Modeling the Diffusion of Private Pension Provision

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Abstract

The purpose of this paper is threefold: to adapt the innovation diffusion models to describe and predict the diffusion of private pension provision; to evaluate the suitability of diffusion models based on the historical data from the Romanian and Ukrainian voluntary pension systems; and to compare the diffusion parameters of private pension provision in these countries. The study proven that diffusion models, such as the Rogers model and the Bass model, can reproduce the diffusion of innovations in the field of pensions. The Rogers diffusion parameters for Romania and Ukraine are almost identical; this gives grounds for a conclusion about the similar behavioral patterns in post-socialist countries. However, some limitations on models use are noted. During the crisis and when using the nudge mechanism, models are not always well-fitting, but when new pension schemes are introduced or new pension funds are opened, models can be used in "guessing by analogy".

Keywords: voluntary pension system; diffusion mechanism; Rogers model; Bass model; CEE countries.

JEL classification: C51; G53.

1. INTRODUCTION

The demographic aging of the population is one of the long-term challenges of a post-industrial society, and the inevitable consequence of this is the growing pressure of pension spending on national economies. This is a particularly serious challenge for aging transition countries in which the Bismarck pension system (earnings-related social insurance for older workers, so-called pay-as-you-go (PAYG) system) has historically been established. Unlike the Beveridge model (universal basic pension for citizens to prevent poverty), these pension systems are based on the principle of intergenerational solidarity and, therefore, collapse in an aging society.

Since the early 1990s, the World Bank has taken a leading role in addressing this challenge through its support for structural pension reform around the world. The multi-pillar pension systems proposed by the World Bank has elements of both Beveridge and

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Bismarck, diversify sources of pensions, and consists of the following formal pillars: (i) