

DYNAMIC SIMULATION OF PENSION SYSTEM DEVELOPMENT PROCESSES

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Abstract

The article considers the structural and dynamic aspects of the pension system development processes and information and analytical support of government decision making in the pension sphere using a set of simulation models. The set is developed using system dynamics methods and agent-based modeling.

Key words: pension system, decision support systems for government, simulation modeling, system dynamic, agent-based modeling, stratificated description of model complex, system flow charts.

Introduction

To work out a common strategy for the development of the pension system it is necessary to have a holistic view of the pension system and its relation to the country's economy. The number of elements and relationships of the pension system is so great that the human brain can not account for all the causal relationships to predict the trajectory of the pension system development. Computer simulation models are built and tools supporting decision-making are used to solve this problem.

Economic problems of the pension system reforming and development

The current stage of the Russian Federation pension system development is characterized by a number of peculiarities and problems. The introduction of new legal and institutional forms and mechanisms had to be carried out in conditions of economic transition processes, accompanied by unfavorable demographic and socio-economic trends. Development of the pension system is accompanied by such negative trends such as population's ageing, difference in the dynamics of population income by industries and regions, permanent deficit of the Pension Fund of Russia (PFR) budget, as well as insufficiency of existing mechanisms for proper funding of the pension system.

Restructuring of the industry is taking place, and market institutions and market relations in this area are being developed. New legal norms and socio-economic institutions have been introduced, including private pension funds (PPF) and management companies that control pension savings. The pension system through its savings component became influenced by the unstable financial market, which implies risks and uncertainties. Issues of efficient cash management of pension savings came to the fore, and the role of population in forming their future pension increased. Social studies conducted recently show that the savings system and PPFs cause distrust of people, and actually the savings system does not work. Inactivity of the insured in the matter of transferring pension savings to private management companies resulted in

concentration of pension savings in the state management company that restrains the development of the pension system's savings component.

Currently the expert community is actively discussing issues and options for the development of the national pension system, trying to strike a balance between policies of development and social equity. Reforming of the system of mandatory pension insurance, ensuring payments of pensions taking into account their increase in accordance with the new legislation, developing the system of voluntary pension insurance and non-state pension schemes are the burning issues of the national social policy. The pension system is prevalingly viewed from a perspective of the macrosystem taking into consideration the overall socio-economic situation in light of the existing structure and problems of employment; low wages in various industries; negative demographic trends and population ageing, causing growing imbalance of pensioners and employed population; deficit of the PFR; economic transition and adjustment accompanied by economic and financial crises, underdevelopment of the financial market, and inflation. Such individual issues as pension calculation formulas, retirement age and tariff policy, etc.) with the focus on the problem of PFR's deficit do not allow to address the complexity of the pension system problems. Particular monetary measures have short-term effect and cannot eliminate long-term challenges.

The genesis of socio-economic processes in the pension system

Time after time researchers turned to studying the pension system: they modeled management processes of private pension funds, and management of their solvency and stability of corporate pension programs. They also modeled processes of formation and disbursement of the pension budget, employment of pensioners age under the pension reform, saving and investment strategies of population in the pension system, and processes of pension savings investing under stochastic uncertainty. But the researchers studied local tasks without systemic or consistent representation of the pension system. The pension system management is the problem of national concern, and it cannot be solved at the level of a single corporation or a private fund.

Development and substantiation of government programs to develop the pension system and the pension system management within new economic realities (changes in the demographic situation and socio-economic conditions may result in changes of indexation rates of different components of retirement pensions, pension tax rates and retirement age) is a challenging task that requires scenario research and use of comprehensive economic and mathematical instruments to form a consolidated scenario of the Russian Federation pension system development based on situational and analytical centers of the Russian Federation Government and regions. The present research focuses on the development of a set of simulation models to analyze functioning and development of the pension system as the integral system, estimate synergetic effect of the system's elements and influencing factors in a changing demographic and socio-economic situation. It solves the task of long-term strategic planning of the industry oriented at constant increase of pensions.

Working out the long-term development strategy of the pension system as formulated in the draft state pension system development program requires building a strategic pension system model focused on structural reforms, including a set of financial, legal and economic decisions. To answer the question concerning the future of the pension system we need to turn from parametric measures and settings of the existing system to system-level changes that correspond to the Russian Federation socio-economic processes and are balanced by a variety of aspects.

Quantitative methods of comparing pension systems of different countries along with actuarial calculations provide an information basis to assess the situation, but they

do not help to form a holistic view of the long-term development strategy of the pension system taking into account a number of macroeconomic factors and assess long-term consequences of possible scenarios of the pension system development and modernization of and relations in the pension sphere.

