

Innovative Investments, Natural Resources and Intergenerational Fairness: Are Pension Funds Good for Sustainable Development?

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1. Introduction

Long-term investments have a major influence on economic development. Accordingly, they constitute an important channel through which the sustainability of development can be promoted. Sustainability means that later generations enjoy a level of welfare which equals or exceeds the welfare of the currently living generation. The quantity and the direction of long-term investments decide on issues which are crucial for welfare, such as changes in natural resource scarcity and the increase of knowledge stocks. Regarding the decisions on investments, pension funds are among the most important actors. In many developed countries, the share of total savings managed by pension funds has reached respectable dimensions. An interesting example is Switzerland, where total assets of pension funds had a market value of 440 bn Swiss Francs by the end of 2002; approximately one fourth was held in shares, see SWISS FEDERAL STATISTICAL OFFICE (2004). At the same time, total capitalisation of the Swiss market, including domestic and foreign shares and bonds, amounted to 644 bn Swiss Francs in shares and 435 bn Swiss Francs in bonds, see SWX (2002). This conspicuously underlines the important role of pension funds for Swiss asset allocation. Looking at investment

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strategies for professional portfolio managers, the endeavour to invest in a socially responsible manner is increasingly emphasised. It has been estimated for the United States that in 2003, over 11 percent of total investment assets under professional management were allocated according to this principle, and that the share will be increasing in the future (see SOCIAL INVESTMENT FORUM, 2003). In the UK, an amendment to the Pensions Act requires trustees of occupational pension funds to declare the extent to which social, environmental, and/or ethical issues are taken into account in their investment policies (see EUROSIF, 2003). In addition, a number of large British insurance companies today report that they invest according to social responsibility criteria.

Departing from the large and rising importance of pension funds, their specific investment behaviour, and the broad public debate on sustainability, the aim of this paper is to analyse the consequences of pension fund savings for the sustainability of long-term development. In particular, we analyse long-term consumption paths in a dynamic two-sector economy with overlapping generations and natural resource scarcity. We focus on the role of pension funds for overall savings and investment. Furthermore the consequences of formulating mandatory investment rules for pension funds – e.g. investment in modern or “clean” sectors only – are considered.

This paper is based on two strands of recent literature. The first considers intergenerational transfers and long-run investment within a dynamic OLG framework, where early contributions include HAMMOND (1975) and KOTLIKOFF et al. (1988). Specific subjects in the field are the debate about funding versus pay-as-you-go systems, see SINN (2000), intergenerational risk sharing, see e.g. THØRGENSEN (1998), BARBIE et al. (2000), and WAGENER (2001) and (2003), and problems faced by aging societies, see e.g. MEIJDAM and VERBON (1996), OECD (1998), LASSILA and VALKONEN (2001) for Finland, ECOPLAN (2003) for Switzerland, and BÖRSCH-SUPAN et al. (2002) for Germany. Yet none of these papers considers the role that intragenerational transfers may play in an economy which, realistically, faces natural resource scarcity. The second strand deals with the impacts of natural resource use on economic and technological development but does not regard the role of intergenerational transfers. The literature has been dominated by continuous time approaches with indefinitely living agents (e.g. BOVENBERG and SMULDERS, 1995; STOKEY, 1998) that preclude the explicit analysis of intergenerational aspects from the outset. Papers that deal with environmental and resource aspects in a discrete time framework include the early approaches by HOWARTH and NORGAARD (1992), JOHN and PECCHENINO (1994) and MARINI and SCARAMOZZINO (1995). More recently, the topic was approached by QUANG and VOUSDEN (2002), SEEGMULLER and

VERCHÈRE (2004) and POPYRAKIS and GERLAGH (2004), who also consider the role of resource scarcity on long-run investment.

Furthermore, in recent theory, the relationship between social security and long run investments, e.g. in the environmental or in the education sector, has prominently been studied by RANGEL (2003). He finds that social security plays a crucial role in sustaining investments favouring future generations, which is one of the keys to achieving sustainable development. To evaluate the total impact of forced savings, the extent to which private savings are crowded out must also be taken into consideration. Pension funds may (but need not) change the quantity and direction of aggregate investments in an economy. In the case of complete crowding out, nothing happens at the aggregate level, i.e. sustainability is not endorsed. ATTANASIO and ROHWEDDER (2003) show that in the case of the UK, the earnings-related tier of pension funds savings has a negative impact on private savings with relatively high substitution elasticities, while the impact of the flat-rate tier is not significantly different from zero.

Modelling of the OLG setting and the inclusion of non-renewable resources draws on the contributions of QUANG and VOUSDEN (2002) and AGNANI et al. (2003), respectively. Technology assumptions are based on ROMER (1990); the impact of natural resource use in this kind of framework is treated in BRETSCHGER (2003). PITTEL (2002) provides a broad survey on the impact of the natural environment on economic growth.

The most important elements of our approach are the following. Each young generation saves for the retirement age, both with private savings and pension funds. Savings are in the form of bonds, two types of innovations and resource stock. Pensions guarantee a statutory minimum consumption of the old generation in terms of their previous consumption. This set-up is aimed at depicting the institutional framework in developed economies. To derive the structural effects of long-term investments, we assume an economy consisting of two final goods sectors. The two sectors differ according to two characteristics: the intensity of using natural resources and the productivity gains which arise from diversification in production. More specifically, in the so-called "modern" sector of the economy, gains from diversification are assumed to be high and relative resource input is low. In the "traditional" sector, the opposite assumptions apply. In both sectors, positive externalities emerge from research raising the public stock of knowledge.

