LONG-RUN IMPLICATIONS OF POPULATION AGING FOR THE PENSION SYSTEM OF UKRAINE

by

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Abstract

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Given relatively short horizon of any government, demographic changes, that have long-run consequences, frequently get neglected in economic policies. Population aging has serious long run implications for economic development. This process will have very important effect on the viability of social security systems of many countries of the world.

Ukraine also was influenced by demographic transformations. Today the share of Ukrainian population that is eligible for pension benefits is about 30% and it will increase further. This has dangerous consequences for the existing pension system, which is Pay-As-You-Go type system. In this work, I study the impact of the demographic development of Ukraine on the sustainability of its pension fund. For this purpose, I adapt the economic-demographic model developed by Social Security Reform Project of the International Institute for Applied System Analysis (Austria). I perform simulations using 6 different scenarios.

I find that according to two out of three demographic scenarios Ukrainian Pension Fund becomes insolvent in 30 years if no changes are made to its arrangement. If pension eligibility age increased to 65 years for both sexes, than system would have positive balance for all demographic scenarios, but only provided that pension contributions will not be reduced. Sensitivity analysis confirms that under the reasonable assumptions about exogenous parameters Ukrainian pension system will not be able to sustain itself in the future due to the problem of population aging.

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GLOSSARY

Pay-As-You-Go pension system – pension system under which benefits of current pensioners are financed from contributions of current workers.

Fully funded pension system – pension system under which contributions of current workers are accumulated on pension accounts. Pensions of these workers are paid as monthly or yearly benefit after they have reached pension age.

Replacement ratio – ratio of average pension benefit to average wage.

Age specific fertility rate – ratio of number of births of women of specific age to a number of women of that age range divided by 1000.

Total fertility rate (TFR) – the sum of the average number of births for female cohorts age 15-49 in a population, divided by 1000. It is the average number of total births a woman would have over her lifetime if she experienced current age-specific fertility rates.

Old-age dependency ratio – ratio of number of retirees to number of persons of working age.

Trust Fund – positive balance of the US pension system that is managed by the Board of Trustees.

Demographic wave – the mechanism that transmits effect of social events that influenced demographic trends in the past to the future demographic structure.

INTRODUCTION

Demographic changes a have significant influence on the economic performance of countries, regions and the whole world. One of the most widely observed demographic trends in the contemporary world is population aging, i.e. increasing proportion of elderly generations in the age distribution of population. In developed countries population aging was the result of two demographic processes: declining fertility and increasing life expectancy. Post-soviet economies (including Ukraine) also face population aging, even though these countries experienced increasing mortality rates and declining life expectancy during the period of transition. Reduction in fertility is so significant that even declining life expectancy cannot compensate for it and proportion of old people in the population keeps rising.

Population aging has serious impact on the future of mankind. One of the most interesting for us as economists and one of the most urgent ones is the impact of population aging on the social security system. The present paper is devoted to studying the consequences aging population may have on the pension system of Ukraine.

Ukraine has been experiencing declining fertility rates through most of the 20th century. Its age and gender structure was also influenced by historic events (such as the Great October Revolution, Civil War, the famine of the early 1930's, World War II, the post-war "baby boom") that affected fertility and mortality patterns of Ukrainian population during this period. As a result, at the moment it has a very unusual population structure. But what is common for Ukraine, other post –soviet countries, European countries, Japan, China, USA, and many other countries is that they all have fertility below replacement (i.e., total fertility rate

below 2.1) and face the problem of population aging, which has serious implications for their social security systems.

Currently Ukraine and most developed countries have a Pay-As-You-Go (PAYGO) pension system, under which pension benefits of current retirees are financed from the social security taxes paid by the current employees. This means that if old age dependency ratio (the number of retirees relative to number of workers in the economy) increases, then system will be unable to provide the same level of benefits to new retirees as before unless social security taxes are increased.

Now, Ukraine has relatively high social security taxes – 33% of total wage bill (32% paid by employer and 1% paid by employee). Thus, it has little room for tax increase. At the same time, level of pension benefits in Ukraine is very low. As of 01.08.2001 minimal old-age pension amounted to UAH 39, while officially reported subsistence level was UAH 311 (Zhalila, 2001).

Until now no major changes were made in social security system of Ukraine. But under the current arrangement it will be impossible to keep the system sustainable for a long time, taking into account limited ability of the government to increase payroll taxes and extremely low level of pensions.

Recently, serious attention has being drawn to the problem of pension reform in most developed and transition countries. Both scientists and policy-makers cooperate their efforts to find the solution. Population aging is one of the major problems of the pension system of Ukraine and many other countries. Unfortunately, pension reform in Ukraine lags behind that of other transition economies.

Although Ukraine has rather severe problems with population aging, it has not attracted appropriate attention. In my research, I would like tp study the impact that demographic changes have on the pension system of Ukraine and its balance. This subject is very broad and in this study I cover only one of its aspects, pointing possible directions of further research.

The aim of this paper is to offer a quantitative assessment of the impact of population aging on the balance of the Pension Fund of Ukraine. I conduct a number of social security simulations to project various scenarios of its further development. The model adapted for these simulations was developed by the International Institute for Applied System Analysis (IIASA, Laxenburg, Austria). This is an economic demographic model with a particular focus on the social security system. It allows us to determine the consequences for the Pension Fund under a variety of demographic and economic scenarios.

The set of scenarios for simulations was determined on the basis of two criteria: demographic dynamics (three types of population projections) and pension eligibility age (55/60 and 65/65 for females and males respectively). All together there are 6 scenarios. The selected period of simulations is between 2000 and 2030. The model allows obtaining results on a number of parameters. But, for the purpose of this paper, particular attention is paid to the balance of public pension system. Obtained results track changes in Pension Fund balance over 30 years under 6 different scenarios.

The rest of the paper is organized as follows: In chapter 1, I present the review of relevant literature, description of different pension systems, and their vulnerability to the population aging risk. Chapter 2 describes Ukrainian pension system in its current setting, and the IIASA social security model together with a complete set of scenarios used in the simulations. The results of the population projections and simulations are presented in chapter 3.

Chapter 1

LITERATURE REVIEW AND DESCRIPTION OF THE DIFFERENT TYPES OF PENSION SYSTEMS.

1.1. Review of relevant literature.

Perhaps, the most comprehensive analysis of an aging population and its economic implications is conducted by Schulz (1992). It is mainly concerned with influence that aging population has had on American society and its social security system. It starts with the history and development of the American social security system and addresses such issues as the change in retirement expectations, economic status of the aged, formation of the decision about whether to work after reaching the retirement age or not, transformation and perspectives of US social security system and the role that employer-sponsored pension system should play in it.

In a number of papers, R. D. Lee and S. Tuljapurkar (2000a, 2000b, 1999, 1998a, 1998b, 1997, 1994) address the issues of population forecasting for the purpose of social security. In one of the most recent papers (Lee, Tuljapurkar, 2000b) they present an exhaustive analysis of the methods that are used for population forecasting, present their own innovative method, and point out the significance of population forecasting for fiscal planning. They stress reasons why long-term demographic forecasts make sense and are more useful than other types of forecasts. "1) The initial age distribution of the population provides early information about future population size, age distribution, and growth rates. … 2) The relative slowness, smoothness, and regularity of change in fertility and mortality facilitate long-term forecasts. … 3) Fertility, mortality, and nuptiality have highly distinctive age patterns, which have persisted over the several centuries for which they have been observed."

Later work by S. Tuljapurkar, and R. D. Lee together with by M. Anderson, (2001) presents stochastic model of demographic change developed by authors. This innovative method of forecasting uses historical trends to model economic and demographic variables as time series. For the purpose of this research they make stochastic projections of demographic variables (fertility and mortality) and economic variables (real annual effective interest rate, real annual year-to-year return on the S&P 500, and real wage growth rate). Applying this method they obtain "less precise but more accurate" conclusions[1] about potential insolvency of the US Social Security Trust Fund, because they are based on history. Results of this method of forecasting express insolvency of the Trust Fund as the probability that it will occur in a given year. Authors study the influence on the solvency of the Trust Fund of several policy measures: increase in the social security taxes, increase in the normal retirement age, and investing portion of the Trust Fund in the stock market. Studying the effect of each measure separately they find that very strong changes required for substantial extension of the date of insolvency with a reasonable degree of certainty. A more effective alternative would incorporate some combination of presented measures. For example, they find that a modest increase in social security taxes and the normal retirement age accompanied with a moderate level of investment in the stock market achieves the goal of long-term solvency of the Trust Fund.

Another work of Lee and Yamagata (2000) focuses on the stability of US social security system. In this paper, their main concern is also with the problem of long-term imbalance of the U.S. Trust Fund due to increase in the dependency ratio. According to the official projections, even if the normal retirement age is increased, the Trust Fund will be exhausted in 2037 (Lee and Yamagata, 2000). Lee notices that the standard measure of long-run Fund solvency, the 75-year

[1] Authors themselves call their projections "less precise but more accurate", because, they obtain not point projections, but probability distribution of future values of each variable. Thus, using this method for forecasting, at each point in time we know only the range in which projected variable will lie.

Actuarial Balance (AB75), which indicates that permanent increase in social security taxes by 1.89% will resolve this problem, is flawed. Indeed, this measure would fix the system only until 2075, but would not keep it solvent after that date (as this measure is based on the Trust Fund balance in 75 years from the date of projecting). To address this issue, Lee proposes several alternative measures of Trust Fund solvency. Three of them are infinite horizon measures and the fourth, is the so-called Flat Fund Ratio criterion, shown to be an alternative to one of the infinite horizon measures. Because it does not require any projections beyond 2075 and has common sense appeal, the authors propose to use it for policy purposes. Estimating the imbalance using various measures and under various demographic assumptions, Lee concludes that imbalance is more than twice as big as found under the standard AB75 measure. The Flat Fund ratio sustainable tax increase is 4.2% under the assumption of a more rapid mortality decline. Other infinite horizon measures indicate even larger imbalance. But, Lee does not argue that tax increase is the only and the best policy measure to achieve long run balance in the system. "For comparing the long-term fiscal implications of various Social Security policy proposals, we suggest that the sustainable tax increase evaluated at 2075 should provide a useful tool… No matter what policies are implemented today, we should expect to modify them as the future unfolds" (Lee and Yamagata, 2000, p.14).

Kuznetsov and Ordin (2001) by means of overlapping generation model study optimal transition from PAYGO to a fully-funded pension system for Russia. Resources for transition are supposed to be accumulated through increased contributions to the pension system. The authors evaluate welfare efficiency of transition from one type of arrangement to another according to three scenarios. All of them assume that Russian economy shifts from steady state with PAYGO system to steady state with fully-funded system, but the speed of transition is different. Analysis suggests that transition will result in total welfare gains.

However, the model suggests that Pareto-improving transition is impossible, as generations that would work when the reform begins have to bear the burden of higher taxation during the transition. "When the decision on the pension system reform is to be determined by majority voting, reforms are unlikely to gain enough support… The experience of developed countries demonstrates that reforms may be postponed endlessly" (Kuznetsov, Ordin, 2001).

Social Security Reform Project of the International Institute for Applied Systems Analysis (IIASA, Laxenburg, Austria) has developed multiregional economic-demographic growth model that allows modeling different scenarios of pension reform in a country that faces the problem of an aging population. MacKellar and Ermolieva (1999) present a general description and algebraic structure of this model.

In later work, MacKellar et al (2000) present the structure and simulation properties of this model. For this purpose, they take data for an imaginary country or region and show how the model performs under various assumptions. They also perform uncertainty analysis changing various exogenous parameters and study their impact on the results of simulations. This way they study uncertainty in the coefficients of Cobb-Douglas production function, uncertainty in age-specific labor force participation rate, and uncertainty in age-specific average propensities to consume. They conclude that "reasonable exogenous assumptions give rise to a reasonable long-run model solutions; when exogenous assumptions or model parameters are changed, the model performs sensibly on the baseline-vs.-alternative basis; and model projection results are reasonably robust … to exogenous assumptions regarding household saving and labor supply; they are sensitive … to the parameters of the core production function."

Dobronogov in a series of two papers used this model to study the Ukrainian pension system. Dobronogov (1998) uses an earlier and simplified version of the

model to study the impact of different scenarios of pension reform on the government debt. Scenarios are based on different shares of informal sector in the economy, different duration of the transition from PAYGO to fully-funded pension system, and different pension eligibility ages. The results show that, first, the share of informal sector plays a crucial role in the determining the outcome of the pension reform. Second, the longer is the duration of the transition the better chances for successful reform are. Third, according to simulations, pension reform has no chances to succeed unless pension eligibility age is increased.

In another work, Dobronogov and Mayhew (2000) focus their attention on the large informal sector of the Ukrainian economy. Authors include better described informal sector of the economy in the latest version of the model. Using this extended model, they try to determine the impact that social security system and its reform will have on the informal sector. Scenarios for simulations are based on the size of the fully-funded component in the pension system, on the method of the financing of the transition (debt-financed and tax-financed), and the degree of the public trust in the reform. The results of the simulations show that public trust plays a very important role in the impact of the pension reform on the informalization of the economy; debt-financed transition will facilitate decrease of the share of the informal sector in the economy; *ceteris paribus*, the larger the private fully-funded pension system, the smaller the informal sector of the economy. Thus, introduction of a fully-funded component to the pension system may have positive impact on the reduction of the informal sector.

In my work, I also use the IIASA social security model. However, unlike previous researches, I concentrate my attention not on the impact that pension reform will have on the economy, but on the impact that demographic changes will have on the pension system and its possible reform.