Formation of a holistic view of the pension system development is not possible without comprehensive analysis of economic and social factors affecting its performance and interaction of its basic elements and institutions. Studying the transition processes' dynamics and structural changes associated with the formation of market institutions and relations in this field, and giving attention to the time lags between payments of insurance fees and pensions seem to be important aspects under current conditions. The pension system operation and development in the period of market relations establishment and restructuring requires analysis of long-term development scenarios taking into account the specified self-organizing mechanisms based on dynamic simulation methods.

Discussions among the expert community trying to offer a variety of development scenarios create conditions for forming the consolidated scenario of the pension system development or the long-term "balance between the interests of the parties." When the role of the state is being associated with regulation and control functions, it is interesting to look at the pension system as at a socio-economic system in which it is necessary to ensure effective communication and abidance of the interests of all its participants, such as the employed, pensioners and succeeding generations; employers and the state. An optimal pension policy is a policy viewing a person's life cycle as a whole, eliminating contradictions between his interests at different stages of life, and contributing to the reproduction and taking into account interests of succeeding generations. One of the important aspects of this research is to consider the interaction and coordination of all parties of this process: the role of the state as a guarantor of the rights with its control function, as well as self-organizing processes associated with establishment of the savings system, consideration of dynamic trajectories in the development of relations of all the participants, and individual strategies of population.

The most complicated category in this system is population that acts as an active independent economic agent in the pension system having an individual pension strategy. A new perspective of the pension system problems is caused by the necessity to take into account the real needs of modern people and modern society. Diversification and an individual approach (by categories of enterprises, and social groups) in the formation of a variety of pension strategies are the challenge of reality. It is expected that the pension strategy will be more individual; a person himself will compare and evaluate risks, and generate individual life and pension strategies. Private funds are expected to play a significant role in the new pension system. Consideration of a person and his individual choice at different stages of the life cycle in simulation models of the pension system is the essential point of the research.

Studying aspects of social behavior in the formation of the individual trajectory of pension insurance, including voluntary pension insurance, selecting the form of managing the accumulative part of insurance fees, retirement age, and motivations of different types are also significant factors.

Thus, the advantage of the proposed set of computer models is that it takes into account the peculiarities of the modern socio-economic conditions under which the Russian Federation pension system is functioning. First, the decline in fertility results in a steady rise in the load on the employed. Second, the management of pension savings is delegated to the private sector, which involves personal goals of management companies into the interaction of elements of the pension system. Third, pension

savings are allowed to be invested in financial assets that made the financial market a participant of the pension system. Price changes and fluctuations of the financial market directly affect the amount of pension savings. Fourth, the role of an individual choice in creating a person's own pension strategy increased. Under the existing pension legislation a person insured has a right to choose a method of forming his funded pension. These points are reflected in the developed simulation models investigating the dynamics of these processes and the system development on the whole.

The proposed models of the Russian Federation pension system are based on agent-based modeling and system dynamics methods that help to take into account dynamics and stochasticity of socio-economic processes within the pension system, as well as to display the social behavior of individuals. An integrated approach to the pension system research based on such simulation methods allows reflecting the dynamic and structural complexity of the studied socio-economic processes. Thus, all the micro-processes relating to such socio-economic processes, as individual social behavior of people in the process of choosing the way of managing pension savings and other components of their individual pension strategies, performance of private pension funds and management companies, taking into account the changing situation at the financial markets, with a certain degree of doubt and risk considered in the model, and state administration tasks are studied in the context of achieving the socio-economic development goals and increase of pensions, as well as the functioning efficiency of the pension system as a whole.

Simulation models of the Russian Federation pension system

Simulation models of the Russian Federation pension system help to solve an economic task of providing rationale for the state pension system development program to achieve target values of the average pension and wage replacement ratio while maintaining budget security of Russian Federation Pension Fund. The developed set of the pension system computer models helps federal authorities to form a consolidated scenario of the pension system development and verify different measures of its modernization, including tariff policy, pension indexation measures, the mandatory saving component of the pension system, changing the retirement age, as well as address the following specific objectives:

- analyze the Pension Fund's financial stability;
- analyzes and forecast average pensions dynamics against economic factors and changes in the pension legislation;
- perform scenario modeling of variants of pension savings distribution between the financial market segments and forecast changes in the overall yield of the investment portfolio after changes in its structure;
- analyze changes in the amount of pension savings;
- analyze the financial market's impact on the investment portfolio yield and pension savings amount.

The designed set of simulation models of the pension system reflects functioning and interaction of basic legal and socio-economic institutions and elements of the Russian Federation pension system, such as the Pension Fund of the Russian Federation, private pension funds, management companies, population (insured persons), employers (insurers), the financial market, and pension legislation as a set of legal provisions regulating pensions in the Russian Federation. Cause and effect diagram of the pension system is shown in Figure 1.