Thus the dynamic behaviour of the economy is driven by two types of R&D and natural resource scarcity, which increasingly diminishes the resource input available for production. When investments in innovative activities are too low, consumption growth may become negative. In this case, later generations receive

lower utility, which violates the sustainability criterion. However, increasing the size of investments and the sectoral mix of investments towards the modern sector increase the chances of sustainability.

For the development in the long run, we distinguish between private optimum paths, chosen by firms and consumers under free market conditions, and paths with an active pension fund. Paths which exhibit non-decreasing individual utility over time are called “sustainable” paths. We study under which conditions pension fund’s activities support sustainability, that is bring development closer to a sustainable pattern. To work out the effects induced by the pension fund more clearly, we abstract from other policy instruments, e.g. taxes or subsidies, that could also be employed to enhance sustainability. There are three mechanisms through which the pension fund’s activities might affect sustainability. First, pension funds have a different objective function compared to households. They aim at achieving a certain standard of living for the old, so that they take their own view regarding specific issues such as production externalities affecting consumption or individual discounting. Second, social responsibility criteria may play a role, either because of the long-term perspective and/or the political environment of pension funds. Third, households may perceive pension fund saving as an incomplete substitute to own saving. This is reasonable given the various uncertainties involved when consigning own savings to an independent institution. As a result of these different mechanisms, pension funds have the potential to affect the total amount of savings in the economy as well as the direction of the savings to different investment opportunities. It emerges that pension funds are indeed a channel through which the chances of sustainable development can be increased.

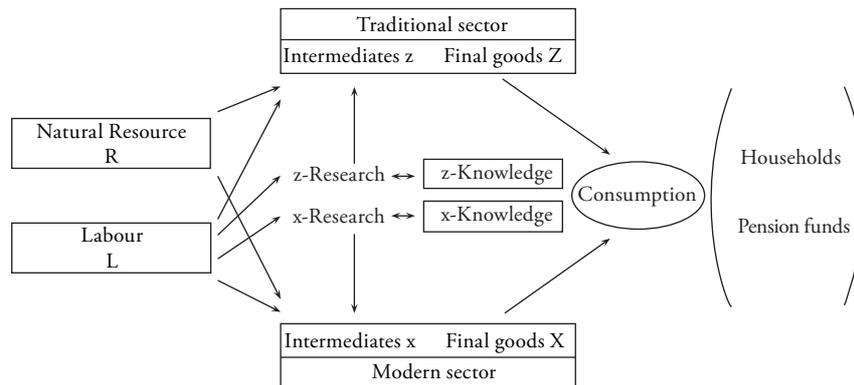
The remainder of the paper is organised as follows. Section 2 describes the model in detail. In Section 3, we take a look at some general features of the balanced growth path for the market economy in which consumers maximise lifetime utility and firms maximise profits. Section 4 specifically analyzes the effects of a pension system in this economy where the task of the pension fund is to provide a specified level of pensions to the consumers in their second period of life. The implications of assuming that households favour their own savings compared to the forced savings by the pension fund are considered in Section 5. Section 6 concludes.

2. The Model

2.1. Overview

We distinguish between two primary inputs, labour and non-renewable natural resources, see Figure 1. Both inputs are used to produce differentiated intermediate goods for two final goods sectors, which we label “modern” and “traditional” sector. The two sectors differ as the modern sector uses relatively few natural resources but exhibits relatively large gains from specialisation in the use of differentiated inputs. Labour is also used as an input into two types of research. Each research type is directed at innovating new blueprints for designs of additional intermediate goods. Research entails positive spill-overs to sector-specific public knowledge. The invention of additional designs is assumed to be relatively more expensive in the modern compared to the traditional sector.

Figure 1: Model Structure



We consider an economy with overlapping generations. It is assumed that each generation consists of a continuum of consumers who live for two periods. During the first period, the agent supplies labour inelastically and works in either the production of intermediates or in the R&D sector. She consumes and saves for her retirement in the second period. Savings are either in the form of bonds, investment in R&D, or in natural resource stock, which means that the young can also invest in the resource stock which they buy from the old. In the second period of her life the agent consumes what she saved in the first period. She receives interest on her savings in bonds and R&D and sells the resources acquired when

young either to firms or to the next generation of consumers. Capital markets are assumed to be perfect, such that individuals can borrow or lend money at the equilibrium interest rate.

Individuals maximise utility over their two-period lifetime, where second-period consumption is discounted as usual. The pension fund collects part of wage earnings from the young, invests the savings and pays pensions to the same generation when it is old. It provides a specified level of pensions (a percentage of first period consumption) to the consumers in their second period of life.

2.2. Production

In the considered economy, two final goods are produced from intermediate inputs under the restriction of CES-production functions. Specifically, the “modern” good X and the “traditional” good Z are assembled from a continuum of intermediate goods, x_i , $i \in [l_{t-1}, l_t]$, and z_j , $j \in [m_{t-1}, m_t]$, according to:

$$X_t = \left(\int_{l_{t-1}}^{l_t} x_{it}^\beta di \right)^{1/\beta} \text{ and } Z_t = \left(\int_{m_{t-1}}^{m_t} z_{jt}^\gamma dj \right)^{1/\gamma} \quad (1)$$

where l and m denote the number of horizontally differentiated intermediate products in the respective sectors and t is the time index. Competition in the intermediates sectors is assumed to be monopolistic, with one firm producing one type of intermediate. Intermediate goods are used in one generation; then they are assumed to be outdated. This is a simplifying assumption which does not alter the quality of the results.