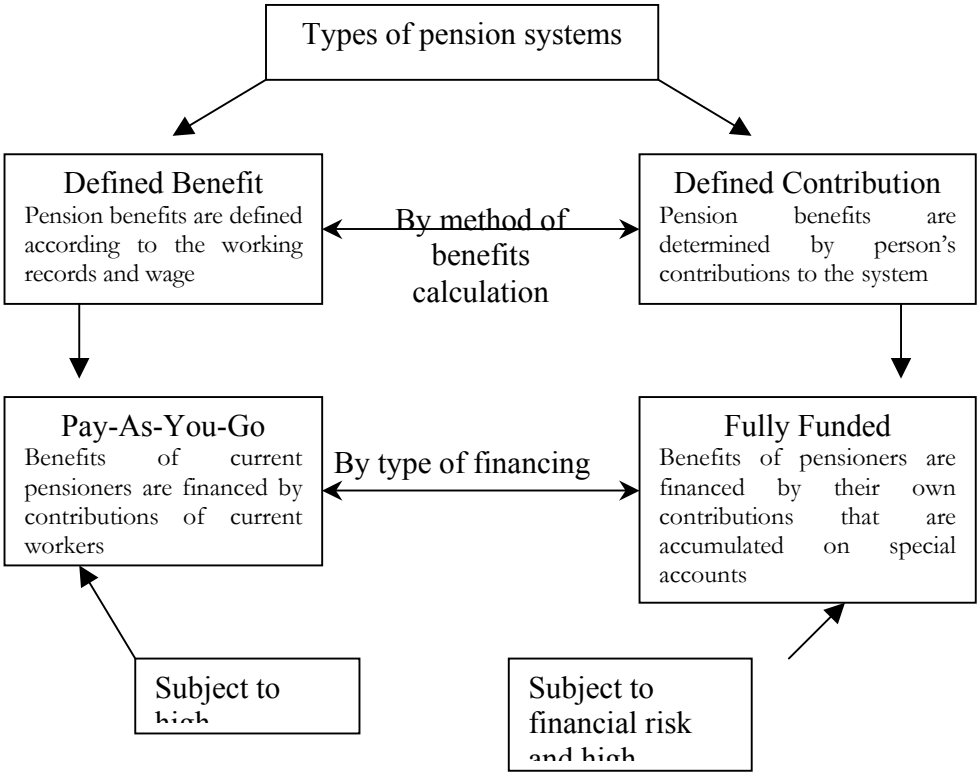
1.2. Different types of pension systems.

There are mainly four ways to support the aged. First, they can continue to work and support themselves. Second, their family (in the wider sense of this word) can support them. Third, they can get pension benefits. Finally, they can live on their lifetime savings. Thus, pension is just one of the means of financing old age expenditures.

Pension benefits play an important role only in developed countries and in part of transition economies (those that previously formed the socialistic bloc). The rest of the world still follows traditional approach where children support their parents, who in turn try to work as much as they can (Dmitriev et al, 1998).

There exist several types of pensions systems. It is possible to classify them according to different principals. First, by the method of benefits calculation there are "defined benefit" (benefits to individual are defined according to his wage and working record) and "defined contribution" (benefits are determined by person's contribution to the system) pension arrangements. Second, by type of financing one can distinguish "fully-funded" (FF, where pension contributions of current workers are accumulated on special accounts and after retirement, they receive benefits form these accounts in the form of annuity) and "pay-as-you-go" (PAYGO, where retirement benefits to current pensioners are financed by current workers) systems. Third, by the form of management there are publicly and privately managed systems. Currently publicly managed defined benefit PAYGO pension system in the world prevails (Dobronogov, Mayhew, 2000). Recently some countries switched to defined contribution FF pension systems (Chile in 1981). While still others have combination of both FF and PAYGO components (Kazakhstan introduced it in 1998; Peru in 1993).

Figure 1. Types of pension systems



Defined benefit PAYGO pension system is the most vulnerable to the demographic shocks. In the context of population aging, it becomes unsustainable in the long-run. If benefits to current retirees are financed by current workers, then increase in the number of pensioners relative to the size of the labor force increases burden placed on the shoulders of the working generations. In addition to demographic risk, this type of arrangement gives workers incentives to understate their earnings and pay lower social security taxes (free rider problem).

At the same time a defined contribution FF system is not subject to demographic risk. Every person that participates in it gets what he or she contributed to the system earlier plus the return (net of administrative costs) earned on those

contributions over the period of time money were held and invested by the pension fund. Demographic risk may be present only in the form of lower returns on contributions as the number of participants increase. This type of system also discourages evasion, and may stimulate higher national savings and development of the financial sector. FF system, however, is subject to financial risk, as contributions are invested in securities. The major concern with this system is that it may provide a rate of return which is less than market rate of return. Another negative feature of the FF pension system is the high administrative and management costs. Finally, this system does not protect the most needy groups of population, those who had very low income level and were unable to save enough for retirement, and those who had long periods of unemployment during their working life. Under PAYGO system, they would usually receive some level of benefits.

Thus, each system has its pros and cons. Choosing between them (or any combination of both systems) we should take into account their particularities as well as the conditions in the country (one of which is the demographic situation).

C h a p t e r 2

BASIC CONDITIONS AND MODEL DESCRIPTION.

2.1. Description of Ukrainian pension system

2.1.1. Ukrainian pension legislation

Ukrainian pension system was formed on the basis of the legislation of the former USSR. Now it consists of several laws. First and the most important one is the Law of Ukraine "On Pension Insurance" adopted in 1991. Other laws determine the level of pension payments for different categories of people. They are:

1. Law "On the Status of People Deputy" (17.11.1992);
2. Law "On the State Service" (16.12.1993);
3. Law "On the Status of Judges" (15.12.1992);
4. Law " On the Public Prosecutor's Office" (05.11.1991);
5. Law "On Pensions of Servicemen and the Officers and Men of the Agencies of Internal Affairs" (09.04.1992);
6. Law "On the Status of War Veterans, Guarantees of their Social Security" (22.10.1993);
7. Law "On the Basic Principles of Social Security of Labor Veterans and Other Elderly Citizens in Ukraine" (16.12.1993);
8. Custom Code of Ukraine (12.12.1991).

Funding of the pension system is regulated by the Law of Ukraine "On Tax for Mandatory State Pension Insurance" adopted in 1997. (Dobronogov and Mayhew, 2000)

The pension system of Ukraine is managed by three organizations.

The Ministry of Labor and Social Policy states social policy and develops laws connected with social security system (and pension system as a part of it). It also calculates the pension level according to the legislation in use, controls the use of funds of the Pension Fund, and cooperates with foreign organizations in the field of social security.

The Pension Fund collects pension contributions from various sources and keeps them in the special accounts in the postal-pension bank "Aval".

The Ministry of Communications distributes pension payments through the local post offices. (Dobronogov and Mayhew, 2000).

2.1.2. Pension benefits level

According to the Law of Ukraine " On Pension Insurance", there are two basic types of pensions: labor pension and social pension.

Labor pension includes four types of pensions: old-age pension, disability pension, survivor pension, and time-of-service pension.

For old-age pension eligible those workers, who have reached the retirement age and have a minimal required working record. Retirement age is 55 and 60 years for women and men respectively. Required working record is 20 years for women and 25 years for men. The periods when person does not contribute to the Pension Fund (military service, years of studying in the university, maternity

leave) are also included in the working record. The level of an old-age pension is 55% of the average monthly wage of the worker during the reference period (see below) but cannot be less than the minimal pension. For every additional year of work, pension increases by 1% of the average monthly wage but this additional part cannot exceed 75% of original pension. The minimum pension is determined by Verkhovna Rada (Parliament of Ukraine). The maximum level is three (in some cases four) times the minimum level.

For disability pension eligible those people, who have partial or total working disability and who have working record from 1 to 15 years depending on age. There are three categories of disability pensions depending on the level of disability the person has. Pension level for the 1st group is 70%, for the 2nd group is 60%, and for the 3rd group is 40% of average monthly wage but not less than the social pension for the respective disability group. The upper limit of disability pension is three (in some cases four) times the minimum level.

Survivor pensions are assigned to disabled dependents of the deceased worker. The level of pension is 30% of average monthly worker's wage but not less than the social pension for the respective disability group.

For the years-of-service pensions eligible workers of certain professions that might cause loss of working capacity prior to the normal retirement age. The procedure of assigning the level of the years-of-service pension is the same as with the old-age pension.

Reference period for the determining of the level of labor pension is the last two working years or any five years of work without interruption. The part of average wage exceeding 10 minimal wages is not taken into consideration for pension calculations. That part of the wage that is less than 4 minimal wages is taken into full account. The fifth minimal wage enter the calculations with the coefficient

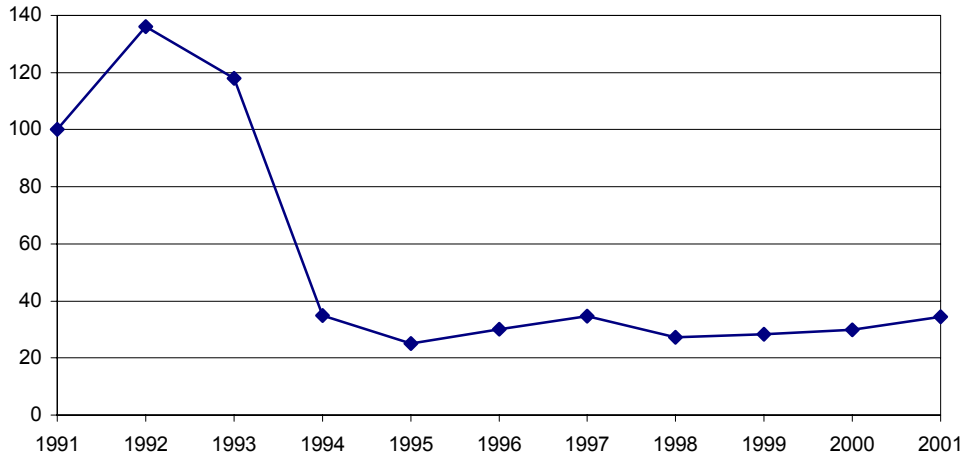
.85, the sixth wage – with coefficient .7, the seventh – with coefficient .55, the eighth– with coefficient .4, the ninth – with coefficient .25, and the tenth – with coefficient .15.

Social pensions are assigned to invalids, children who have lost working parents' income, and persons who have reached pension age, if they are not eligible for labor pension. The level of social pension is between 30% and 200% of the minimal old-age pension.

There also exist a number of categories of workers who are eligible for different types of privileges. For example, at the moment, 28% of pensioners, who obtains old-age pensions had privilege to retire earlier than the official retirement age (Ivankevich, 2001). Another type of privileged categories of pensioners receives pensions that significantly exceed those of regular retirees (for example, judges, people deputies, etc.). These categories of pensioners do not have upper bound for pension benefits as regular pensioners do. At the same time, all categories of workers have upper bound of earnings that are subject to social security payments. Thus, there exists backward redistribution of funds from low-income workers to high-income workers as pension benefits of the latter are partially financed by contributions of the former (Nechaj, 2001).

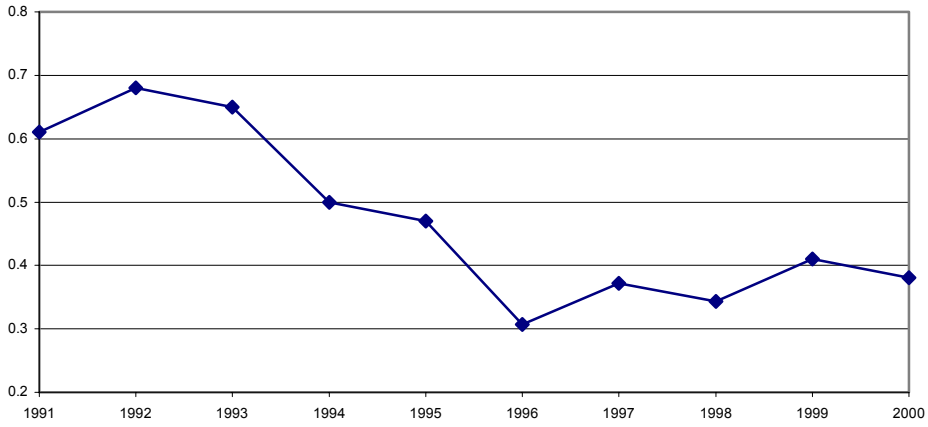
This type of arrangement of the pension system of Ukraine generates a number of problems for its participants. During the transition period, pension benefits obtained by Ukrainian pensioners have deteriorated significantly. As shown in Figure 2, compared to the beginning of this process, pensions in real terms have declined more than two times. After 1995, we observe slight improvement, nevertheless current pension benefits are still more than two times lower than in 1991.

Figure 2. Index of average monthly pension in Ukraine, 1991=100 (beginning of the period)



Source: State Statistical Committee of Ukraine, own calculations and Dobronogov, 1998 (data 1991-1995).

Figure 3. Replacement ratio in Ukraine (beginning of the period)



Source: State Statistical Committee of Ukraine, IMF Country Report, 2001, own calculations and Dobronogov, 1998 (data 1991-1995)

It is clear from Figure 3 that pensions have not only decreased in their absolute value, they have also decreased relative to wages. Thus, severe economic crises affected first of all and most of all the weakest. As you may see in Figure 3,

replacement ratio has also declined during the period when pensions showed downward trend.

2.1.3. Pension Fund Contributions

Pension Fund has two major sources of funds:

- Employers transfer 32% of the total wage bill to the Fund;
- Workers pay 1% of their wage.

The only type of investment that Fund can make if it has excess resources is purchase of the state bonds (Dobronogov and Mayhew, 2000).

2.1.4. Necessity of the pension reform

Thus, the pension system of Ukraine has a number of problems.

First, employers pay a very large part of the pension taxes (32% out of 33% of total wage bill), that gives them incentive to reduce official wages and leads to increase of the informal sector of the economy (Dobronogov and Mayhew, 2000). This fact imposes additional burden on pension system.

Second, it has a very low pension eligibility age requirement. At the moment, life expectancy at retirement is approximately 22 years for women and 14 years for men (Ostanin, 2001). In addition, as mentioned above, there exist relatively large number of people who are entitled for early retirement (representatives of about 20 professions) (Dobronogov and Mayhew, 2000).

