partial C} = \frac{\bar{w}}{2\,(\bar{F}_L + \bar{w})} \left(1 - 2\gamma_c^*\right). \tag{A14}$$

In order to sign the derivative $\partial Q / \partial C$, we use the following two relationships:

$$\frac{\bar{w}}{\bar{F}_L + \bar{w}} < 1 \tag{A15}$$

$$-1 \le \left(1 - 2\gamma_c^*\right) \le 0 \,. \tag{A16}$$

The latter follows from the fact that $\gamma_c \in \left[\frac{1}{2}; 1\right]$. Hence, the derivative $\partial Q / \partial C$ lies within the following interval:

$$-1 < \frac{\partial Q}{\partial C} \le 0 \,. \tag{A17}$$

This has to be compared with the derivative of the socially optimal solution

$$\frac{\partial I_{s,c}^*}{\partial C} = -1 \,. \tag{A18}$$

As a comparison of equation (A17) and (A18) shows, a marginal increase in the costs C means that the marginal decrease of the socially optimal education level $I_{s,c}^*$ is higher in absolute terms than the marginal decrease of the education level $\gamma_c^* Z_c^*$ within the interval

$C \in [0; \overline{F}_L]$. We know that at the right border of the interval (i.e. $C = \overline{F}_L$) $I^*_{s,c} = \gamma^*_c Z^*_c = 0$, and so the socially optimal value exceeds $\gamma^*_c Z^*_c$ for all *C* within the interval.

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