The modern and traditional sectors differ with respect to the gains from specialisation; the gains are assumed to be higher in the modern sector ($\beta < \gamma$). This implies that *ceteris paribus* the effect of an additional variety of a modern intermediate on the productivity of all modern intermediates is higher than the effect of an additional variety in the other sector. Intermediates are produced from labour L and non-renewable resources R under the restriction of Cobb-Douglas production functions:

$$x_i = \left(L_{x,t} \right)^\alpha \left(R_{x,t} \right)^{1-\alpha} \text{ and } z_j = \left(L_{z,t} \right)^\delta \left(R_{z,t} \right)^{1-\delta} \quad (2)$$

where L_k and R_k , $k = x_i, z_j$, denote the input of labour and resources in the production of x_i and z_j . The production of intermediates in the modern sector

is assumed to be more labour and less resource intensive than in the traditional sector, that is we have $\alpha > \delta$.

To obtain the right (or the capability) to produce a specific type of intermediate, firms have to acquire (to invent) the according patent or blueprint for the design first. The patent for a new good lasts for one period; after that, the good is replaced by subsequent intermediates. The invention of new intermediates entails proportional positive spill-overs to sectoral public knowledge, which is in turn a free input in the research sector. The number of new designs in period t is determined by:

$$l_{t+1} - l_t = \frac{L_{lt}}{a_l} l_t \quad \text{and} \quad m_{t+1} - m_t = \frac{L_{mt}}{a_m} m_t \quad (3)$$

where L_l and L_m denote the input of labour in the production of blueprints for the two sectors and a_l and a_m the per-unit input factors of labour in research for the respective sector; l and m stand for the knowledge input. We assume that the invention of a new blueprint in the modern sector requires relatively more labour input (is more expensive), so that $a_l > a_m$.

The size of the population is constant and normalised to unity. Labour is used in four different sectors, so that the labour market equilibrium becomes:

$$1 = L_{xt} + L_{zt} + L_{lt} + L_{mt} \quad (4)$$

On resource markets, supply equals demand, according to:

$$R_t = R_{xt} + R_{zt} \quad (5)$$

where R is the part of the resource owned by firms and used for current production. Finally, the non-depletion condition states that the whole resource Stock V_0 is used for production when integrating over time, that is:

$$\sum_0^{\infty} R_t = V_0 \quad (6)$$

where V_0 is predetermined and $V_0 \geq 0$. At any point in time we have:

$$V_t = V_{t-1} - R_{t-1} \quad (7)$$

2.3. Pension Fund

The pension fund's task is to assure a minimum standard of living of the consumer in his retirement period. The pension system is assumed to be fully funded, i.e. the pension fund collects a share τ_t of the consumer's wage income in the working period, invests the collected revenues on the capital market, and repays the revenues plus the interest to the consumer as a pension in the retirement period. To take an extreme assumption, we postulate that the pension fund has the statutory obligation to invest in R&D for modern intermediates' blueprints only.

The pension paid to the consumer is defined in terms of expenditures for first period consumption $p_{C_t} C_{1t}$, where p_C is the price index of consumption goods C . The share of $p_{C_t} C_{1t}$ to which the pension has to amount is politically determined. The budget constraint of the pension fund is therefore given by

$$P_{t+1} = \xi(1+r_{t+1})p_{C_t} C_{1t}, \quad 0 < \xi < 1 \quad (8)$$

with P denoting the pension paid to the consumer in the second period of his life and r and ξ being the interest rate and the politically determined consumption share.

2.4. Consumers

The representative consumer maximises lifetime utility U which is received from consumption C in both periods (young and old) and aggregate own savings Φ :

$$U_t = \ln C_{1t} + \varrho \ln \Phi_t + \frac{1}{1+\rho} (\ln C_{2t+1}) \quad (9)$$

where ρ denotes the individual discount rate, ϱ determines the intensity of the preference for own investment (in contrast to forced savings through a pension fund) and 1 and 2 stand for young and old, respectively. ϱ can be positive because of portfolio considerations and/or incomplete information about the pension fund's activities; we will discuss its impact below, especially the case $\varrho = 0$. Aggregate own savings are used for investment in R&D, S_t , or investment in resources, $(p_{H_t}/p_{C_t})H_t$, where H_t is the stock of the resource which is owned by consumers (and therefore not used in current production) and p_{H_t} is the price of H_t . The nominal value of the households' resources are normalised by the price index of C . Thus, aggregate nominal savings are given as:

$$p_{C_t} \Phi_t = p_{C_t} S_t + p_{H_t} H_t. \quad (10)$$

Consumption is determined by:

$$C_t = X_t^\phi Z_t^{1-\phi}. \quad (11)$$

In every period, C_t is consumed by the two currently living generations, i.e. $C_t = C_{1t} + C_{2t}$.

Individuals supply labour inelastically when they are young and are subject to the following budget constraints in the two periods:

$$p_{C_t} C_{1t} + p_{H_t} H_t + p_{C_t} S_t = w_t(1 - \tau_t) \quad (12)$$

$$p_{C_{t+1}} C_{2t+1} = (1 + r_{t+1}) p_{C_t} S_t + p_{R_{t+1}} R_{t+1} + p_{H_{t+1}} H_{t+1} + P_{t+1} \quad (13)$$

$$H_t = H_{t+1} + R_{t+1} \quad (14)$$

where w is the labour wage and p_R the price of R . It is assumed that the contributions to the pension fund as well as the pension payments are exogenous to the consumers, i.e. consumers do not consider (8) in their optimisation. The resource stock owned by households is sold in the second period of life to the next generation and to firms which employ these resources in the production of modern and traditional intermediates.

3. Long-run Equilibrium

Before we turn to the specific implications of the pension fund's activities for investment and growth, let us consider some general properties of the balanced growth path of this economy. Consumers are assumed to maximise their lifetime utility (9) subject to their budget constraints (12) to (14) while firms optimise profits. From the resulting first-order conditions we can derive the balanced growth path (see Appendix).