Third, existing limits on maximum pension reduce differentiation of pension benefits. Person that never contributed to Pension Fund might receive approximately the same pension benefits as the one that contributed to it during

the whole working life. This reduces incentives for workers to participate in official labor force and in Pension Fund formation. At the same time, according to current legislation, large part of pensioners has preferential treatment and has no limits on maximum pension (about 10% of new retirees). Such situation reduces the average level of benefits received by non-privileged categories of retirees and reduces their motivation to participate in this system even further. Preferential treatment of some categories of workers contradicts to basic principals of pension reform as pension benefits, that are paid out of Pension Fund should be determined exclusively by contributions that persons made to the system (Ivankevich, 2001).

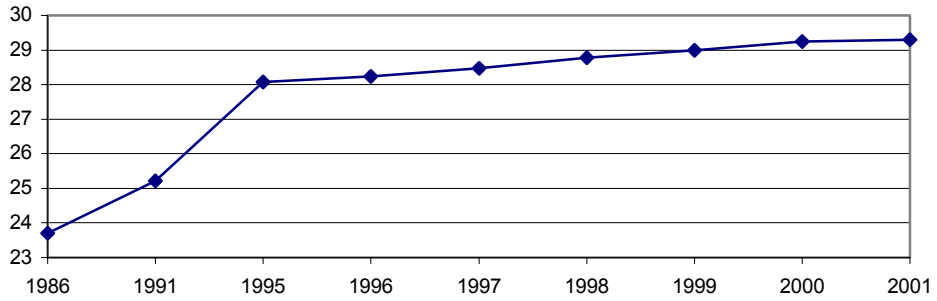
Hence, to overcome problems of existing pension system and to improve needy position of the pensioners urgent pension reform is required.

We should also mention, that demographic situation and its dynamics suggests that the next decade will be a relatively more favorable time for pension reform (see next section).

2.1.5. Demographic foundation of the pension reform.

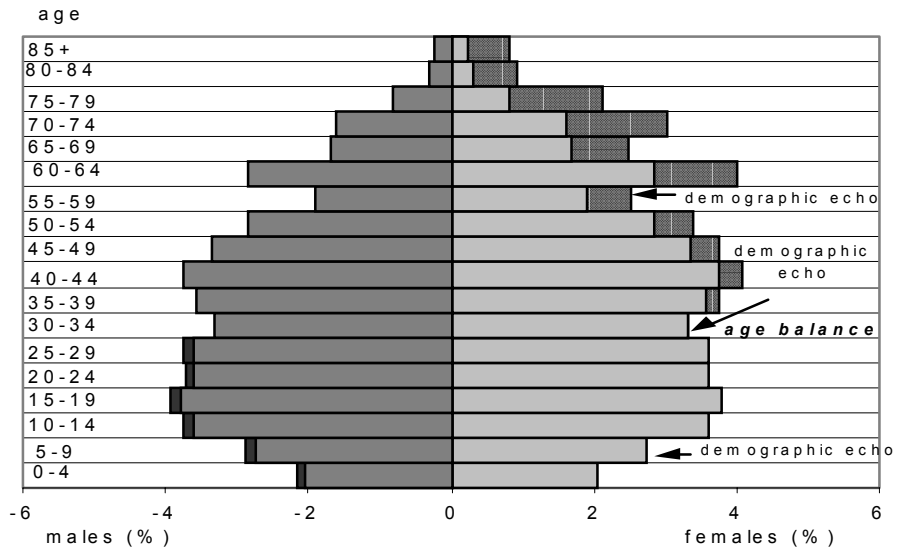
Difficult situation of the Pension Fund due to described reasons aggravated by growing number of pensioners (see Figure 4). As a result, large share of the Ukrainian population lives below the poverty level. As of 01.08.2000 minimal old-age pension amounted to UAH 39, while officially reported subsistence level is UAH 311 (Zhalila, 2001). Another illustration of the desperate position of pensioners is the fact that at the beginning of 2000 average pension level was UAH 68.91 while poverty level was UAH 90.7 (Ostanin, 2001).

Figure 4. Proportion of pensioners in total population of Ukraine, % (beginning of the period)



Source: State Statistical Committee of Ukraine, own calculations.

Figure 5. Population pyramid of Ukraine as of 01.01.2001.

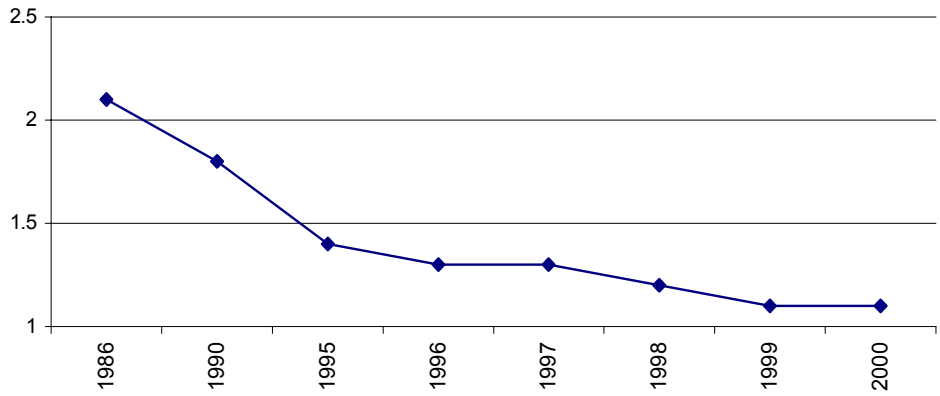


Source: State Statistical Committee of Ukraine, own calculations.

The fact that pension reform has to be designed in the context of population aging is the key challenge to this issue. Population age structure (Figure 5) shows clear tendency to population aging.

The process of a population aging consists of two more or less independent demographic trends. The first is the declining fertility rate, which leads to smaller proportion of young generations in the population structure. The second is the increasing life expectancy, which increases the number of elderly people. Many countries in the world experience sharply declining fertility rates. Ukraine, in particular, has total fertility rate below replacement level since 1986 (see Figure 6). Unlike developed countries, that experience very rapid growth in life expectancy due to advances in health care, transition economies had declining life expectancy during the transition period caused by economic and social instability. But at the moment, Ukraine also has tendency toward increase of life expectancy at birth after it experienced the lowest for the last 50 years level in 1995-1996 (66.9 for both sexes) (see Figure 7).

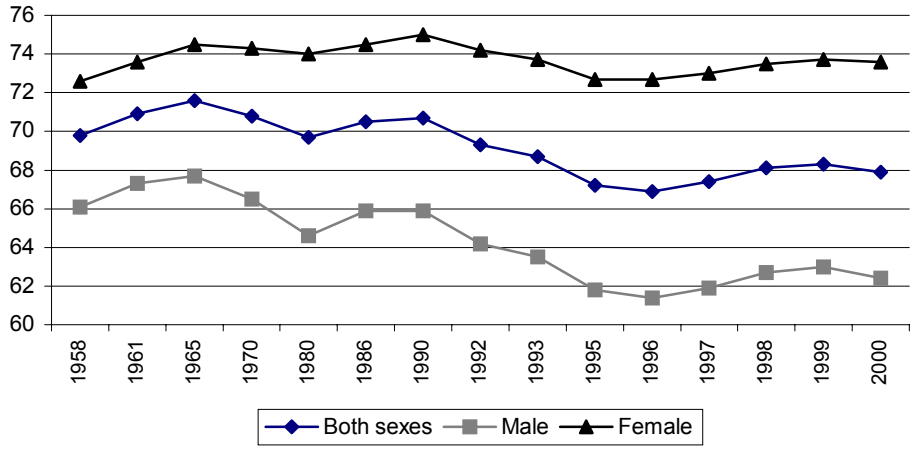
Figure 6. Total fertility rate[2] in Ukraine (number of births).



Source: State Statistical Committee of Ukraine

[2] Total fertility rate is the average number of births a woman would have over her lifetime if she experienced current age-specific fertility rates.

Figure 7. Life expectancy at birth (years).



Source: State Statistical Committee of Ukraine.

Hence, Ukraine is likely to have improvement in the life expectancy, which will speed up the process of population aging.

Taking into account the issue of population aging, we can predict that if current design of the pension system is not changed, affordable replacement ratio[3] will fall.

Analyzing the structure and dynamics of the population we should pay particular attention to the so-called phenomenon of "demographic waves"[4]. Although, as I mention, demographic structure of Ukraine shows tendency towards population aging, during the first decade of the third millennium it will experience slight improvement in the population structure. This fact can be explained by simultaneous action of several demographic trends. First of all, at the beginning of the century thin cohorts that were born during the WWII enter the retirement

[3] Replacement ratio is the ratio of average pension benefits to average wage.

[4] Demographic waves transmit effect of social events, that influenced demographic trends in the past, to the future demographic structure.

age. At the same, relatively large cohorts that were born during the first half of the 1980's reach working age and increase labor force (see Figure 5). Thus, till 2006 we can expect increase in the size and share of working age generations. Number of birth may also increase in the nearest future, as large cohorts of females that were born at the and of 1970's -- beginning of 1980's will reach most active fertility age (20-26 years old).

For this reason, the first decade of the 21st century is regarded as "demographic chance" to implement pension reform in Ukraine (Kurilo, 2001).

2.2. Model description

In order to simulate future development of Ukrainian pension system, I adapt the economic demographic model based on the one developed by IIASA's (International Institute for Applied System Analysis) Social Security Reform Project (MacKellar and Ermolieva, 1999). This is a neoclassical two factor model with particular focus on demographic development and pension system. The original model was modified to include large informal sector (which is the case with Ukrainian economy). This modification was presented where they studied the influence of different scenarios of pension reform in Ukraine on the informal sector of economy. In this work, I use one-region version of the model. Algebraic structure of the model is presented in the Appendix 1.

The list of notations used in this sub-section is presented in Table 1. I preserve notation presented in Dobronogov and Mayhew (2000) for ease of comparison.

Table 1. The list of notations

#	Notation (in order of appearance)	Meaning
1	*GDP*	Gross domestic product
2	*Ktot*	Total capital of the economy
3	*Emp*	Total size of working population
4	α, β	Exogenous coefficients of the Cobb-Douglas production function
5	g	Exogenous total factor productivity growth rate
6	R	Interest rate
7	$\overline{W}$	Average wage
8	*KTotF*	Total capital utilized in the formal sector
9	*KRes*	Residential capital
10	*KPUE*	Capital utilized by private unincorporated enterprises
11	*KPvtPenSys*	Capital held by private pension system
12	*KOFI*	Capital held by other financial institutions (financial intermediaries except for pension funds)

13	*WageY*	Wage income – sum of wage earnings of all workers of the economy
14	*PubPenSysContRate*	Share of earned income that is contributed to the public pension system
15	*ContPubPenSysWageY*	Contribution to the public pension system out of wage income
16	*EntrY*	Entrepreneurial income—sum of earned income over all entrepreneurs
17	*ContPubPenSysEntrY*	Contribution to the public pension system out of entrepreneurial income
18	*BenEntPubPenSys*	Pension benefits entitlement in public pension system
19	*RtrmntDuration*	Number of years the person lives in retirement
20	*LabForcePartRate*	Labor force participation rate
21	*RefPeriod*	Reference period—number of years just before retirement that are taken into account for calculation of pension benefits
22	*ReplRate*	Replacement rate—proportion of average wage during the reference period that initial pension benefits provide
23	*EligAge*	Pension eligibility age
24	*BalPubPenSys*	Balance of the public pension system
25	*ContPubPenSys*	Total contributions to the public pension system
26	*BenPubPenSys*	Total benefits paid out of public pension system
27	*r*	Interested rate net of depreciation and indirect taxes

The model is based on the UN System of National Accounts. Age-specific saving rates, labor force participation rates, and rates of distribution of savings between different types of investments are exogenous.

There are five types of agents in the economy: individuals by single-year age group, private unincorporated enterprises, firms (i.e. corporate enterprises), financial intermediaries (private pension system and other financial institutions), and government. The model tracks receipts and disbursements (i.e. net savings) of individuals, firms, and government.

There are two sectors of economy, the formal and the informal, each characterized by its own Cobb-Douglas production function.

$$GDP(t) = \alpha(1+g)^t \, KTot(t)^{\beta} \, Emp(t)^{1-\beta} \tag{1}$$

Rates of return to factors are neoclassical under competitive assumption:

$$R(t) = \beta\left[\frac{GDP(t)}{KTot(t)}\right], \text{ and} \tag{2}$$

$$\overline{W}(t) = (1-\beta)\left[\frac{GDP(t)}{Emp(t)}\right], \tag{3}$$

Informal sector in this model represents those agents that do not pay social security taxes from their earned income. At the same time, it is possible that individuals pay social security taxes only from part of their earnings. Thus, it represents tax evasion from a specific type of tax, namely social security tax (as it is possible, that agents that do not pay social security taxes pay other types of taxes). For the purpose of this model, we call informal sector the share of total earnings from which social security taxes are not paid. It constitutes the share of labor that is employed in the informal sector (as model tracks only average wages), and the share of capital that attached to this labor and used for activity, from which social security taxes are not paid.

Capital in the formal sector (*KTotF*) consists of four types of capital. Residential capital (*KRes*), capital operated by private unincorporated enterprises (*KPUE*), and capital operated by firms and held on behalf of households by private pension system (*KPvtPenSys*) and by other financial institutions (*KOFI*). Capital in the informal sector includes residential capital and capital of PUE. Firms operate only in the formal sector. Firms earn profits pay taxes and distribute dividends to

holders of claims. Other financial institutions represent all types of financial intermediaries except for pension funds. In both sectors, rents earned on residential capital and profits of PUE accrue directly to the households.

Number of working people (*Emp*) depends on population, labor force participation rate and unemployment rate. Size of the population and its age-sex structure is taken from population projection.

Public pension system is Pay-As-You-Go system (PAYGO). Workers, who are employed in the formal sector, and their employees make pension contributions to it. After retirement, individuals receive public pension, calculated on the basis of their working records and average wage earnings.