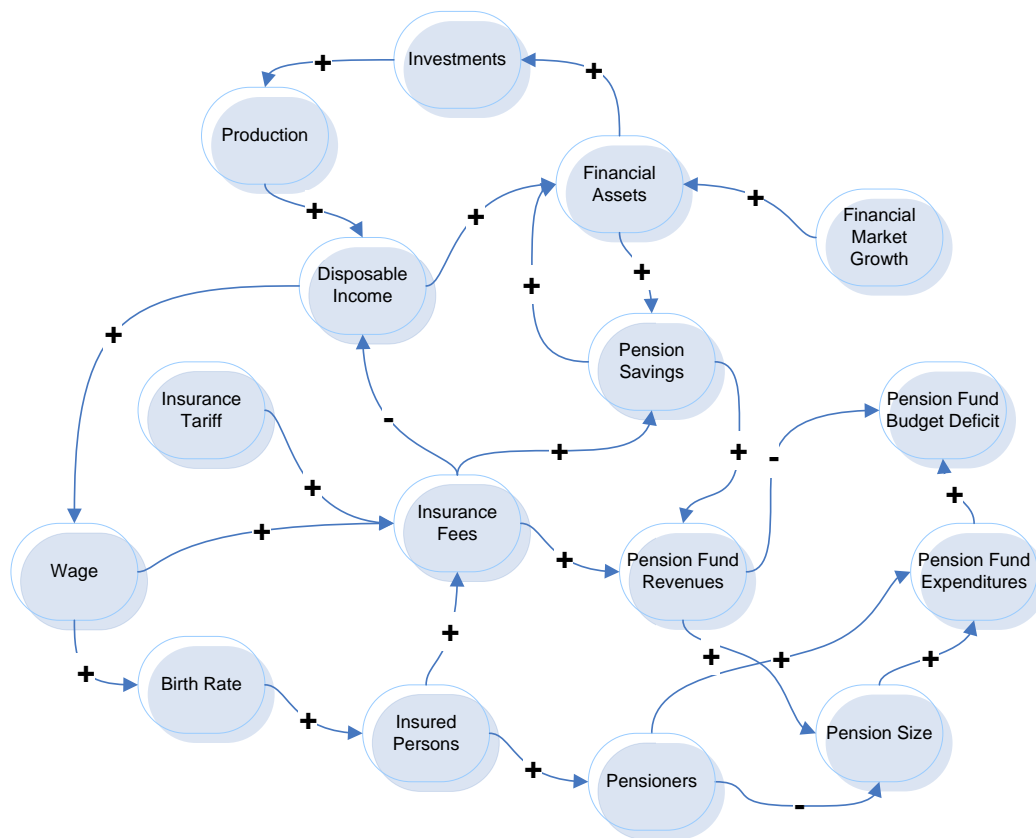


Figure 1 – Cause and effect diagram of the pension system

Structuring of the range of problems and the pension system under study is based on a stratified description, which simplifies experts' handling of the models set and provides information interaction between submodels of the decision support system. The upper level of the pension system's structural and functional representation shown in Figure 2 reflects the basic structure of the simulation model subsystems and their interactions.

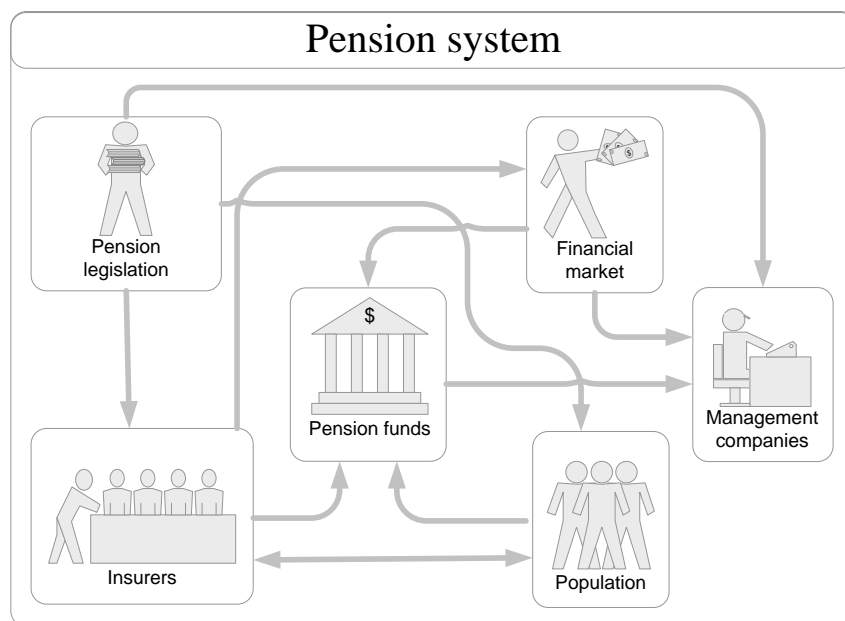


Figure 2 - Subsystems of the pension system simulation model

The pension system's simulation models describe the relationships of the specified elements and processes and performance features thereof (by subsystems):