Consumers allocate their consumption over time regarding the rate of interest paid on their savings, their discount rate and their preference for own investment:

$$\frac{p_{C_{t+1}} C_{2t+1}}{p_{C_t} C_{1t}} = \rho \frac{p_{C_{t+1}} C_{2t+1}}{p_{C_t} \Phi_t} + \frac{1 + r_{t+1}}{1 + \rho}. \quad (15)$$

Assuming for a moment that consumers have no preference for own investment, i.e. $\varrho = 0$, we are back at the familiar Keynes-Ramsey-rule where the growth of consumption over time is solely driven by the wedge between interest rate and discount rate. Yet if savings also generate an extra utility apart from providing the means for future consumption, households save more and consequently also consume more when they are old. The extent to which they reallocate more funds to the future thereby depends positively on the degree to which they relish own savings ϱ (see also Section 5).

In equilibrium the prices for resources sold by the consumers to firms and to the next generation are equalised, as they are perfect substitutes to the consumer. Besides buying and selling resources, consumers invest in research, either in the modern or in the traditional sector. In the second period of their life, consumers are paid back their original investment plus the interest. As resources constitute a perfect substitute for investment in research, their price has to increase at the same rate in the equilibrium, i.e. at the interest rate, leading to the familiar Hotelling rule. A lower interest rate consequently induces resource prices to grow at a lower rate. For (6) to hold, i.e. for the entire resource stock to be exhausted over time, this implies that initial prices are higher. Due to this change in the price schedule, the demand for resources by intermediate firms is lower at the outset, but increases above its original level later. As a result, the stock of resources held by the households is higher in early stages of development and lower later on. Due to the specific production technology chosen in our framework, the effects of the interest rate on resource prices and extracted quantities cancel out in the equilibrium, leaving the expenditure share of firms for resources constant over time.

It can furthermore be shown that the equilibrium wage rate depends negatively on the interest rate

$$\begin{aligned} w &= \frac{(1-\beta)\phi}{1+r} + \frac{(1-\gamma)(1-\phi)}{1+r} + \alpha\beta\phi + \delta\gamma(1-\phi) \quad (16) \\ &= wL_t + wL_m + wL_x + wL_z, \end{aligned}$$

where variables without time indices denote equilibrium values. The single terms on the RHS represent firms' expenditures on labour in modern and traditional research and intermediates production. It can easily be seen that a lower interest rate is accompanied by a higher wage rate. The decrease of r thereby mirrors an increase in consumer savings which on the other hand induces a higher demand for labor in R&D. Due to the increase in demand for labour the equilibrium wage

rate increases. Labour is reallocated from the intermediate sector to the research sector. The aggregate wage bill in the intermediate sector remains unchanged, as the effects of the higher wage rate and the lower labour input cancel each other out – which is again due to the chosen production technology.

From (15) it can be shown that the equilibrium in the considered economy is unique, where consumption growth is determined by

$$g_C = \left((1+r)^{-(1-\alpha)\beta} g_I^{1-\beta} \right)^\phi \left((1+r)^{-(1-\delta)\gamma} g_M^{1-\gamma} \right)^{1-\phi}. \tag{17}$$

Consumption growth depends positively on the two rates of innovation growth and negatively on the interest rate. The interest rate’s negative effect on growth in our scenario is due to the fact that a higher interest rate leads to a faster depletion of the resource.

4. Impact of Pension Fund Activities

Let us now take a closer look at the implications of the pension fund’s activities in this economy. To do this we compare the economy in which the pension fund is active to an economy without a pension system.

From (15) it can be seen that the optimal allocation households choose with respect to consumption in the first and second period, and aggregate savings is unperturbed by the pension fund’s activities. Yet inserting the budget constraints into (15) shows that, although the relative consumption-savings-decision remains unaffected by the pension fund’s activities, the aggregate level of savings of households has changed:

$$\frac{1}{w_t - (p_{C_t} \Phi_t + \tau_t w_t)} = \frac{\varrho}{p_{C_t} \Phi_t} + \frac{1}{1 + \rho} \frac{1}{(p_{C_t} \Phi_t + \tau_t w_t)}. \tag{18}$$

As shown in the appendix, the investment of the pension fund leads to an increase in aggregate savings, i.e. the additional investment is not perfectly crowded out, as households do not consider the forced savings through the pension fund as a perfect substitute for their own savings. Consequently the equilibrium interest rate is lower in the presence of the pension fund.

However, the pension fund’s activities alter not only the optimal level, but also the optimal composition of households’ investments. As the pension fund

invests in modern sector research only, this additional investment exerts a downward pressure on the associated returns. This again induces households to reallocate their investment towards the traditional sector and investment in resources until the returns to all three assets are again equalised. So, compared to the households' portfolio in absence of the pension fund, households invest relatively less in the modern sector than in a system without the pension fund.