Contributions to the public pension system out of wages are

$$ContPubPenSysWageY(t,age)=PubPenSysContRate(t)*WageY \quad (4)$$

The social security contribution rate *PubPenSysContRate(t)* is assumed to be age-independent. No distinction is made between employees' and employers' contributions. Social security contributions out of entrepreneurial income are calculated similarly:

$$ContPubPenSysEntrY(t,age)=[PubPenSysContRate(t)*EntrY((t,age)) \quad (5)$$

Let *BenEntPubPenSys(t, age, RtrmntDuration)* be the social security benefit entitlement for the average person aged *age,* who retired *RtrmntDuration* years ago, where we assume that *BenEntPubPenSys(t,age,0) = 0*. The pension for persons entering retirement is computed according to the formula:

$$BenEntPubPenSys(t, age, 1) =$$

$$\text{Re } plRate(t) \frac{\left(\sum_{j=1}^{age-14} LabForcePartRate(t-j, age-j) \right)}{age-14} \frac{\sum_{k=1}^{\text{Re } fPeriod} W(t-k, age-k)}{\text{Re } fPeriod} ($$

6)

ReplRate(t) is a coefficient of proportionality which translates earnings into an initial pension entitlement. This replacement ratio is applied to the average labor force participation rate between age 15 and *age* (assuming *age*≥*EligAge* (eligibility age*))* times average annual earnings during the *RefPeriod* (reference period) years prior to retirement.

System balance at time *t* is calculated as follows.

BalPubPenSys(t)= BalPubPenSys(t-1)+(1+r) BalPubPenSys(t-1)+
+ContPubPenSys (t)*--BenPubPensSys* (t) (7)

There is defined contribution private pension system (PvtPenSysDC), where pension benefits are calculated on the basis of workers contribution to the system and age to which the person is expected to live.

There are six sources of household income. They are wages, profits earned on capital operated by PUE's, imputed rents from residential capital (housing services), dividends on capital operated by firms, public pension benefits, and private pension benefits.

In addition to disposable income, resources available for household consumption include capital transfers, which take the form of sales of assets accumulated during the work life in old age and inheritance of assets by the surviving population.

Thus, the model tracks accumulation of assets during the working age and their depletion after retirement.

One-region version that includes informal sector requires data on 93 parameters to perform simulations and gives results on 311 parameters (complete list of parameters is available from the author).

2.3.Set of scenarios

In this work, I analyze the effect that population aging has on solvency of public pension system. In fact, Ukrainian Pension Fund cannot become bankrupt in a literal sense. Indeed, in 1995 and 1996 benefits paid out of Pension Fund exceeded contributions to the Fund. But in this situation state budget covered the difference (in IIASA model deficit of the public pension system is one of the composite parts of the government debt). Thus, speaking about Pension Fund solvency, I mean non-negative balance on the public pension system. In any case pension system by design is assumed to sustain itself and state budget cannot cover system debts forever.

Scenarios used for simulation are defined according to two criteria.

The first is the type of population projection that is used for simulations. There are three of them:

- First population projection (high fertility and low life expectancy assumptions are used);
- Second population projection (medium fertility and medium life expectancy assumptions are used);
- Third population projection (low fertility and high life expectancy assumptions are used);

The second criterion is pension eligibility age:

- Remains unchanged (55 for women and 60 for men);
- Will be increased to 65 for both sexes till 2010.

Hence, altogether we have 6 scenarios (see Table 2).

Table 2. Set of scenarios

Number of scenario	Type of population projection	Pension eligibility age
1	First population projection (high total fertility rate, low life expectancy)	55 for females, 60 for males
2		65 for both genders
3	Second population projection (medium total fertility rate, medium life expectancy)	55 for females, 60 for males
4		65 for both genders
5	Third population projection (low total fertility rate, high life expectancy)	55 for females, 60 for males
6		65 for both genders

Chapter 3

POPULATION PROJECTIONS, SIMULATION RESULTS, AND POLICY IMPLICATIONS.

3.1. Population projections

All population projections are produced using fertility and life expectancy assumptions made by IIASA population project for the European part of the Former Soviet Union countries[5] (including Ukraine) (Lutz et al, 1996).

In this work, I take only assumptions about fertility and mortality levels assuming migration out. This is done because of the high degree of uncertainty about migration level and direction, as it depends not only on the economic and political conditions in the country in question, but also on the economic and political conditions in all other countries. While I neglect migration in this work it can be a big issue for the development of pension system, which requires further investigation.

Assumptions about the total fertility rate (TFR) and the life expectancy at birth are presented in Table 3.

Table 3. Assumptions about total fertility rate and life expectancy at birth.

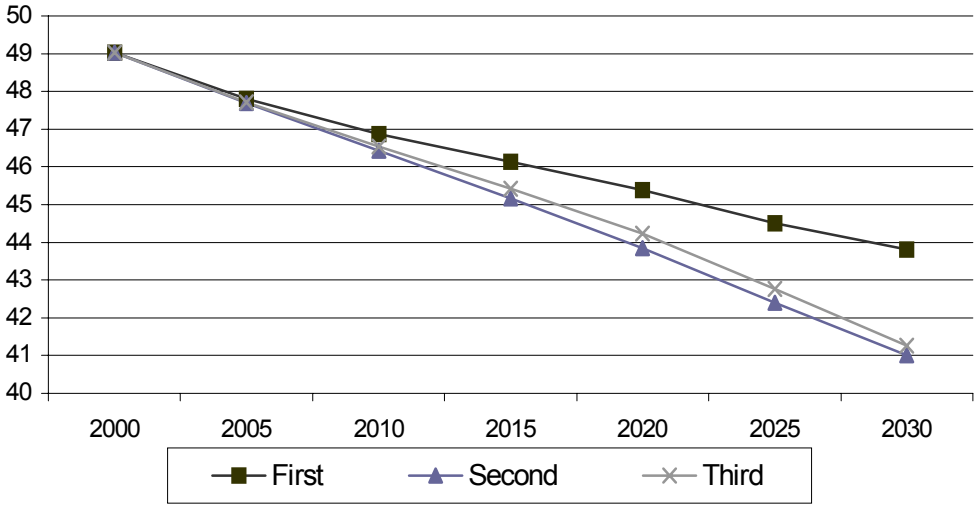
European FSU region		2000	2030-2035			2045-2050		
		Actual	Low	Medium	High	Low	Medium	High
Total fertility rate		1.1	1.3	1.7	2.1	1.4	1.7	2.1
Life expectancy at birth	Male	62.4	62.4	68.6	76.1	63	70	77
	Female	73.6	76.6	80.3	84.1	77	81	85

[5] European FSU region includes following countries: Armenia, Latvia, Azerbaijan, Lithuania, Belarus, Moldova, Estonia, Russian Federation, Georgia and Ukraine

Second column of Table 3 presents the actual level of the TFR and life expectancy at birth reported by the State Statistical Committee. For 2030-2035 and 2045-2050 projected values are presented. Between 2000 and 2030, and 2030 and 2045 the TFR and the life expectancy at birth are assumed to converge smoothly to the corresponding projected level.

To make population projection I used computer program Demproj. On the basis of initial age-sex distribution and assumptions about the TFR, age distribution of fertility, and life expectancy at birth it allows to project size and composition of the population for 50 years. Results of projections are presented in Figure 8.

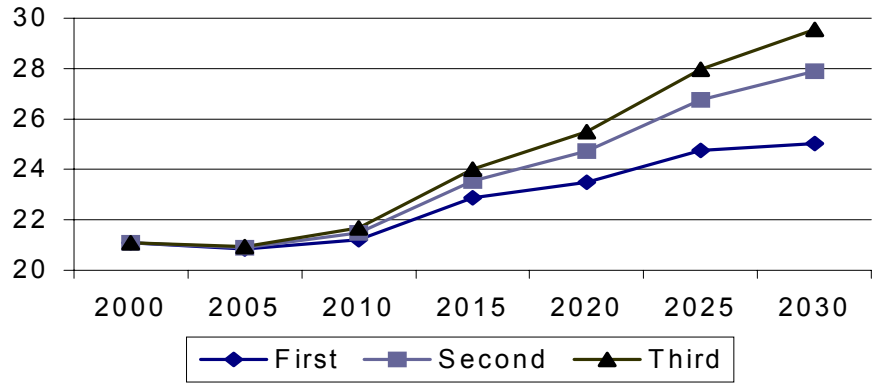
Figure 8. Total projected population of Ukraine according to different demographic assumptions (millions of people).



As can be seen in the figure projected population of Ukraine steadily falls according to all demographic scenarios. For the First population projection decline is not that rapid and projected population in 2030 is almost 3 millions larger than for other types of projections. This can be explained by higher TFR and favorable population structure. As mentioned above, during the next 10-15

years Ukraine will have large cohort of fertile females that were born during 1980's, years that were characterized by relatively high fertility levels. When those cohorts will have children the relative number of births will increase. We also should take into account that age-specific mortality rates are lower in younger generations. Thus, we can expect relatively larger total population according to the First population projection, which is based on high TFR and low life expectancy assumptions, than, say, that of the Third population projection, which is based on low TFR and high life expectancy.

Figure 9. Proportion of the total population eligible for pension benefits according to different demographic assumptions, % (pension eligibility age 55/60).



Common characteristic of all types of population projections is increasing proportion of the population eligible for the pension benefits. It is described in Figure 9. The Third population projection has the largest proportion of population eligible for pension benefits due to two reasons. Firstly, it is based on the assumption of high life expectancy, which means larger number of people eligible for pension benefits. Secondly, according to the Third population projection Ukraine will experience low TFR, which means smaller size of young

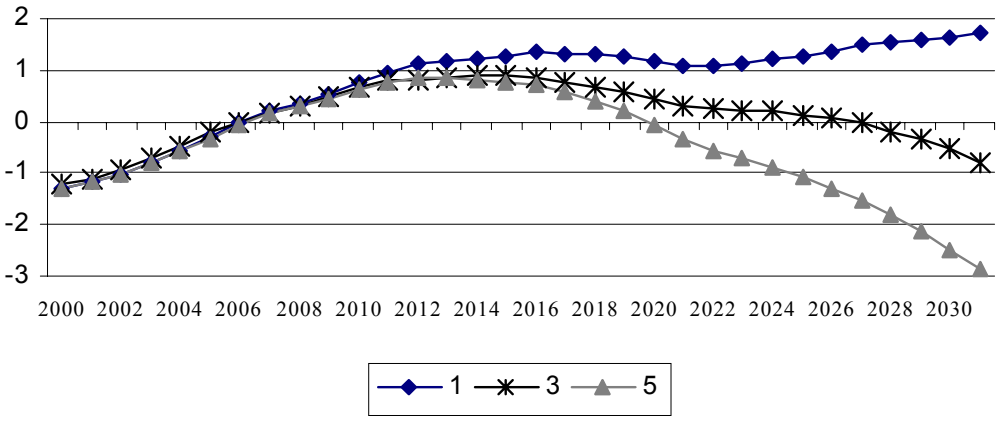
generations. Both these factors results in the larger proportion of elderly generations.

It is also worth noting that during the first 5-6 years of projections proportion of population eligible for pension benefits according to current legislation will slightly decrease. This fact can be explained by the "demographic waves" described in the previous chapter.

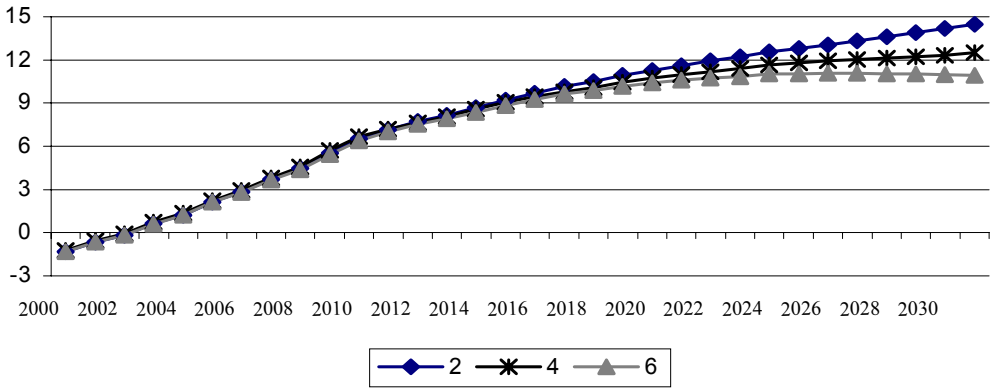
3.2. Results of the simulations

The simulations are made for the period from 2000 till 2030. The model allows us to obtain results on a number of aspects, but here particular focus is on the balance of public pension system. Results of the simulation are presented in Figure 10.

Figure 10. Balance of the Public Pension system from 2000 till 2030 for different scenarios (UAH bln).



a) Results for scenarios 1, 3, and 5



b) Results for scenarios 2, 4, and 6

Thus, according to two out of six scenarios, Pension Fund will go bankrupt during the next 30 years. Both these scenarios are based on the present pension eligibility age. Results for the scenario number one show positive balance of the public pension system, although it is also based on the current pension eligibility age. But this scenario is based on the First population projection which has high TFR assumption and low life expectancy, which means that Ukraine will experience slower growth of the proportion of population eligible for pension benefits. But, as mentioned above, Ukraine is likely to have a tendency toward increasing rather than decreasing life expectancy. Thus, more attention should be paid to the third scenario, which is based on a medium assumption about fertility and mortality levels and has better chances to be closer to the reality.

Some limitations of the model also make situation with Pension Fund look better than it actually is. As shown in Figure 9, the proportion of people eligible for pension benefits in 2000 is about 21% of total population. At the same time, Figure 4 suggests that in 2000 Ukraine had about 29% pensioner in the structure of total population. This difference can be explained by the fact that some pensioners start to receive pension benefits before the official pension eligibility age for various reasons (disability, privileges, etc.). Although the model tries to account for those pensioners that obtain disability or survivors pension, it does not consider the possibility of earlier retirement, which, as was mentioned, is very significant in Ukraine. Thus, actual number of pensioners *ceteris paribus* would exceed that calculated by the model. Obtained results on the public pension system balance are unambiguously better than they would be if the possibility of earlier retirement was taken into account.

Another fact of reality that is not taken into account in our research is migration. As was mentioned above, we neglected this issue because of high degree of uncertainty attached to it. But still, we have to keep in mind that at the moment

Ukraine has net emigration (Lutz et al, 1996 also assumes that Former Soviet Union region will have net emigration in the future). If this tendency will persist in the future the size of Ukrainian labor force is likely to decrease due to emigration in larger proportion than the number of pensioners, as emigrants are mostly young, high-skilled and highly motivated people. Hence, our population projections are likely to be more favorable for Ukrainian pension system, than those that would take migration into account.