- Population element describes processes of population growth and migration, changes of labor activities (recruitment, dismissal, change of activity, retirement), formation of pension rights of the insured, individual behavior of the insured in terms of choosing an investment portfolio and a management company;
- Insurers element describes processes of formation of average wages, insurance fees paid by employers for employees by economic sectors;
- Pension funds element describes processes of managing funds by the Russian Federation Pension Fund and private pension funds, as well as processes of transferring pension savings in accordance with decisions of the insured to management companies and private pension funds and pension payments;
- Management companies element describes processes of investing pension savings in the settled financial assets and investment portfolio management by state and private management companies;
- Financial market element describes the dynamics of financial assets, in which pension savings are invested (government and corporate securities, mortgage-backed securities, international securities, deposits, funds on accounts) taking into account such exogenous factors such as budget surplus, refinancing rate, USD rate, oil prices, the Dow Jones and so on;
- Pension legislation element represents methods of forming pensions depending on the accepted formula to calculate pensions, social characteristics of a pensioner, retirement conditions, indexing and recomputation of pensions, as well as tariff rates and regulatory controls of pension savings investing.

The set of simulation models for the pension system is implemented on the basis of mechanisms of compensatory combination of agent, system and dynamic and mathematical models. Parameterization of the simulation models is performed through the methods of regression analysis of historical data according to results of socio-economic processes monitoring.

Formalization and details of the basic elements (subsystems) of the modeled socio-economic system are as follows.

Population system and dynamic model describes the population dynamics by age groups, population growth and migration. The agent-based model complements the system and dynamic model and specifies algorithms of agents' behavior in social systems and aspects of human life associated with pension coverage problems such as Work Activities, Residency, Family, Health, Pension Rights Formation, Choice of Savings Formation Method, and Admission to Pension.

Work Activities submodel describes the possible states of a person in respect of labor activity such as employment, unemployment, hired labor, self-employment and random transitions from one state to another.

Pension Rights Formation submodel is similar to an individual account of a person insured that takes into consideration the incoming premiums forming the state pension obligations. Such premiums depend on tariffs and surcharge base set by the pension legislation and received wages.

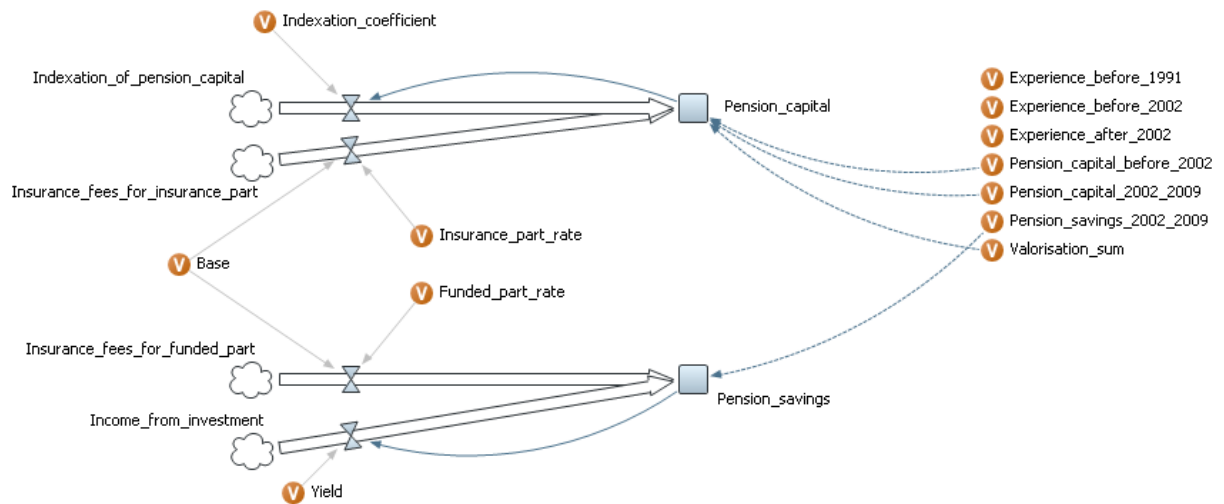


Figure 3 - Fragment of Pension Rights Formation system flow chart

The dynamics of pension capital and pension savings of a person insured is described by differential equations:

$$dPK / dt = Ss (t) + I (t), \text{ where} \quad (1)$$

PK – pension capital,

Ss – insurance fees for the insurance part of pension,

I – pension capital indexation.

$$dPN / dt = Sn (t) + D (t), \text{ where} \quad (2)$$

PN - pension savings,

Sn - insurance fees for the funded part of pension,

D – income from the pension savings investment.