Yet overall, relative investment in the two types of research remains unaffected by the pension fund's activities as can be seen from inserting (28) into (29) and rearranging:

$$\frac{p_{C_i} S_{i_t} + \tau_i w_{i_t}}{p_{C_i} S_{m_t}} = \frac{\phi}{1-\phi} \frac{1-\beta}{1-\gamma}. \quad (19)$$

A rise in the pension fund's investment in the modern sector induces a partial crowding out of private investment in this sector, and increases investment in the traditional sector until the investment ratio is again equal to $[\phi/(1-\phi)][(1-\beta)/(1-\gamma)]$. As the relative investment in the two research sectors remains unchanged by the pension fund's activities, so does the optimal allocation of labour between the two types of R&D:

$$L_{i_t} = \frac{\phi}{1-\phi} \frac{1-\beta}{1-\gamma} L_{m_t}. \quad (20)$$

The optimal allocation solely depends on parameters that determine intermediate goods production and the production of C : The higher the relative gains from specialisation in modern intermediates compared to traditional intermediates, i.e. the higher $(1-\beta)/(1-\gamma)$, the more labour is allocated towards R&D in the modern sector. Along the same lines, a higher relative productivity of modern intermediates in C -production, $\phi/(1-\phi)$, also results in a relatively higher input of labour in modern R&D. Note that the allocation of labour between the two research sectors is independent of the productivity parameters a_i and a_m . It can be shown by deriving the solution of the corresponding social planner optimisation problem, that along the socially optimal growth path the labour allocation across research sectors indeed depends on the relative labour productivity in R&D. The independency of a_i and a_m therefore reflects market failures arising because of knowledge spillovers in R&D.

It can furthermore be shown that the optimal allocation of labour between the two intermediate sectors is also only driven by exogenous parameters:

$$L_{x_i} = \frac{\phi}{1-\phi} \frac{\alpha}{\delta} \frac{\beta}{\gamma} L_{z_i} \quad (21)$$

where $L_{x_i} = \int_{l_{i-1}}^{l_i} L_{x_{i_i}}$ and $L_{z_i} = \int_{m_{i-1}}^{m_i} L_{z_{i_i}}$.

The reasoning with respect to (21) follows the same lines as the reasoning with respect to (20): A higher value of the relative elasticity of X_i in C_i , relatively higher gains from specialisation in modern intermediates and a relatively higher productiveness of labour in the production of modern intermediates lead to more labour input in modern production.

While the allocation of labour within the research sector as well as within the intermediates sector only depends on exogenous parameters, the allocation of labour between the research sector as a whole and the intermediate sector is determined endogenously via the interest rate. Along the balanced growth path the following relations have to hold:

$$L_z = \delta \frac{\gamma}{1-\gamma} (1+r) L_m \quad \text{and} \quad L_x = \alpha \frac{\beta}{1-\beta} (1+r) L_l. \quad (22)$$

The dependency on the interest rate mirrors the fact that the patents produced in period t are employed in production with a one-period lag. (22) can be better understood by regarding it not only along the balanced growth path, but in general:

$$w_{t+1} L_{z_{t+1}} = \delta \frac{\gamma}{1-\gamma} (1+r_{t+1}) w_t L_{m_t}. \quad (23)$$

The returns to the input of labour in research in period t are only attained in $t+1$. Equalisation of the returns of labour therefore requires that the returns to intermediates production in $t+1$ are equalised to the returns from research conducted in t , multiplied by $1+r_{t+1}$.

As the pension fund's activities have a negative effect on the equilibrium interest rate, more labour is allocated towards research at the expense of production in the intermediate sector. The increased input in research of both sectors leads to an increase in innovation growth in both sectors. Yet, whether modern sector R&D expands more or less than traditional R&D, i.e. whether economic growth

becomes less resource dependent, solely hinges on the model parameters as the optimal allocation of labour between modern and traditional research is independent from any endogenous influence (see (20)). Consequently, the mandatory investment rule for the pension fund to invest in the modern sector only, has no effect in shifting the economy on a less resource dependent path.

From (16) it can be seen that due to the lower interest rate, the equilibrium wage rate is higher. The decrease in r and increase in w induce an effect on the relative input prices of resources and labour, thereby changing the optimal input mix of intermediate firms. The decrease in r implies an increase in the initial resource price which then rises at a lower rate. Due to change in the price schedule following the introduction of the pension fund, the input of resources in production first decreases and then increases compared to the non-pension fund scenario until it surpasses its non-pension fund level. Compared to the situation without the pension fund, the input mix in intermediates production is consequently more resource-intensive in later stages of development. The decreased input of resources in production following the introduction of the pension fund furthermore implies that more resources are sold by the households to the succeeding generation which means that households' investment in resources increases.

The increase in innovation growth as well as the decrease in the interest rate lead to a rise in consumption growth. This is due to the fact that, by raising investment in R&D, the pension fund internalises part of the spill-overs generated by the increase in the available knowledge stock in the traditional as well as in the modern sector.

5. Role of Preference for Own Savings

Let us now compare the effects of the pension fund's activities in the presence of consumers preferences for own investment to the case where they are indifferent between their own savings and the investment of the pension fund, i.e. $\varrho = 0$.

Setting $\varrho = 0$ in (18) shows that in case of no preference for own savings, the overall level of savings $p_{c_t} \Phi_t + \tau_t w$ is solely determined by the level of income and the rate of time preference. In this case households only care about the overall level of savings, while it is of no consequence whether these savings are in the form of forced pension fund savings or privately conducted by households. So, introducing a pension system (i.e. $\tau_t \neq 0$) only leads to a reallocation of savings from the households to the pension fund. As a result, the pension fund's investment is perfectly crowded out by a decrease in households' savings, such

that overall investment remains unchanged. By assuming that consumers have a preference for own investment ($\varrho \neq 0$), a wedge is driven between the marginal utility from own investment and the marginal utility from the pension fund's investment. Due to this wedge, a perfect crowding out does not take place and overall savings increase. This effect on savings is higher, the higher the assumed preference for own savings. A higher ϱ induces a stronger increase in the interest rate resulting from a stronger impact of ϱ on savings.