Taking all these facts into account, we can conclude that, according to these simulations, there are very big chances that Pension Fund of Ukraine will go bankrupt during the next 30 years if no changes are made in the arrangement of pension system.

Panel b) on Figure 10 presents results of simulations for scenarios 2, 4, and 6, that assume increase in pension eligibility age to 65 years for both sexes. In this case, for all population projections system has large positive balance. Results look very promising. Unfortunately, it is unrealistic to assume that pension eligibility age can be increased by 5 years for males and by 10 years for females and contribution rate will stay unchanged. Decrease in contribution rate would reduce total contributions to the system and, consequently, would decrease the balance of the system. We investigate this possibility in the next section.

3.3. Sensitivity analysis

Results that are presented in the previous section can be sensitive to the values of exogenous parameters. For sensitivity analysis we expand the period of simulations to 50 years because in some cases for changes to become obvious it takes longer.

First, let's see what influence on the balance of the public pension system a simultaneous increase in pension eligibility age and reduction in contribution rate would have. For this purpose, I take scenario 4 (2nd population projection and increased pension eligibility age) and change contribution rate form 32% (as of now) to 22%. Results of simulation are presented in Figure 11. As we see, if contributions to the pension fund are reduced, pension fund would have problems even if pension eligibility age is increased.

Second, let's see how the balance of public pension system is affected by the share of employed labor that does not pay pension taxes (we should remember that as the model tracks only average wages, this parameter presents share of earned income from which pension taxes are not paid). For this purpose, I take scenario 3 (2nd population projection, current pension eligibility age) and change share of labor that doesn't make contributions to the pension system from 25% to 45% (baseline scenario is 40%). Results are presented in Figure 12. Results are very sensitive to this exogenous parameter, but even with the lowest level of 25%, public pension system becomes insolvent within next 40 years.

Third, let's see what effect total factor productivity growth has on the balance of the public pension system. For this purpose I take scenario 3 and change the assumption about total factor productivity growth from 0.5% to 5% per year (baseline scenario is 1%). Results of the simulations are presented in Figure 13. As the figure reveals, even under the assumption that average total factor

productivity growth during the next 50 years will be 3%, resources of the public pension system will be depleted within next 40 years. However, average total factor productivity growth of 5% is sufficient to keep the system solvent for the next 50 years. With such a high total factor productivity growth, balance of the public pension system reaches its maximum in 2040. After that it starts to decline rapidly. Thus, we can conclude that if we expand the period of simulation, system would become insolvent after 2050 even with such a high average total factor productivity growth. Moreover, average total factor productivity growth of 5% during the next 50 years can be regarded as a miracle, and government officials should not hope for the miracle, while planning Ukrainian pension reform.

Hence, it is possible to see that most of the extensions to the original scenarios also suggest that during the next 50 years, the Ukrainian pension system in its current setting, most likely, will not be able to sustain itself.

Figure 11. Balance of the public pension system under assumptions of scenario 4 with different levels of contributions to the pension fund (bln of UAH) (baseline scenario is 32%)

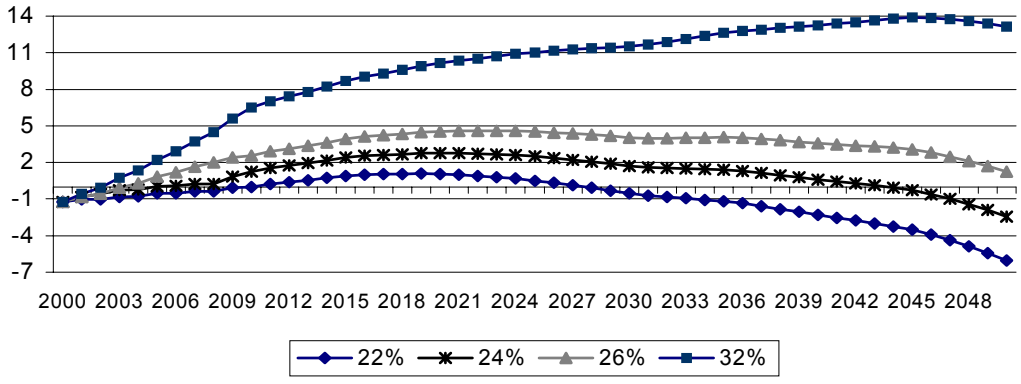


Figure 12. Balance of the public pension system under assumptions of scenario 3 with different shares of employed labor that does not make contributions to the pension fund (bln of UAH) (baseline scenario is 40%)

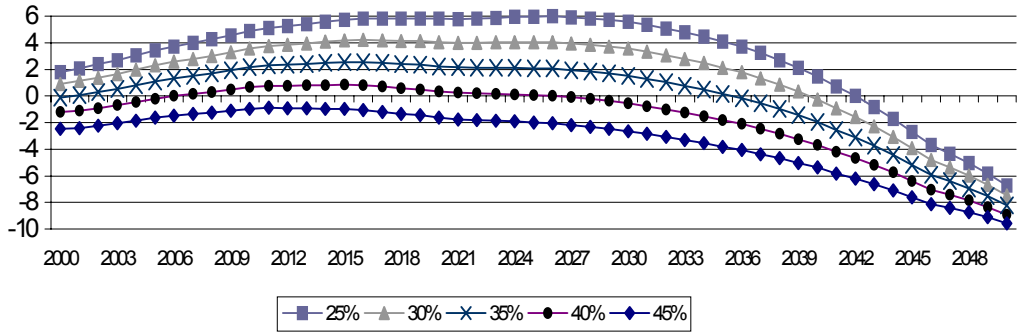
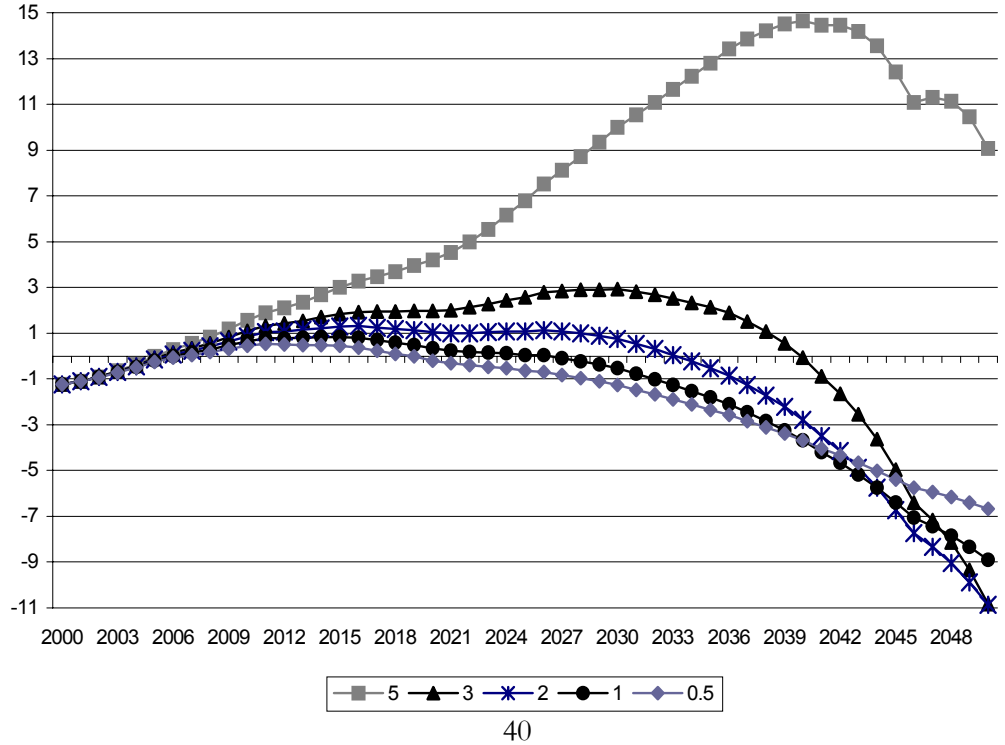


Figure 13. Balance of the public pension system under assumptions of scenario 3 with different levels of the total factor productivity growth (bln of UAH) (baseline scenario is 1%).



CONCLUSION AND POLICY IMPLICATIONS

Ukraine currently has a Pay-As-You-Go public pension system. Under this type of arrangement benefits to current retirees are paid out of the contributions of current workers. This type of system is subject to high demographic risk. If the number of workers decline and number of pensioners increase this type of system is unable to sustain itself in the long-run.

Ukraine, as well as many other countries, currently faces the problem of population aging. In case of Ukraine, this is primarily the result of the dramatically low level of fertility, which it experienced during the last half of the 20th century. This will have serious negative impact on the Ukrainian pension system if it keeps its current features.

During the next 5-10 years, the demographic situation in Ukraine is expected to improve due to the effect of the "demographic wave" discussed in the paper. But after that period, it is likely to worsen very rapidly. That is why specialists call next decade the "demographic chance for pension reform". Results of this work show how crucial it is for Ukrainian pension system to use this "demographic chance" and start serious pension reform in the nearest future.

Simulations that are performed by means of demographic-economic model developed by the International Institute for Applied System Analysis (IIASA, Laxenburg, Austria) reveal that if no changes are made to the system, then it will become insolvent during the next 30 years according to the two out of three demographic scenarios discussed.

Results are rather sensitive to the assumptions about the share of employed labor that does not contribute to the pension system and about the level of total factor

productivity growth. But even under the most favorable (out of reasonable range) assumptions about these two parameters simulations show that public pension system will become insolvent in about 40 years.

If pension eligibility age is increased, the system will have growing positive balance, but only under the assumption that contribution rate will not be reduced. But system will go bankrupt within 50 years even with moderate reduction from 32% to 26% of wage bill.

The message is clear: if current demographic trends persist, prospects of Ukrainian pension system are rather bleak. Increase of the pension eligibility age can serve as partial solution but only in the short-term.

The nature of the problem of population aging and its impact on the pension system suggests two major directions, in which we can look for a solution.

One possibility is to reduce the effect of demographic trends on the pension system. Population aging, that has significant adverse effect on Pay-As-You-Go type of systems, has no effect on the fully-funded systems. Hence, in principle a switch to fully-funded system could solve this problem. However, this is not that simple, as transition from one type of system to another is very costly. During the transition period, both systems should be financed. Workers have to accumulate funds for their retirement in fully-funded system. At the same time, pension benefits to retirees, who contributed to Pay-As-You-Go system during their working career, have to be paid out of the old system. There are two possible types of transition. One is tax-financed transition, when both systems are financed from internal sources, i.e. by taxes. Another is debt-financed transition, when government finds external sources to finance transition, for example, borrowing from international financial organizations (as was the case with Kazakhstan). Both types of transition may have very significant negative

consequences for economic situation in the country. We also should remember that although fully-funded system is not subject to demographic risk, it has other negative features. Perhaps, some combination of the two systems would do a better job than any of them by itself. This obviously calls for further research.

Another possibility is to find the way to change the demographic structure and dynamics. There are two ways to do it. First of them is increased fertility affecting policy. However; one should keep in mind that a pro-fertility policy is first of all, very difficult to implement in free and democratic society, second, it is very costly, third, it is not likely to change fertility behavior very much, and finally, this measure can affect the labor force and the pension system only in the long-run as it takes a couple of decades for the new born generation to join the labor force.

The other possible way could have desired short-term effects, but has other controversial features. It is immigration. Having an active immigration policy, Ukraine could at least partially solve the population aging problem in the short-term, as immigrants are mostly young and active people. Immigration could also have other positive effects on economic and demographic situation in the country (development of international trade, effect on the genetic pool). The effect that immigration could have on the Ukrainian pension system requires independent research. Additionally immigration raises some political issues.

To sum up, this research reveals that if demographic trends will not change dramatically in the nearest future, Ukrainian Pay-As-You-Go public pension system will not be able to serve its function in the full magnitude due to the problem of population aging. Analysis shows that increase in the pension eligibility age could partially resolve the problem. Other major options, such as transition to a fully-funded system, stimulation of fertility and implementation of an active immigration policy are areas worth exploiting.

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APPENDIX 1.

THE IIASA MODEL: ALGEBRAIC STRUCTURE (MacKellar et al 2000)

In the following pages, the algebraic structure of the IIASA model is presented and its economic logic is described. Here the single-region version of the model is described. MacKellar and Ermolieva (1999) present an earlier version of the model in two-region form.

1. Population, labor force, and employment

1.1 Population

Population is divided into age groups *age* = 0,*MaxAge* where *MaxAge* is the beginning year of the terminal age category (for example, 100= *MaxAge* if the terminal age category is 100+). Single deterministic demographic scenario consisting of population by single-year age groups is loaded from another source.

Total population is the sum over age groups

$$Pop(t) = \sum_{age=0}^{MaxAge} Pop(male,t,age) + \sum_{age=0}^{MaxAge} Pop(female,t,age) \qquad (1.1.1.)$$

1.2 Labor force and employment

Total labor force is the sum over age groups:

$$LabForce(t) = \sum_{age=15}^{MaxAge} LabForce(t.age) \qquad (1.2.1.)$$

where

$$LabForce(t) = Pop(t, age)LabForcePartRate(t, age) \qquad (1.2.2.)$$

Age-specific labor force participation rates are exogenous assumptions, as are unemployment rates:

$$\begin{aligned} Emp(t) &= \sum_{age=15}^{MaxAge} Emp(t, age) \\ Emp(t) &= LabForce(t, age)\left[1 - UnempRate(t, age)\right] \end{aligned} \qquad (1.2.3.)$$

2. Capital and the nature of claims

There are four types of capital: residential capital (*KRes*), capital operated by private unincorporated enterprises (*KPUE*), capital operated by firms and held on households' behalf by the private pension system (*KPvtPenSys*), and capital operated by firms and held on households' behalf by other financial institutions (*KOFI*). Also implicitly assigned to *OFI* are households themselves to the extent that they individually hold claims on capital operated by firms (i.e., claims that are disintermediated). Firms operate capital, either distributing or reinvesting earnings; they do not own shares in other firms. Financial claims on the capital operated by firms are held on behalf of households by institutions (*PvtPenSys* and *OFI*) which collect and distribute dividends. No distinction is made between equity and debt claims.