Choice of Savings Formation Method submodel describes the process of selecting a method of forming a pension's savings component via a state management company (SMC), a private management company (PMC) or a private pension fund (PPF). The model considers the dependence of the selection on investment yield of pension savings and a person's efforts in managing his own pension savings. The selection influences the amount of pension savings transferred to be managed by SMCs, PMCs and PPFs.

Insurers submodel using differential and regression equations describes the relationships and dynamics of employers' performance indicators by industries (including preferential categories of insurers), such as output of goods and services, average wages, insurance fees, fixed assets cost, investments in fixed assets, employment in the industry, employment characteristics such as the share of those employed in arduous and harmful working conditions and the share of self-employed.

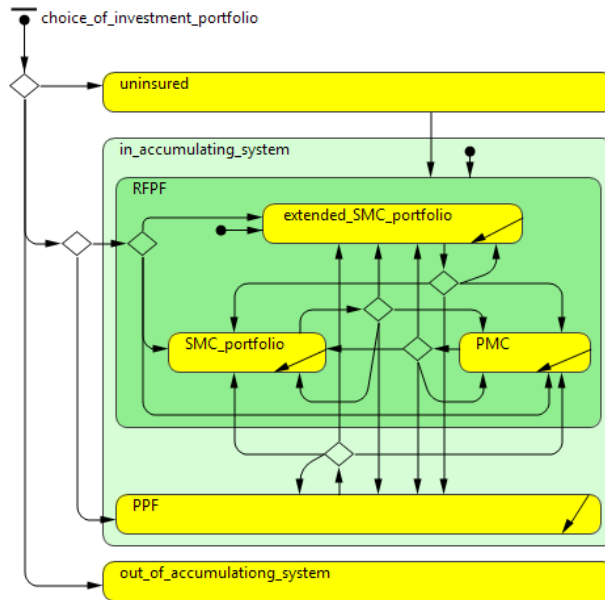


Figure 4 - Choice of Savings Formation Method chart

Pension Funds system and dynamic model is developed based on flow representations, describes the structure and dynamics of incomes and expenditures of the pension system and consists of PFR and PPF submodels.

PFR submodel describes such indicators as the Pension Fund's balance of incomes and expenditures and pension savings. Balance of incomes and expenditures represents the difference between incoming insurance fees to finance an insurance component of pensions and payments of this component.

$$dPFR / dt = Ss (t) + FB (t) + D (t) - VS (t) - VI (t) - VK (t), \text{ where} \quad (3)$$

PFR (t) - balance of incomes and expenditures of PFR,

Ss (t) - premiums for the insurance component,

FB (t) - federal budget funds,

D (t) - income from allocation of PFR funds,

VS (t) - payment of retirement pensions,

VI (t) - payment of disability pensions,

VK (t) - payment of survivor pensions.

Pension savings, which are in the PFR, are increased due to incoming insurance fees to finance the pension's funded component, income on their temporary investments, funds withdrawn from management companies (MC) and private pension funds to be transferred to other MCs according to the statements of the insured, and funds withdrawn from MCs to be paid to the insured or their successors. Reduction of pension savings held by the PFR is performed through the funded pension payments and lump-sum payments to successors of deceased insured persons.

$$dPN / dt = Sn (t) + D (t) + P (t) + SVN (t) + SVP (t) - U (t) - V (t), \text{ where} \quad (4)$$

PN (t) - pension savings,

Sn (t) - premiums for the savings component of pension,

D (t) - income from temporary investment of pension savings,

P (t) - funds transferred from PPFs and MCs,

SVN (t) - funds for payment of the funded part of the pension,
 SVP (t) - funds for the payment of pension savings successors,
 U (t) - funds transferred to management companies,
 V (t) - payment of pension savings.

The ratio of income and expenses, excluding the federal budget funds, is calculated to assess the PFR's budget security:

$$BO = (S_s + D) / (VS + VI + VK), \text{ where} \quad (5)$$

BO - budget security of the PFR,
 S_s - premiums for the insurance component,
 D - income from temporary investment of the PFR's funds,
 VS - payment of retirement pensions,
 VI - payment of disability pensions,
 VK - payment of survivor pensions.

Private Pension Funds submodel includes a set of indicators determining the financial condition of private pension funds (Financial Condition submodel) and Investment Portfolio submodel reflecting the process of managing pension savings.

$$dA / dt = D (t) + P (t) - U (t) - R (t) - V (t) - VPN (t), \text{ where} \quad (6)$$

A (t) - net asset value of the PPF,
 D (t) - income from the investment of pension savings,
 P (t) - receipts from the PFR,
 U (t) - transferred to the PFR,
 R (t) - pension savings investment costs,
 V (t) - remuneration to private pension funds for pension savings management,
 VPN (t) - payment of pension savings.

$$V = D \cdot DV, \text{ where} \quad (7)$$

V - remuneration to private pension funds for pension savings management,
 D - income from the investment of pension savings,
 DV - share of remuneration in investment income.

$$VPN = VP + VN, \text{ where} \quad (8)$$

VPN - payment of pension savings,
 VP - payments to successors,
 VN - payments of the savings component of pension.