It is straightforward that equilibrium savings are lower when households receive no extra utility from savings – independent of whether a pension fund is active or not. With respect to the extraction of resources and employment of labour in the respective sectors, setting $\varrho = 0$ triggers qualitatively the opposite reactions as described for the introduction of a pension fund in the previous section. Wages decrease, and the rate at which the resource price rises over time increases. Furthermore the decreased savings imply on the one hand a higher equilibrium interest rate, and on the other hand reduce the financial means available for research and development. As a consequence consumption growth is lower in an economy without additional utility from savings.

6. Conclusions

Pension hold a substantial share of savings in many economies. The different types of investments, such as investments in innovative activities and knowledge build-up or disinvestments in natural resource stocks, govern long-term development and decide on the welfare of future generations. Investment criteria of pension funds differ from private households because the latter have an undiscounted consumption target and, possibly, social responsibility considerations instead of the discounted utility target of households.

In this paper, we have introduced dynamics in a two-sector economy through endogenous innovations and non-renewable natural resource use. The results of the paper show that the long-term dynamic impact of pension funds crucially depends on saving preferences of households. In the case of positive preferences for own investments, pension fund savings are an incomplete substitute for private savings and the pension fund activities contribute to higher knowledge build-up. On the other hand, without such preferences, private savings are completely crowded out by pension funds. Then, there is no effect of social security on long-term economic development and sustainability.

The reasons and conditions of the preferences for own investments could be determined more explicitly in a future stage of the research programme. In

addition, the implications of market failures in resource markets like pollution should not be neglected. Also, to scrutinise the consequences of various statutory investment rules and optimisation targets for pension funds is a rewarding research topic left for future research.

Appendix: Derivation of the Balanced Growth Path

From the maximisation of (9) subject to (12) to (14) we derive the familiar first-order conditions with respect to young- and old-age consumption plus a modified FOC for consumer savings. Combining these first-order conditions gives (18) after inserting the budget constraints of the household.

Furthermore it follows from the first-order conditions for H_{t+1} and R_{t+1} that the price of the non-renewable resources sold to firms, p_{R_t} , and the price of those resources sold to the next generation, p_{H_t} , have to be equal, that is $p_{R_t} = p_{H_t}$. With respect to the price of the resource, the familiar Hotelling pricing rule, $g_{p_R} = g_{p_H} = 1 + r_{t+1}$, follows from the FOC for young consumers' investment in resources, H_t . Initial resource prices are chosen to satisfy (6). With respect to resource extraction along the balanced growth path, it will be shown below that R_t and H_t decrease at the rate $1/(1+r)$.¹

With respect to the production side of the economy we get for the aggregate demands for the modern and the traditional good, X_t and Z_t :

$$X_t = \frac{\phi}{p_{X_t}} \text{ and } Z_t = \frac{1-\phi}{p_{Z_t}} \quad (24)$$

where we made use of the normalisation $p_{C_t} C_t = 1$ which is adapted to facilitate calculations and is possible because the model has no other numeraire.

Optimality in the research sector requires that in equilibrium prices are equalised to marginal costs in both research sectors

$$p_{l_t} = \frac{a_l}{l_t} w_t \text{ and } p_{m_t} = \frac{a_m}{m_t} w_t. \quad (25)$$

1 Throughout this paper $g_k = k_{t+1}/k_t$ is referred to as the growth rate of a variable. Variables which do not carry time indices denote equilibrium values along the balanced growth path.

As R&D is financed by consumer savings $S_t = S_{l_t} + S_{m_t}$ and research firms operate at zero profits

$$p_{C_t} S_{l_t} + \tau_t w_t = w_t L_{l_t} = (l_{t+1} - l_t) \frac{a_l}{l_t} w_t \quad (26)$$

and

$$p_{C_t} S_{m_t} = w_t L_{m_t} = (m_{t+1} - m_t) \frac{a_m}{m_t} w_t.$$

also have to hold in equilibrium.

Maximisation of profits in the intermediate sector yields the familiar price-over-marginal-cost pricing rules²

$$\begin{aligned} \alpha \beta x_i L_{x_i} p_{x_i} = w_t \text{ and } \delta \gamma z_j L_{z_j} p_{z_j} = w_t \\ (1 - \alpha) \beta x_i R_{x_i} p_{x_i} = p_{R_t} \text{ and } (1 - \delta) \gamma z_j R_{z_j} p_{z_j} = p_{R_t}. \end{aligned} \quad (27)$$

Aggregating over all produced varieties, the sectoral profits are given by

$$\Pi_x = \phi(1 - \beta) \text{ and } \Pi_z = (1 - \phi)(1 - \gamma). \quad (28)$$

Consumers are compensated for their R&D investment by the profits generated in the intermediate sector in period $t + 1$. In equilibrium savings have to yield the same return as investment in resources. As patents are worthless after one period, the no-arbitrage conditions for the patent market read

$$\Pi_{x_{t+1}} = (1 + r_{t+1})(p_{C_t} S_{l_t} + \tau_t w_t) \text{ and } \Pi_{z_{t+1}} = (1 + r_{t+1}) p_{C_t} S_{m_t}. \quad (29)$$

Using (26) to (29) we can now derive conditions for the equilibrium allocation of labour: From (26), (28) and (29) we can derive (20). Furthermore we get (21)

2 Using (27) we can now prove $g_R = 1/1 + r$: From (27) it follows that $(1 - \alpha)/\alpha L_x w_t = R_x p_{R_t}$ and $(1 - \delta)/\delta L_z w_t = R_z p_{R_t}$. As w , L_x and L_z are constant along the balanced growth path, the LHSs of these equations are constant over time. Taking the equations at time $t + 1$ and time t and dividing them gives $g_R = R_{t+1}/R_t = p_{R_t}/p_{R_{t+1}} = g_{p_R}^{-1}$.

for the relation between aggregate inputs of labour in the two intermediate sectors by employing (20), (27) and (28). Finally, the allocation of labour between the production of traditional patents and the production of intermediates from these patents along the balanced growth path, (22), follows from (26) and (28).