The private pension system is divided into two components, one of which is a partially funded defined benefit (DB) system (*PvtPenSysDB*) and the other of which is a fully funded defined contribution (DC) system (*PvtPenSysDC*). Voluntary retirement savings accumulated outside pension funds are implicitly assigned to *PvtPenSysDC*. Corresponding to each of the four types of capital is an age-specific capital accumulation equation, which tracks the accumulation of assets for each cohort as it ages. There is a structural difference between the

dynamics of *KPvtPensSys* and the dynamics of the other three asset classes. Funds flow into *PvtPenSys* only through payroll deductions (including deductions from entrepreneurial income) on behalf of system participants. Dividends earned on assets held by the *PvtPenSys* remain within the system. By contrast, savings of all origins, not just captive retirement-related savings, are invested in *KOFI, KRes, and KPUE*. Dividends earned on assets held by *OFI* accrue to households, instead of being retained by the intermediary, and may be allocated to consumption at any point during the life cycle, as may profits accruing to *KPUE*. Implicit rents on *KRes* are consumed, by assumption, in their entirety; equivalently, all housing is assumed to be owner-occupied. If saved, dividends earned on assets held by *OFI* may remain within *OFI*, or be allocated to residential investment or investment in capital operated by *PUE*.

All capital ultimately belongs to households. As described in Section 8, each single-year age-cohort is tracked as it accumulates capital during its working life and draws it down during retirement. Total assets of a cohort in a given year are

$$Ktot(t,age) = KPvtPenSys(t,age) + KRes(t,age) + KPUE(t,age) + KOFI(t,age) \qquad (2.1.)$$

which expresses a cohort's wealth as the sum of pension- and non-pension wealth.

3. Output and rates of return to factors

3.1 GDP, wage rate, and rate of return to capital

Gross domestic product (*GDP*) is given by a Cobb-Douglas production function

$$GDP(t) = \alpha(1+g)^t \, KTot(t)^{\beta} \, Emp(t)^{1-\beta} \qquad (3.1.1.)$$

where *g*, the rate of total factor productivity growth, is exogenous. Rates of return to factors are neoclassical:

$$R(t) = \beta\left[\frac{GDP(t)}{KTot(t)}\right] \tag{3.1.2.}$$

$$\overline{WageRate}(t) = (1-\beta)\left[\frac{GDP(t)}{Emp(t)}\right] \tag{3.1.3.}$$

where *R* is the gross profit rate, including depreciation and indirect taxes net of subsidies; and *WageRate* is average (over age groups) employee compensation, including social insurance contributions (contributions to public and private pension schemes).

In order to net depreciation and indirect taxes out of the rate of return to capital, we define

$$r(t) = R(t) - \frac{IndTaxRate(t)GDP(t)}{KTot(t)} - DeprRate(t) \tag{3.1.4.}$$

where *IndTaxRate* is defined with respect to *GDP* and *DeprRate* is the depreciation rate. The advantage of netting out depreciation and indirect taxes immediately is that we can henceforth ignore them in calculating income, outlay, and net savings.

3.2 Age-specific wage rates

In a model with age-structure detail, we require a procedure to ensure that the average wage rate calculated from the marginal productivity condition above equals the average wage rate calculated by summing across age groups. In practice, this means that age-specific wage rates must be adjusted to be consistent

with the overall average wage rate. We have approached this problem by defining a scale factor *σ (t,age)* and then calculating age-specific wage rates as

$$WageRate(t,age) = \sigma(t,age)\overline{WageRate}(t) \qquad (3.2.1.)$$

σ (t,age), a proxy for human capital, is specified to be logarithmic in age and parameterized so that wages rise rapidly in the twenties and thirties, the average wage over the life cycle is earned at approximately age 45, and there is little increase after 55. The required consistency condition is

$$\overline{WageRate}(t) = \frac{\sum_{age=15}^{MaxAge} Mult(t,age)\sigma(t,age)\overline{WageRate}(t)Emp(t,age)}{\sum_{age=15}^{MaxAge} Emp(t.age)} \qquad (3.2.2.)$$

To simplify the problem, let *Mult(t,age)* to be the age-invariant

$$Mult(t) = \frac{\overline{WageRate}(t)\sum_{age=15}^{MaxAge} Emp(t)age}{\sum_{age=15}^{MaxAge} \sigma(t,age)\overline{WageRate}(t)Emp(t,age)} = \frac{\sum_{age=15}^{MaxAge} Emp(t,age)}{\sum_{age=15}^{MaxAge} \sigma(t,age)Emp(t,age)}$$

(3.2.3.)

This variable can be interpreted as total "nominal" employment relative to total "effective," i.e. human capital adjusted employment. Then the identity required for consistency may be rewritten

$$\overline{WageRate}(t) = \frac{\sum_{age=15}^{MaxAge} \left\{ \frac{\sum_{age=15}^{MaxAge} Emp(t,age)}{\sum_{age=15}^{MaxAge} \sigma(t,age) Emp(t,age)} \sigma(t,age) \overline{WageRate}(t) Emp(t,age) \right\}}{\sum_{age=15}^{MaxAge} Emp(t,age)}$$

(3.2.4.)

Moving age-invariant terms outside the braces,

$$\overline{WageRate}(t) = \frac{\frac{\sum_{age=15}^{MaxAge} Emp(t,age)}{\sum_{age=15}^{MaxAge} \sigma(t,age) Emp(t,age)} \overline{WageRate}(t) \sum_{age=15}^{MaxAge} \sigma(t,age) Emp(t,age)}{\sum_{age=15}^{MaxAge} Emp(t,age)}$$

(3.2.5.)

which will clearly always hold true. Therefore, we calculate

$$WageRate(t,age) = Mult(t)\sigma(t,age)\overline{WageRate}(t) \qquad (3.2.6.)$$

where *Mult(t)* is as defined above.

4. Income, capital transfers, outlay, and net saving of households

The articulation of income flows elaborated below has two main purposes. The first is to disaggregate income and consumption by age. The second is to make explicit the role of the private pension system in saving and the allocation of capital.

4.1 Income

The sources of household income are wages, imputed rents from residential capital, profits which accrue to capital operated by unincorporated enterprises, dividends distributed from earnings on capital operated by firms, public social security system benefits, and private pension benefits.

4.1.1 A note on taxation

The taxation of factor incomes in this model follows three simplifying assumptions. First, factor income is taxed once and only once, when it is earned. Thus, dividend income is not taxed because profits have already been taxed at the level of the firm; similarly, there is no capital gains tax when assets are sold because capital gains reflect profits which have already been taxed. Second, no distinction is made from a taxation point of view between different types of capital: profits on capital operated by firms, capital operated by private unincorporated enterprises, and the imputed services of residential housing are all assumed to be taxed at the same rate. Third, tax rates are not indexed by income or age.

4.1.2 Wage income

Disposable wage income is equal to gross wages minus direct taxes minus social insurance contributions to the public PAYG and private pension systems:

$$WageY(t,age) = WageRate(t,age)Emp(t,age) \qquad (4.1.2.1.)$$

$$DispWageY(t,age) = WageY(t,age) - DirTaxWageY(t,age) - \\ - ContPubSysWageY(t,age) - ContPenSysWageY(t,age) \qquad (4.1.2.2.)$$

where *ContPvtPenSysWageY (t,age)* consists of the sum of contributions to the DB and DC components of the private pension system. Calculations of direct taxes and pension system contributions are described in Sections 6 and 7, respectively. Note that, even though *PvtPenSys* contributions really represent the acquisition of a financial asset, rather than a current expenditure flow, the System of National Accounts (SNA) nonetheless counts such transactions as a debit in the calculation of disposable income. However, an adjustment is made (see Section 4.1.9) to ensure that the savings associated with such flows are credited to households.

4.1.3 Rental income

Imputed rental income is assumed to be taxed like any other form of income; however, social contributions are assumed to be zero:

$$RntlY(t,age) = r(t)K\,\mathrm{Re}\,s(t,age) \tag{4.1.3.1.}$$

$$DispRntlY(t,age) = RntlY(t,age) - DirTaxRntlY(t,age) \tag{4.1.3.2.}$$

Recall, from Section 3.1, that capital returns are already net of depreciation and indirect taxes.

4.1.4 Entrepreneurial income

Profits from capital operated by unincorporated enterprises are treated the same as wages:

$$EntrY(t,age) = r(t)KPUE(t,age) \tag{4.1.4.1.}$$

$$\begin{aligned} DispEntrY(t,age) = {} & EnrtY(t,age) - DIrTaxEntrY(t,age) \\ & - ContrPubPenSysEntrY(t,age) \\ & - ContrPvtPenSysEntrY(t,age) \end{aligned} \tag{4.1.4.2.}$$

4.1.5 Dividend income

The assets held on households' behalf by *PvtPenSys* and *OFI* earn dividends. However, in the first case, dividends are not considered by the SNA to be part of household income; rather, they are considered to represent the acquisition of a financial asset. The adjustment described in Section 4.1.9 will add these dividend earnings captured by the private pension system to household income. Unadjusted household disposable income includes only dividends on assets held by *OFI*:

$$DividY(t, age) = DividDistErningsFirmsKOFI(t.age) \qquad (4.1.5.1.)$$

The calculation of distributed earnings is given below in Section 5.2.2. Having already been taxed when earned, dividend earnings are not taxed when received by households. Disposable dividend income is thus simply:

$$DispDividY(t, age) = DividY(t, age) \qquad (4.1.5.2.)$$

4.1.6 Pensions income

Pension income comes from three sources: the public PAYG pension system, the private DC pension system, and the private DB pension system. All three systems provide benefits, which are current transfers in the first case and, while representing sales of capital assets in the second two cases, are nonetheless considered for accounting purposes to represent income. The calculation of pension benefits is described in Section 7. In addition, as described in Section 7.2.2, in any year, some persons will change jobs and a given proportion of these will choose to withdraw their assets from the private pension system rather than rolling them over into new plans. These withdrawals are also treated as income. We assume that withdrawals occur only from the DC pension system. While this

point is debatable, however, most countries have in place measures that strongly encourage job-switchers to transfer their DB pension assets into another plan. (The logic behind this is that, on retirement, the benefit entitlement from the private DB pension scheme is calculated on the basis of years of participation and earnings. If we were to allow withdrawal of assets, it would be necessary to "restart the clock" every time assets were withdrawn, or to link benefits with accumulated assets (as in the DC private pension system) rather than earnings.).Combining the two components of the private pension system,

$$PensionY(t, age) = BenPubPenSys(t, age) + BenPvtPenSys(t, age) + WthdrwlKPvtPenSys(t, age) \quad (4.1.6.1.)$$

Public pension income is subject to taxation because it is a current transfer. Private pension income and early withdrawals from the DC pension system are not taxed because these represent the sale of capital assets whose returns were taxed at the level of the firm. Disposable pension income is therefore

$$DispPensionY(t, age) = [1 - DirTaxRate(t)]BenPubPenSys(t, age) + BenPvtPenSys(t, age) + WthdrwlKPvtPenSys(t, age) \quad (4.1.6.2.)$$

Since private pension system benefits represent the drawing-down of a capital asset, they are included in the adjustment to disposable income described in Section 4.1.9. Early withdrawals (usually in consequence of job change) from the DC private pension system are described in Section 4.2.3; these are also included in the adjustment to disposable income described below.

4.1.7 Total income

Total income of households is equal to the sum over all income sources:

$$TotYHH(t,age) = WageY(t,age) + RntlY(t,age) + EntrY(t,age) + DividY(t,age) + PensionY(t,age) \quad (4.1.7.1.)$$

4.1.8 Disposable income

Disposable income is analogous:

$$DispYHH(t,age) = DispWageY(t,age) + DispRntlY(t,age) + DispEntrY(t,age) + DispDividY(t,age) + DispPensionY(t,age) \quad (4.1.8.1.)$$

4.1.9 Adjusted disposable income.

Adjusted disposable income is equal to disposable income

- plus contributions to *PvtPenSys*,
- plus dividends earned on assets held by *PvtPenSys*,
- minus benefits received from *PvtPenSys*.
- minus early withdrawals from the defined contribution private pension system (see Section 4.2.3)

Thus,

AdjDispYHH (t,age) =
DispYHH(t,age)+ContPvtPenSys(t,age)+DividKPvtPenSys(t,age) (4.1.9.1.)
–BenPvtPenSys(t,age) -- WthdrwlKPvtPenSysDC

where the third term represents the sum over DB and DC components of the private pension systems of dividends paid out by firms (given in Sections 7.2.1 and 7.3.1, respectively).

Adjusted disposable income is close to, but not exactly the same as, disposable income plus change in pension wealth. The latter would be equal to

$$\Delta KPvtPenSys(t,age)= ContPvtPenSys(t,age)+DividKPvtPenSys(t,age)--BenPvtPenSys(t,age) –BeqKPvtPenSys(t,age) –WthdrwlKPvtPenSysDC(t,age) \quad (4.1.9.2.)$$

where *BeqKPvtPenSys(t,age*) reflects the fact that upon the death of the claimant, accumulated pension assets are paid out to heirs.(From the standpoint of calculating individual wealth, the bequest term is irrelevant, because the individual must die in order to bequeath. In calculating cohort wealth, however, bequests must be taken into account) There is no accounting for inheritance of pension wealth because paying-out is assumed to take the form of cash allocated either to consumption or to the acquisition of non-pension capital assets. Stated differently, there is no explicit modeling of survivors' benefits, which amount to reassigning title to existing pension assets. In conclusion, we could also write

$$AdjDispYHH(t,age)=DispYHH(t,age) + \Delta KPvtPenSys(t,age)+ BeqPvtPenSys(t,age) \quad (4.1.9.3.)$$

4.2 Capital transfers

Resources available for household consumption take the form of disposable income and the proceeds of transferring claims to capital assets. In this section, the second of these is elaborated.