Pension Legislation model describes algorithms of pension formation depending on the set pension calculation formula, social characteristics of a pensioner, conditions for retirement, indexing and recomputation of pensions, as well as tariff rates and regulatory controls of investing pension savings.

Management Companies system and dynamics model describes the process of managing pension savings by management companies including the state management

company and private management companies, considering the dependence of the investment of pension savings on the financial market conditions and regulatory restrictions as to the shares of financial assets in the investment portfolio. Simulated performance indicators of state and private management companies for investing pension savings include the dynamics of the net asset value, the cost of investment and remuneration for management of pension savings.

Investment portfolio model describes the process of investing pension savings in financial assets by the management companies (see Figure 5).

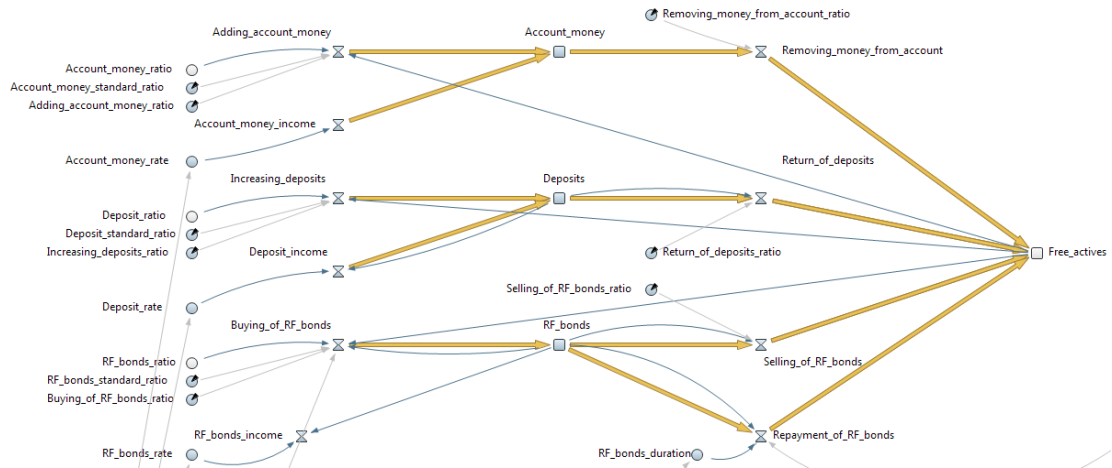


Figure 5 - Investment Portfolio model flow chart

The structure of investment portfolios is limited by regulatory shares of financial assets, which are defined in Pension Legislation subsystem. Profitability of investment portfolios is determined in accordance with the yield of financial assets that are dynamically generated in Financial Market subsystem.

The net asset value dynamics of the investment portfolio of the management company is calculated with use of the following differential equation:

$$dA_i / dt = D_i(t) + P_i(t) - U_i(t) - R_i(t) - V_i(t), \text{ where} \quad (9)$$

$A_i(t)$ - net asset value of the i -th investment portfolio,

$D_i(t)$ - incomes of the i -th investment portfolio,

$P_i(t)$ - receipts from the PFR in the i -th investment portfolio,

$U_i(t)$ - transferred to the PFR of the i -th investment portfolio,

$R_i(t)$ - expenditures of the i -th investment portfolio,

$V_i(t)$ - remuneration for management of the i -th investment portfolio.

The amount of savings transferred to the PFR is the sum of the pension savings of the insured wishing to transfer their pension savings to other investment portfolios, as well as payments to pensioners and those who survived the insured who died before reaching the retirement age.

$$P_i = PP_i + V_i + VP_i, \text{ where} \quad (10)$$

P_i - transferred to the PFR from the i -th investment portfolio,

PP_i - savings transferred from the i -th investment portfolio according to the statements of the insured,

V_i - payments by the savings component of pension to insured persons

who chose the i-th investment portfolio,

V_{Pi} - payments to successors of the insured who chose the i-th investment portfolio.

Investment costs are determined as a percentage of the portfolio's net assets cost

$$R_i = DR_i \cdot A_i, \text{ where} \quad (11)$$

R_i - costs of i-th investment portfolio,

DR_i - share of the costs in the net asset value of the i-th investment portfolio,

A_i - net asset value of the i-th portfolio.

The amount of pension savings invested in financial assets such as bankroll in the accounts of credit institutions, deposits, shares of Russian joint-stock companies, shares of index funds is described by the following differential equation:

$$dFA_i / dt = P_i(t) + R_i(t) - Pri(t), \quad (12)$$

$FA_i(t)$ - pension savings invested in the i-th financial asset,

$P_i(t)$ - amount of pension savings invested in the i-th asset,

$R_i(t)$ - increase in value of the i-th asset,

$Pri(t)$ – refund of pension savings invested in the i-th asset.