Combining (20), (21) and (22) with (4) gives the share of labour employed in the production of traditional intermediates as a function of the interest rate:

$$L_m = \left[1 + \frac{1-\beta}{1-\gamma} \frac{\phi}{1-\phi} + \frac{1+r}{1-\gamma} \left(\alpha\beta \frac{\phi}{1-\phi} + \gamma\delta \right) \right]^{-1} \quad (30)$$

To obtain a second condition for L_m and r we consider (15). To derive an expression for (15) in terms of the allocation of labour recall that investment in the modern sector is given by $w_t L_t = p_{C_t} S_t + w_t \tau_t$, whereby $w_t \tau_t = \xi p_{C_t} C_{1t}$ has to hold. $p_{C_t} C_{1t}$ is therefore equal to $w_t(L_t + L_m) + p_{H_t} H_t$. Furthermore consider that $p_{H_{t+1}}(R_{t+1} + H_{t+1}) = (1+r_{t+1})p_{H_t} H_t$, where using (14) it can be shown that, along the balanced path, $H_t = R_t/r = 1/r(R_{x_t} + R_{z_t})$ has to hold.³ To express $p_{H_t} R_t$ in terms of labour we use the equilibrium conditions in intermediates' production (27). We can now rewrite (15) as a function of labour shares. Finally employing (20), (21) as well as (22) and inserting (4) in the resulting expression gives

$$\frac{E(r)}{1-E(r)} = \rho \frac{1}{1-\xi\left(\frac{1}{E(r)}-1\right)} + \frac{1}{1+\rho} \quad (31)$$

with

$$E(r) = \frac{B + (1 + \frac{1}{r})D}{B + (1+r)A} > 0$$

$$\text{and } A = \alpha\beta\phi + \delta\gamma(1-\phi), \quad B = (1-\beta)\phi + (1-\gamma)(1-\phi),$$

$$D = (1-\alpha)\beta\phi + (1-\delta)\gamma(1-\phi)$$

3 From (14) it follows that $R_{t+1}/H_{t+1} = -1 + H_t/H_{t+1}$. As along the balanced growth path the growth rate of H_t is constant, this implies that R_{t+1}/H_{t+1} also has to be constant along the balanced growth path, such that R_t and H_t have to grow at the same rate. Knowing from above that $g_R = 1/(1+r)$, equality of growth rates, i.e. $g_R = g_H$ gives $H_t = R_t/r$.

It can be shown by regarding the functional forms of the LHS and RHS of (31) that for permissible values of r there exists one unique equilibrium interest rate.

To determine the effect of a change in the interest rate on the wage rate, consider (26), (28), (29) and (30) which give

$$w = \frac{B}{1+r} + A \quad (32)$$

where it can easily be seen that $dw/dr < 0$. Rearranging (21), (22), (27) and (32), we can now show that the spending of firms on R_t is given by $p_{R_t} R_t = D$. Using this result and again employing (27) as well as (20), (21) and (22) yields (16).

References

- AGNANI, BETTY, MARÍA-JOSÉ GUTIÉRREZ and AMAIA IZA (2003), "Growth in Overlapping Generation Economies with Non-Renewable Resources", mimeo.
- ATTANASIO, ORAZIO P. and SUSANNE ROHWEDDER (2003), "Pension Wealth and Household Saving: Evidence from Pension Reforms in the United Kingdom", *American Economic Review*, 93, pp. 1499–1521.
- BARBIE, MARTIN, MARCUS HAGEDORN and ASHOK KAUL (2000), "Dynamic Efficiency and Pareto-Optimality in a Stochastic OLG Model with Production and Social Security", Bonn Econ Discussion Papers 8/2000.
- BÖRSCH-SUPAN, AXEL, FLORIAN HEISS, ALEXANDER LUDWIG and JOACHIM WINTER (2002), "Pension Reform, Capital Markets, and the Rate of Return", mimeo.
- BOVENBERG, A. LANS and SJAK A. SMULDERS (1995), "Environmental Quality and Pollution-augmenting Technical Change in a Two-sector Endogenous Growth Model", *Journal of Public Economics*, 57, pp. 369–391.
- BRETSCHGER, LUCAS (2003), "Natural Resource Scarcity and Long-Run Development: Central Mechanisms when Conditions are Seemingly Unfavourable", Economics Working Paper Series 03/29, ETH Zurich.
- ECOPLAN (2003), *Analyse der Finanzierungsquellen für die AHV. SWISSOLG – ein Overlapping Generation Modell für die Schweiz. Bericht im Rahmen des Forschungsprogramms zur längerfristigen Zukunft der Alterssicherung (IDA ForAlt)*, Bern.
- EUROSIF (2003), *SRI among European Institutional Investors, 2003 Report*, Paris, www.eurosif.org.