4.2.1 Annuitization of assets in old age

Starting at the pension eligibility age, households are assumed to divest themselves of non-pension assets in a way calculated to exhaust assets at age 100. This "annuitization" process -- which we model for simplicity's sake just as a program of asset sales -- is assumed to begin whether households are still in the labor force or not. For [•]=*Res, PUE, OFI,* annuity income is:

$$AssetSalesK[\bullet](t, age) = \frac{K[\bullet](t, age)}{100 - age} \quad , age \geq EligAge \qquad (4.2.1.1.)$$

If the propensity to consume out of the proceeds of asset sales is unity, there is no bequest motive; if, for example, the propensity is 0.95, elderly households aim to die with 5 percent of their wealth intact, etc. Note that it is assumed that no assets are sold prior to retirement, apart from the special case of assets received via inheritance and the withdrawal of DC pension assets associated with job change, which we discuss in the next sections.

4.2.2. Bequests/Inheritance

In all asset classes, age-specific bequests are equal to assets times the proportion of persons in the age group dying. For [•]=*Res, PUE, OFI, PvtPenSysDC, PvtPenSysDB*:

$$BeqK[\bullet](t, age) = K[\bullet](t, age)\left[\frac{Deaths(t, age)}{Pop(t-1, age-1)}\right] \qquad (4.2.2.1.)$$

Without question, DC pension system assets, like non-pension wealth, belong to the individual and are heritable. As we discuss in Section 8.2, the case of assets of the DB pension system is more debatable. Bequests are received, in the form of

inheritance, by the surviving population. For simplicity, we estimate age-specific inheritance simply by dividing total bequests by population age shares. We exclude the population under age 15. Total bequests are

$$BeqK[\bullet](t) = \sum_{age=15}^{MaxAge} BeqK[\bullet](t, age) \qquad (4.2.2.2.)$$

and inheritance (for age groups over 15) is

$$InhK[\bullet](t, age) = \left[\frac{Pop(t, age)}{\sum_{age=15}^{MaxAge-1} Pop(t, age)} \right] \sum_{age=15}^{MaxAge} BeqK[\bullet](t, age) \qquad (4.2.2.3.)$$

Summing over age groups,

$$InhK[\bullet](t) = \sum_{age=15}^{MaxAge} InhK[\bullet](t, age) \qquad (4.2.2.4.)$$

This simplification admittedly exaggerates the number of "backwards" bequests (elderly persons inheriting wealth from middle-aged persons, who are in fact more likely to bequeath assets to their children than to their parents). (One expedient way to solve this problem is to assume that only persons under some age, say 65, but this runs the danger of failing to account for significant spousal bequests. Ultimately, a vector of age-specific share coefficients should be applied to allocate bequests from persons of a given age group over heirs by age group) The assumption is made that, when wealth is inherited, it is converted to cash, some of which is allocated to consumption and the remainder of which is allocated among *.KOFI*, *.KRes*, and *.PUE* using the same share coefficients applied to household net saving (see Section 8.3). Note, however, that the portion

not consumed does not comprise new household savings; it represents the acquisition of a claim formed as the result of past saving.

Under these assumptions, sales of inherited assets are

$$SaleInhK[\bullet](t, age) = InhK[\bullet](t, age) \qquad (4.2.2.5.)$$

Consumption out of the proceeds of such sales is described in Section 4.3.4.

4.3 Outlay

4.3.1 Direct taxes.

These are described in Section 6.1.

4.3.2 Social insurance contributions

These are described in Section 7.

4.3.3. Consumption out of income

Average propensities to consume (*AvgPropCons*) out of disposable income streams are exogenous assumptions:

ConsWageY (t,age) = DispWageY(t,age) AvgPropConsWageY(t,age) (4.3.3.1.)

ConsEntrY(t,age) = DispEntrY(t,age) AvgPropConsEntrY(t,age) (4.3.3.2.)

ConsDividY(t,age) = DispDividY(t,age) AvgPropConsDividY(t,age) (4.3.3.3.)

ConsBenPubPenSys(t,age) = BenPubPenSys(t,age) AvgPropConsBenPubPenSys(t,age) (4.3.3.4.)

ConsBenPvtPenSysDC(t,age) =

BenPvtPenSysDC(t,age) AvgPropConsBenPvtPenSysDC(t,age) (4.3.3.5.)

ConsBenPvtPenSysDB(t,age) =

BenPvtPenSysDB(t,age) AvgPropConsBenPvtPenSysDB(t,age) (4.3.3.6.)

It is assumed that all imputed housing services are consumed:

ConsRntlY(t,age)=DispRntlY(t,age) (4.3.3.7.)

4.3.4 Consumption out of the proceeds of asset sales.

It is assumed that consumption out of the proceeds of asset sales takes place in the year of the sale, i.e., households do not hold liquid balances.

4.3.4.1 Consumption out of the proceeds of selling inherited assets

For [•]=*Res, PUE, OFI, PvtPenSysDC, PvtPenSysDB* consumption out of the sales of inherited assets is

ConsSaleInhK[•](t,age)=*SaleInhK*[•](t,age) *ConsShareSaleInhK* [•](t,age) (4.3.4.1.1.)

and the sharing-out of what is not consumed between Δ*KOFI*, Δ *KRes*, and . Δ*KPUE* is described in Section 8.3 below. We use a mnemonic corresponding to "consumption share" instead of *AvgPropCons* because average propensity to consume is properly considered with reference to income.

4.3.4.2 Consumption out of retirement annuity income.

Consumption in old age financed by the sale of assets accumulated during working life is treated in the same way. Because private pension system benefits

are classified for purposes of the SNA as income, rather than capital transfers, this component has already been described above. For the remaining components [•]=*OFI, PUE, Res*:

ConsAssetSalesK[•]*(t,age)*=*AssetSalesK*[•]*(t,age)ConsShareAssetSalesK*[•]*(t,age)* (4.3.4.2.1.)

As mentioned above in discussion private pension system benefits, if there is no bequest motive, the consumption shares are assumed to be unity. However, this assumption can be generalized to allow for bequests. In this case, the complement of the consumption share is simply the proportion of wealth upon retirement which households wish to bequeath.

4.3.4.3 Consumption out of the proceeds of selling DC pension assets withdrawn in consequence of job change.

The final component of consumption is:

ConsWthdrwlKPvtPenSysDC(t,age)=
WthdrwlKPvtPenSysDC(t,age) ConsShareWthdrwlKPvtPenSys(t,age) (4.3.4.3.1.)

Early withdrawals from the private defined-benefit pension system are assumed to be zero.

4.4 Net savings of households

Recapitulating, disposable and adjusted disposable household incomes are

DispYHH(t,age)=
DispWageY(t,age)+*DispRntlY(t,age)*+*DispEntrY(t,age)*
+ *DispDividY(t,age)* + *DispPensionY(t,age)* (4.4.1.)

$$AdjDispYHH(t,age)= DispYHH(t,age) + ContPvtPenSys(t,age) + DividPvtPenSys(t,age - BenPvtPenSys(t,age) — WthdrwlKPvtPenSysDC(t,age) \quad (4.4.2.)$$

and total consumption is

$$\begin{aligned} PvtCons(t,age)= & \\ & ConsDispWageY(t,age) + ConsDispRntlY(t,age) + ConsDispEntrY(t,age) \\ & + ConsDispDvidY(t,age) + ConsDispPensionY(t,age) \\ & + ConsSaleInhKRes(t,age) + ConsSaleInhKPUE(t,age) \\ & + ConsSaleInhKOFI(t,age) + ConsSaleInhKPvtPenSysDC(t,age) \\ & + ConsAassetSalesKOFI(t,age) + ConsAssetSalesKRes(t,age) \\ & + ConsAssetSalesPUE(t,age) \\ & + ConsWthdrlKPvtPenSysDC(t,age) \end{aligned} \quad (4.4.3.)$$

The first two lines on the right-hand side give consumption out of income (including pension income), the second two lines give consumption financed by the sale of inherited assets, the third two lines gives consumption out of annuity income, and the seventh line covers consumption which occurs when a worker changes jobs and elects to withdraw DC pension assets.

Household net saving is the difference between disposable income and consumption:

$$NetSvngHH(t,age)= DispYHH(t,age)- PvtCons(t,age) \quad (4.4.4.)$$

and adjusted net savings includes savings captured by the private pension system:

$$AdjNetSvngHH(t,age)= AdjDispYHH(t,age)-PvtCons(t,age) \quad (4.4.5.)$$

or, expressing in terms of unadjusted disposable income and change in pension wealth (see Section 4.1.9),

AdjNetSvngHH(t,age)=

DispYHH(t,age)+Δ *KPvtPenSys(t,age)*+ *BeqKPvtPenSys(t,age)*- *PvtCons(t,age)* (4.4.6.)

In performing the consistency check in Section 9 below, we will use this identitiy in the form

NetSvngHH(t,age)=
AdjNetSvngHH(t,age)—Δ*KPvtPenSys(t,age)*+ *BeqKPvtPenSys(t,age)* (4.4.7.)

5. Income, outlay, and net savings of firms

Firms operate capital, earn profits and pay out direct taxes and dividends.

5.1 Income

Earnings of firms consist of earnings on capital owned by the three institutional claimants [•]= *OFI, PvtPenSysDB, PvtPenSysDC*:

ErngsFirmsK [•] *(t,age)* = *r(t) K*[•]*(t,age)* (5.1.1.)

$$ErndsFirmsK[\bullet](age) = \sum_{age=0}^{MaxAge} ErngsFirmsK[\bullet](t, age) \quad (5.1.2.)$$

Recall that depreciation and indirect taxes have already been netted out.

5.2 Outlay

5.2.1 Direct taxes

Taxes on profits are described in Section 6.1.

5.2.2 Dividends

Dividend distributions are made out of pre-tax earnings, and the proportion of earnings distributed is independent of the claimant by assumption. For the three claimants [•]=*OFI, PvtPenSysDB, PvtPenSysDC:*

DividDistErngsFirmsK[•]*(t,age)* = *DividDistShare(t)* *ErngsFirmsK*[•]*(t,age)* (5.2.2.1.)

$$DividDistErngsFirmsK[\bullet](t) = \sum_{age=0}^{MaxAge} DividDistErngsFirmsK[\bullet](t, age) \quad (5.2.2.2)$$

where the share of earnings distributed as dividends is an exogenous variable.

5.3 Net savings of firms

Net savings (retained earnings) of firms are

NetSvngErngsFirmsK[•]*(t,age)*=*ErngsFirmsK*[•]*(t,age)*
-- *DirTaxErngsFirmsK*[•]*(t,age)* -- *DividDistErngsFirmsK*[•]*(t,age)* (5.3.1.)

The sum over claimants is total net savings of firms:

$$NetSvngFirms(t, age) = \sum_{[\bullet]} NetSvngErngsFirmsK[\bullet](t) \quad (5.3.2.)$$

and the sum over age groups gives total corporate savings:

$$NetSvngFirms(t) = \sum_{age=0}^{MaxAge} NetSvngFirms(t, age) \qquad (5.3.3.)$$

6. Income, outlay, and net savings of government

The government sector is rudimentary. Government consumes an exogenous share of GDP, collects taxes and social security contributions and pays social security benefits.

6.1 Income

Government revenues are

$$GovRev(t) = IndTax(t) + DirTax(t) + ContPubPenSys(t) \qquad (6.1.1.)$$

where

$$IndTax(t) = IndTaxRate(t)\ GDP(t) \qquad (6.1.2.)$$

$$DirTax(t) = \sum_{age=15}^{MAxAge} DirTaxWageY(t, age) + \sum_{age=15}^{MaxAge} DirTaxEntrY(t, age) + \\ + \sum_{age=EligAge}^{MaxAge} DirTaxRntlY(t, age) + \\ + \sum_{age=15}^{MAxAge} DirTaxBenPubPenSys(t, age) + \sum_{age=0}^{MaxAge} \sum_{[\bullet]} DirTaxErngsFirmsK[\bullet] \qquad (6.1.3)$$

where $[\bullet]$=*OFI, PvtPenSysDB, PvtPenSysDC* and the direct tax streams are

$$DirTaxWageY(t,age) = DirTaxRate(t,age)\ WageY(t,age) \qquad (6.1.4.)$$

$$DirTaxRntlY(t,age) = DirTaxRate(t,age)\ RntlY(t,age) \quad (6.1.5.)$$

$$DirTaxEntr\ Y(t,age) = DirTaxRate(t,age)\ EntrY(t,age) \quad (6.1.6.)$$

$$DirTaxBenPubPenSys(t,age) = DirTaxRate(t,age)\ BenPubPenSys(t,age) \quad (6.1.7.)$$

$$DirTaxErngsFirmsK[\bullet](t,age) = DirTaxRate\ \ ErngsFirmsK[\bullet](t,age) \quad (6.1.8.)$$

Contributions to the public pension system are described in Section 7.1.1.

6.2 Outlay

Government expenditure is:

$$GovExp(t) = GovCons(t) + BenPubPenSys(t) \quad (6.2.1.)$$

where government consumption is taken simply as a fixed share of GDP:

$$GovCons(t) = GovConsShare\ (t)\ GDP\ (t) \quad (6.2.2.)$$

and benefits paid out by the public pension system are described in Section 7.1.2.1

6.3 Net savings of government

Government net savings are

$$NetSvngGov(t) = GovRev(t) - GovExp(t) \quad (6.3.1.)$$

Net savings of government are allocated across age groups using shares drawn from the age-distribution of wealth:

7. Pension system

7.1 Public DB PAYG pension system

7.1.1 Income

Contributions to the public pension system out of wages are

$$ContPubPenSysWageY(t,age)=PubPenSysContRate(t)WageY \qquad (7.1.1.1.)$$

The social security contribution rate *PubPenSysContRate(t)* is assumed to be age-independent. No distinction is made between employees' and employers' contributions. Social security contributions out of entrepreneurial income are calculated similarly:

$$ContPubPenSysEntrY(t,age)=PubPenSysContRate(t)EntrY((t,age)) \qquad (7.1.1.2.)$$

Contribution rates out of wage and entrepreneurial income are assumed to be the same.