The amount of pension savings invested in government, corporate, mortgage-backed securities and international financial bonds is described by the following differential equation:

$$dFA_i / dt = P_i(t) - Gi(t) - Pri(t), \quad (13)$$

$FA_i(t)$ - pension savings invested in the i-th financial asset,

$P_i(t)$ - amount of pension savings invested in the i-th asset,

$Gi(t)$ - repayment of the i-th asset,

$Pri(t)$ - sale of assets invested in the i-th asset.

The income from the investment of pension savings consists from the increase of value of assets and income from securities.

$$D = \sum D_i + \sum R_i, \text{ where} \quad (14)$$

D - income from investments,

D_i - income from i-th security,

R_i - increase in value of the i-th asset.

The average yield of the investment portfolio is defined as the ratio of the income from investment to the net asset value.

$$SD = D / A, \text{ where} \quad (15)$$

SD - average yield of the investment portfolio,

D - income from investments,

A - net asset value.

The funds management is carried out by redistributing available assets of a management company (or a private pension fund), that are formed by the assets sold

(assets recovered), redemptions of securities, revenues generated from the securities, as well as the pension savings newly transferred to a management company.

$$dSA / dt = \Sigma Pri (t) + \Sigma Di (t) + \Sigma Gi (t) + PPF (t) - UPF (t), \text{ where} \quad (16)$$

SA (t) - available assets,

Pri (t) - refund of pension savings invested in the i-th asset,

Di (t) - income from the i-th asset,

Gi (t) - repayment of the i-th asset,

PPF (t) – funds transferred from a private pension fund to a management company,

UPF (t) - funds that are not managed any more.

Financial Market system and dynamic model describes the dynamics of financial assets in which pension savings are invested. These are government, corporate, mortgage-backed and international securities, deposits, and bankroll in the accounts of credit organizations. The model takes into considerations the impact of exogenous factors such as the budget surplus, the refinancing rate, USD rate, oil price, the Dow Jones and others.

The volume of government securities of each type increases due to emission of securities and decreases due to redemptions (see Figure 6).

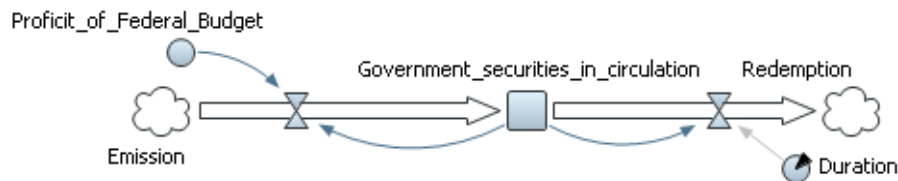


Figure 6 - Financial Market model flow chart

$$dORi / dt = Ri (t) - Pi (t), \text{ where} \quad (17)$$

ORi (t) - volume of i-th government securities in circulation,

Ri (t) - emission of i-th government securities,

Pi (t) - redemption of i-th government securities.

The yield of government securities of Russia is influenced by refinancing rate.

$$DRF = K \cdot S, \text{ where} \quad (18)$$

DRF – yield of government securities of the Russian Federation,

S - refinancing rate,

K - linear regression coefficient.

The yield of government securities of the Russian Federation influences the yield of regional bonds.

$$DS = K \cdot DRF, \text{ where} \quad (19)$$

DS - regional bonds yield,

DRF - yield of government securities of the Russian Federation,

K - linear regression coefficient.

Dynamics of corporate bonds in circulation is described by the following differential equation:

$$dOR / dt = R (t) - P (t), \text{ where} \quad (20)$$

OR (t) - volume of corporate bonds in circulation,

R (t) - emission of corporate bonds,

P (t) - repayment of corporate bonds.

Emission of corporate bonds is inversely proportional to the increase in corporate profits for the previous period.

$$R (t) = K \cdot B (t- 2) / B (t- 1), \text{ where} \quad (21)$$

R (t) - emission of corporate bonds,

B (t) - profit of Russian organizations,

K - linear regression coefficient.

The volume of corporate bond repayments depends on the amount of corporate bonds in circulation and their duration.

$$P = OR / T, \text{ where} \quad (22)$$

P - repayment of corporate bonds,

OR - volume of corporate bonds in circulation,

T_i - duration of corporate bonds.

The refinancing rate influences the yield of corporate bonds.

$$DK = K \cdot S, \text{ where} \quad (23)$$

DK - yield of corporate bonds,

S - refinancing rate,

K - linear regression coefficient.