- HAMMOND, PETER (1975), "Charity: Altruism and Cooperative Egoism?", in: Phelps, E. (1975), *Altruism, Morality, and Economics*, New York, pp. 81–92.
- HOWARTH, RICHARD B. and RICHARD B. NORGAARD (1992), "Environmental Valuation under Sustainable Development", *American Economic Review, Papers and Proceedings*, 82, pp. 473–477.
- JOHN, ANDREW and ROWENA PECCHENINO (1994), "An Overlapping Generations Model of Growth and the Environment", *Economic Journal*, 104, pp. 1393–1410.
- KOTLIKOFF, LAWRENCE B., THORSTEN PERSSON and LARS E.O. SVENSSON (1988), "Social Contracts as Assets: A Possible Solution to the Time-consistency Problem", *American Economic Review*, 78, pp. 662–677.
- LASSILA, JUKKA and TARMO VALKONEN (2001), "Pension Prefunding, Ageing, and Demographic Uncertainty", *International Tax and Public Finance*, 8, pp. 573–593.
- MARINI, GIANCARLO and PASQUALE SCARAMOZZINO (1995), "Overlapping Generations and Environmental Control", *Journal of Environmental Economics and Management*, 29, pp. 64–77.
- MEIJDAM, LEX and HARRIE A. A. VERBON (1996), "Aging and Political Decision Making on Public Pensions", *Journal of Population Economics*, 9, pp. 141–158.
- OECD (1998), "Macroeconomic Effects of Pension Reforms in the Context of Aging Populations: Overlapping Generations Model Simulations for Seven OECD Countries", Economics Department Working Paper, No. 201.
- QUANG, DOAN H. and NEIL VOUSDEN (2002), "Unionisation, Unemployment, and Economic Growth", Working Paper of the Asia Pacific School of Economics and Government, Australian National University 02-10, 2002.
- PAPYRAKIS, ELISSAIOS and REYER GERLAGH (2004), "Natural Resources, Investment and Long-Term Income", FEEM Working Paper 87.2004.
- PITTEL, KAREN (2002), *Sustainability and Endogenous Growth*, Cheltenham, UK and Northampton, MA, US.
- RANGEL, ANTONIO (2003), "Forward and Backward Intergenerational Goods: Why is Social Security Good for the Environment?", *American Economic Review*, 93, pp. 813–834.
- ROMER, PAUL M. (1990), "Endogenous Technological Change", *Journal of Political Economy*, 98, pp. 71–102.
- SEEGMULLER, THOMAS and ALBAN VERCHÈRE (2004), "Pollution as a Source of Endogenous Fluctuations and Periodic Welfare Inequality in OLG Economies", *Economics Letters*, 84, pp. 363–369.
- SINN, HANS-WERNER (2000), "Why a Funded Pension System Is Useful and Why It Is Not Useful", NBER Working Paper, No. 7592.

- SOCIAL INVESTMENT FORUM (2003), *Report on Socially Responsible Investing, Trends in the United States*, Washington, www.socialinvest.org.
- STOKEY, NANCY L. (1998), "Are there Limits to Growth?", *International Economic Review*, 39, pp. 1–31.
- SWISS FEDERAL STATISTICAL OFFICE (2004), *Press Communication 13 Social Security*, April, Neuchâtel 2004.
- THØRGENSEN, ØYSTEIN (1998), "A Note on Intergenerational Risk Sharing and the Design of Pay-as-you-go Pension Programs", *Journal of Population Economics*, 11, pp. 373–378.
- SWX (2002) *Swiss Exchange*, Swissindex, Zurich 2002.
- WAGENER, ANDREAS (2003), "Pensions as a Portfolio Problem: Fixed Contribution Rates vs. Fixed Replacement Rates Reconsidered", *Journal of Population Economics*, 16, pp. 111–134.
- WAGENER, ANDREAS (2001), "Equilibrium Dynamics with Different Types of Pay-as-you-go Pension Systems", *Economics Bulletin*, 8, 6, pp. 1–12.

SUMMARY

We analyse long-term consumption paths in a dynamic two-sector economy with overlapping generations. Each young generation saves for the retirement age, both with private savings and pension funds. The productivity of each sector can be raised by sector-specific research, while the essential use of a non-renewable natural resource poses a threat to consumption possibilities in the long run. Bonds, the two types of innovations, and resource stocks are the different investment opportunities. We show that pension funds have a positive impact on long-term development, provided that individuals have a preference for own investments. In this case, sustainability is more likely to be achieved due to pension fund savings.

ZUSAMMENFASSUNG

Wir untersuchen langfristige Konsumpfade in einer Zweisektoren-Ökonomie mit überlappenden Generationen. Die Produktivität in den zwei Produktionssektoren kann durch sektorspezifische Forschung gesteigert werden, jedoch werden die langfristigen Konsummöglichkeiten durch den essentiellen Einsatz einer nicht-erneuerbaren natürlichen Ressource in der Produktion bedroht. Die junge Generation spart für den Ruhestand durch eigene Ersparnisse sowie Einzahlungen

in die Pensionskassen. Haushalte können ihre Ersparnisse verwenden, um in Anleihen, Innovationstätigkeiten oder Ressourcenbestände zu investieren. Wir zeigen, dass Pensionskassen einen positiven Einfluss auf die langfristige Entwicklung ausüben, solange die Individuen eine Präferenz für eigene Ersparnisse besitzen. In diesem Fall wird Nachhaltigkeit aufgrund der Aktivitäten der Pensionskassen eher erreicht.

RÉSUMÉ

Nous analysons les chemins de consommation à long terme dans une économie dynamique avec deux secteurs et générations entrelacées. Chaque jeune génération épargne pour la retraite par l'épargne privée et les fonds de retraite. La productivité de chaque secteur peut être augmentée par la recherche spécifique au secteur, tandis que l'utilisation essentielle d'une ressource naturelle non-renouvelable met en danger les possibilités de consommation dans le long terme. Les obligations, les deux types d'innovations, et les stocks de ressources constituent les différentes opportunités d'investissement. Nous montrons que les fonds de retraite ont un impact positif sur le développement à long terme, à condition que les individus aient une préférence pour les investissements privés. Dans ce cas, la soutenabilité est plus probable grâce aux épargnes des fonds de retraite.