Total social security system revenues out of each income stream are

$$ContPubPenSysWageY(t)=\sum_{age=15}^{MaxAge} ContPubPenSysWageY(t,age) \qquad (7.1.1.3.)$$

$$ConrPubPenSysEntrY(t)=\sum_{age=15}^{MaxAge} ContPubPenSysEntrY(t,age) \qquad (7.1.1.4.)$$

and the system total is:

$$ContPubPenSys\ (t)= ContPubPenSysWageY(t) + ContPubPenSysEntrY(t) \qquad (7.1.1.5.)$$

7.1.2 Outlay

The public pension system is assumed to be a DB system financed on a Pay As You Go (PAYG) basis. Let *BenEntPubPenSys(t, age, RtrmntDuration)* be the social security benefit entitlement for the average person aged *age* who retired *RtrmntDuration* years ago, where we assume that *BenEntPubPenSys(t,age,0) = 0*. The pension for persons entering retirement is computed according to the formula:

$$BenEntPubPenSys(t, age,1) = \text{Re } plRatePubPenSys(t) \frac{\left(\sum_{j=1}^{age-14} LabForcePartRate(t-j, age-j) \right)}{age-14} \frac{\left(\sum_{k=1}^{\text{Re } fPeriod} WageRate(t-k, age-k) \right)}{\text{Re } fPeriod} \quad (7.1.2.1.)$$

ReplRatePubPenSys(t) is a coefficient of proportionality which translates earnings into an initial pension entitlement. This replacement ratio is applied to the average labor force participation rate between age 15 and *age* (assuming *age*≥*EligAge*) times average annual earnings during the *RefPeriod* years prior to retirement.

Social security system benefits paid out by age group of recipient are equal to the age- and retirement-duration specific entitlement times the number of recipients:

$$BenPubPenSys(t, age) = \sum_{RtrmntDuration=0}^{MaxAge-EligAge+1} BenEntPubPenSys(t, age, RtrmntDuration) Pop(t, age.RtrmntDuration) \quad (7.1.2.2.)$$

where, making the simplifying assumption that once retired, persons stay retired,

$$Pop(t, age, RtrmntDuration) = Pop(t, age)$$
$$\left[\begin{array}{l} LabForcePartRate(t - RtrmntDuration, age - RtrmntDuration) \\ - LabForcePartRate(t - RtrmntDuration + 1, age - RtrmntDuration + 1) \end{array}\right] \quad (7.1.2.3.)$$

for $\text{age} = \overline{1, \text{age - RtrmntAge} + 1}$. System-wide expenditures are equal to the summation over age groups

$$BenPubPenSys(t) = \sum_{age=EligAge}^{MaxAge} BenPubPenSys(t, age) Pop(t, age)$$

7.1.3 System balance

In a classic PAYG system total contributions equal total benefits; there is neither accumulation of a return-generating surplus nor a deficit to be financed out of general government revenue. The default model solution option is one in which the required contribution rate is calculated by setting contributions equal to expenditures. However, there are cases where nominally PAYG public pension systems are currently running large surpluses in an effort to pre-finance the retirement of the baby boom generation. In other cases, deficits in the PAYG pension system are financed by transfers from general tax revenue. To cover such cases, an alternative solution option is to set the contribution rate independent of benefits, in which case the model solves for the implied surplus or deficit. In this case, the balance of the social security system is:

BalPubPenSys(t)= *ContPubPenSys* (t) -- *BenPubPensSys* (t) (7.1.3.1.)

7.2 Private DC pension system

7.2.1 Revenue.

Income of the private DC pension system is comprised of (1) current contributions (zero for persons who have retired), and (2) receipt of dividends. (1) is the sum over contributions out of wage and entrepreneurial income, each consisting of the share of the workforce participating times the proportion of total income contributed:

ContPvtPenSysDCWageY(t,age)=

[*PartSharePvtPenSysDC ContRatePvtPenSysDCWageY(t,age)*] *WageY(t,age)* (7.2.1.1.)

ContPvtPenSysDCEntrY(t,age)=

[*PartSharePvtPenSysDC ContRatePvtPenSysDCEntrY*] *EntrY(t,age)* (7.2.1.2.)

Total contributions and dividend earnings are

ContPvtPenSysDC(t,age)=

ContPvtPenSysDCWageY(t,age)+ContPvtPenSysDCEntrY(t,age) (7.2.1.3.)

and

$$DividPvtPenSysDC(t) = \sum_{age=15}^{MaxAge} DividDistErngsFirmsKPvtPenSysDC(t, age) \quad (7.2.1.4.)$$

where the paying-out of dividends was described in Section 5.2.2.

7.2.2. Expenditure

Expenditures of the private DC pension are (1) benefits paid out (zero for persons still in the labor force), (2) pay-out to heirs of the pension assets of system participants who die, and (3) withdrawal of assets by job-switchers who choose not to roll over their pension wealth into another plan. (1) is analogous to the "annuitization" of non-pension capital assets described in Section 4.2.1 above, with the difference that only those who have left the labor force receive pension benefits:

$$BenPvtPenSysDC(t,age) = \left[1 - LabForcePartRate(t,age)\right] \frac{KPvtPenSysDC(t,age)}{100 - age} \qquad (7.2.2.1.)$$

where $age \geq EligAge$. and 100 is the maximum age to which a person expects to live. (2) was described above in Section 4.2.2. (3) is calculated using an exogenously assumed withdrawal rate reflecting both the number of job-changes and the proportion who choose not to roll over their assets:

$$WthdrwlPvtPenSysDC(t,age) = WthdrwlRatePvtPenSysDC(t,age)\ KPvtPenSysDC(t,age) \qquad (7.2.2.2.)$$

If, for example, 10 percent of system participants change jobs every year and half choose to withdraw their assets, we would have $WthdrwlRatePvtPenSysDC = .05$.

7.3 Private DB pension system

7.3.1 Revenue

This is analogous to the public pension system:

ContPvtPenSysDBWageY(t,age)=

[*PartSharePvtPenSysDB(t,age) ContRatePvtPenSysDB(t,age)*] *WageY(t,age)* (7.3.1.1.)

ContPvtPenSysDBEntrY(t,age)=

[*PartSharePvtPenSysDB(t,age) ContRatePvtPenSysDB(t,age)*] *EntrY(t,age)* (7.3.1.2.)

and total contributions are the sum over the two sources:

ContPvtPenSysDB(t,age)=

ContPvtPenSysDBWageY(t,age)+ContPvtPenSysDBEntrY(t,age) (7.3.2.3.)

Age-specific dividends are

DividKPvtPenSysDB(t,age)= DividDistErngsFirmsKPvtPenSysDB(t,age) (7.3.2.4.)

where the paying-out of dividends by firms is described in Section 5.2.2. The total over age groups is

$$DividPvtPenSysBDB(t) = \sum_{age=15}^{MaxAge} DividKPvtPenSysDB(t, age) \qquad (7.3.2.5.)$$

7.3.2 Expenditure

The average private DB pension entitlement for a newly-retired person is calculated similarly to the average initial public pension entitlement:

$$BenEntPvtPenSysDB(t, age, 1) = \left[PartSharePvtPenSysDB \,\mathrm{Re}\, plRatePvtPenSysDB(t)\right] \frac{\left(\sum_{j=1}^{age-14} LabForcePartRate(t-j, age-j)\right)\left(\sum_{k=1}^{\mathrm{Re}\, fPeriod} WageRate(t-k, age-k)\right)}{age-14 \qquad \mathrm{Re}\, fPeriodPvtPenSysDB}$$

(7.3.2.1.)

Benefits are

$$BenPvtPenSysDB(t,age) = \sum_{RtrmntDuration=0}^{MaxAge-EligAge+1} BenEntPvtPenSysDB(t,age,RtrmntDuration)Pop(t,age,RtrmntDuration) \quad (7.3.2.2.)$$

We assume that *RtrmntDuration* is the same for the public PAYG and private DB pension systems. The total benefits paid out are

$$BenPvtPenSysDB(t) = \sum_{age=EligAge}^{MaxAge} BenPvtPenSysDB(t,age)Pop(t,age) \quad (7.3.2.3.)$$

Bequests of DB pension system assets were described in Section 4.2.2. Recall that withdrawals from the DB pension system associated with job-change were assumed to be zero.

7.4 Total private pension system contributions and benefits

Private pension system totals are

$$ContPvtPenSysWageY(t,age) = ContPvtPenSysDCWageY(t,age) + ContPvtPenSysDBWageY(t,age) \quad (7.3.2.4.)$$

$$ContPvtPenSysEntrY(t,age) = ContPvtPenSysDCEntrY(t,age) + ContPvtPenSysDBEntrY(t,age) \quad (7.3.2.5.)$$

$$DividKPvtPenSys(t,age) = DividKPvtPenSysDC(t,age) + DividKPvtPenSysDB(t,age) \quad (7.3.2.6.)$$

$$BenPvtPenSys(t,age) = BenPvtPenSysDB(t,age) + BenPvtPenSysDC(t,age) \quad (7.3.2.7.)$$

8. The life-cycle dynamics of capital accumulation

Corresponding to each of the types of capital *KPvtPenSysDC*, *KPvtPenSysDB*, *KRes*, *KPUE* and *KOFI* is an age-specific capital accumulation identity.

8.1 DC private pension system

Change in age-specific private DC pension wealth is

$$\Delta KPvtPenSysDC(t,age) = ContPvtPenSysDC(t,age) + DividKPvtPenSysDC(t,age) - BenPvtPenSysDC(t,age) - BeqKPvtPenSysDC(t,age) - WthdrwlKPvtPenSysDC(t,age) \quad (8.1.1.)$$

The most important characteristic of the private DC pension system is that there is a fixed relationship between the amount a cohort pays in during its working life and the amount it receives after retirement. For an individual cohort born in year $t = 0$ whose last members die out in year $t = 100$ lifetime pension contributions plus lifetime earnings on pension assets minus lifetime pension benefits received equals bequest of pension wealth. Expressing this differently,

$$\sum_{t=0}^{100}\sum_{age=15}^{100}\Delta KPvtPenSysDC(t,age) = \sum_{t=0}^{100}\sum_{age=15}^{100}\begin{bmatrix} ContPvtPenSysDC(t,age) \\ + DividPvtPenSysDC(t,age) \\ - BenPvtPenSysDC(t,age) \\ - BeqKPvtPenSysDC(t,age) \\ - WthdrwlKPvtPenSysDC(t,age) \end{bmatrix} = 0 \quad (8.1.2.)$$

8.2 DB private pension system

Contributions to the private DC pension system purchase an asset, which is owned by the system participant who made the contribution. Contributions into

the private DB pension system, by contrast, purchase a claim on a future pension to be paid by the firm, which is in turn backed by an asset acquired by the firm. The question of whether assets backing a DB pension scheme belong to system participants or to the firm is a complicated one, and legal regimes differ from country to country. For accounting purposes, however, we treat assets of the DB pension system the same way we treat assets of the DC pension scheme.

$$\Delta KpvtPenSysDB(t,age) = ContPvtPenSysDB(t,age) + DividPvtPenSysDB(t,age) - BenPvtPenSysDB(t,age) - BeqKPvtPenSysDB(t,age) \quad (8.2.1.)$$

For very aged cohorts, unlike in the case of the DC pension scheme, DB pension wealth can be negative. In this case, there is a negative "inheritance" upon death; however, with reasonable parameterization. The number of persons in cohorts characterized by negative DB pension wealth will be small (Let a hypothetical individual contribute 5 percent of annual wages, set equal to 1, from age 20 to 60. Then upon retirement at age 60, assuming an annual rate of return of 6 percent, the individual will have assets equal to 7.7. Now let the individual receive a benefit equal to 0.5 (i.e., the replacement rate is 50 percent) while continuing to earn 6 percent per year on remaining assets. Than at age 100, there are still assets of 1.8 remaining. At the level of the cohort, proportion in the labor force and proportion of workers participating must be taken into account, but as both contributions and benefits are adjusted equally, the same qualitative insight applies).

8.3 Other assets

For [•] =*OFI, PUE, Res,* the age-specific accumulation equations are

$$\Delta K[\bullet](t,age) = K[\bullet]Share(t)$$
$$[NetSvngHH(t,age) + NetSvngFirms(t,age) + NetSvngGovt(t,age)]$$
$$- AssetSalesK[\bullet](t,age) + K[\bullet]Share(t)\sum_{[\bullet]} AssetSalesK[\bullet]$$
$$- BeqK[\bullet](t,age) + InhK[\bullet](t,age) - SaleInhK[\bullet](t,age) + K[\bullet]Share(t)\sum_{[\bullet]} SalaInhK[\bullet]$$
$$+ K[\bullet]Share(t)[SaleInhKPvtPenSysDC(t,age) + SaleInhKPvtPenSysDB(t,age)]$$

(8.3.1.)

The components of change are, in order:

- In the first line on the right-hand side of the identity, a share variable $K[\bullet]Share(t,age)$ summing to unity across the three forms of non-pension wealth is used to apportion unadjusted household net savings plus the imputed age-specific savings of firms and government between $\Delta KRes$., $\Delta KPUE$. ,and $\Delta KOFI$ (Allocation shares are not indexed by age for computational simplicity when the model is solved in stochastic mode, however, shares may be age-indexed in non-stochastic model applications)

- The second line on the right-hand side is of relevance only for elderly households. The first term subtracts dissaving in the form of annuitization of assets, as described in Section 4.2.1. The second term, when combined with the consumption from annuity income which is implicit in net household savings in the first line, has the effect of distributing savings from annuity income between the non-pension asset classes.

- The third line on the right-hand side subtracts net bequests (the first two terms) and, analogously to the second line, distributes that portion of inherited wealth not converted into consumption among asset classes. Consumption financed by the sale of inherited assets is not accounted for

here because, like consumption from annuity income, it has already been subtracted off in calculating net household savings in the first line.

- The fourth line on the right-hand side distributes inheritance of pension assets between the non-pension asset classes (Note that early withdrawals from the private DC pension system, as well as consumption financed by such withdrawals, are included in net household savings in the first line). Again, associated consumption has already been accounted for when net household savings in the first line are calculated.