Return on stocks of Russian companies is determined as the share of the profits of Russian organizations based on stock market capitalization.

$$DA = B / KA \cdot DB \cdot 100, \text{ where} \quad (24)$$

DA - return on stocks of Russian companies,

B - Russian profit organizations

KA - stock market capitalization,

DB - share of profits to pay dividends.

The volume of mortgage-backed securities is increased due to emission of mortgage securities and reduced by the repayment thereof.

$$dOR / dt = R (t) - G (t), \text{ where} \quad (25)$$

OR (t) - volume of mortgage-backed securities in circulation,

R (t) - emission of mortgage securities,

G (t) - repayment of mortgage securities.

Emission of mortgage securities is directly proportional to the volume of refinanced mortgage loans, provided that the share of mortgage-backed securities in refinanced loans will persist.

$$R = RK \cdot DR, \text{ where} \quad (26)$$

R - emission of mortgage securities,

RK - volume of refinanced loans,

DR - share of mortgage securities in refinanced loans.

The yield of mortgage-backed securities depends on the mortgage rates.

$$DI = K \cdot SI, \text{ where} \quad (27)$$

DI - the yield of mortgage-backed securities,

SI – mortgage rate.

The Dow Jones index is adopted as the growth rate of shares of index funds.

$$KP = IDJ(t) / IDJ(t-1) - 1, \text{ where} \quad (28)$$

KP - growth rate of shares,

IDJ - the Dow Jones index.

The yield of securities of international financial organizations is accepted as the yield of U.S. Treasury bonds, which correlates with the Dow Jones index.

$$DKO = K \cdot IDJ, \text{ where} \quad (29)$$

DKO – yield of U.S. Treasury bonds,

K - linear regression coefficient,

IDJ - the Dow Jones index.

Deposit rate depends on the refinancing rate.

$$SD = K \cdot SR, \text{ where} \quad (30)$$

SD - deposit rate,

K - linear regression coefficient,

SR – the refinancing rate.

Yield of each asset determines profitability of investment portfolios of management companies and private pension funds (Management Companies and Pension Funds subsystems). The dynamics of financial assets affects the economic performance of industries (Insurers subsystem).

Dynamic models of the pension system represent socio-economic indicators slices by all the selected elements, including indices of population growth and migration by age groups and territories, the distribution of the insured by methods of forming the funded component of pensions, the average pension for different categories of pensioners, the amount of insurance fees transferred to the Pension Fund of the Russian Federation, private pension funds, management companies, as well as key indicators by economic sectors, financial performance indicators of state and private pension funds, the amount of pension payments, management companies performance indicators, profitability of financial assets, and the share of pension savings in various financial market segments.

Conclusion

Information and analytical decision support of government authorities in the field of pension provision based on situational centers and decision support systems includes tools to perform monitoring, data analysis, generation of scenarios, dynamic scenario analysis and computer support of an expert's interactive participation in modeling and forming management decisions based on simulation. The central core of decision support systems is the set of simulation models of the Russian Federation pension system.

The set of simulation models of the pension system helps to investigate the pension system as an integrated dynamic system, study the synergistic effect of the interaction of its elements, influencing factors and control solutions, including elements of social behavior of people as for selecting the method of forming a funded pension. The developed set's peculiarity is that it is implemented on the basis of software performing compensatory combination of agent-based, system and dynamic and mathematical models. The simulation models' parameterization is based on the results of socio-economic processes monitoring.

The developed set of the pension system models can be used by the federal government to analyze functioning and formation of a long-term development strategy of the Russian Federation pension system, especially when justifying the State Pension System Development Program.

References

1. Forrester J.W. World Dynamics. Pegasus Communications: Waltham, MA. 1971.
2. Sterman J. Modeling managerial behavior: misperceptions of feedback in a dynamic decision making experiment. *Management Science* 35(3): 1989. p. 321-339.
3. Morecroft J. Strategic Modelling and Business Dynamics A Feedback Systems Approach, John Wiley&Sons Ltd. 2007.
4. Lychkina N.N., Shults D.N. Simulation modeling of regions' social and economic development in decision support systems - Proceeding of the 27 International Conference, July 26-30, 2009 Albuquerque, New Mexico, USA/
5. Lychkina N.N., Morozova Y.A. Simulation modeling of social sphere. – Germany: LAP LAMBERT Academic Publishing, 2011. – 388 c.
6. Lychkina N.N., Andrianov D.L., Morozova Y.A. Social Sphere Modeling Based on System Dynamics Methods // 29th International Conference of the System Dynamics Society, Washington DC, USA, July 24th-28th, 2011.
7. Lychkina N.N., Morozova Y.A., Shults D.N. Stratification of Socio-economic Systems Based on the Principles of the Multi-modeling in a Heterogeneous Information-analytical Environment // 2nd. International Multi-Conference on Complexity, Informatics and Cybernetics, Orlando, Florida, USA: International Institute of Informatics and Cybernetics, March 27th - 30th, 2011. pp. 97-100.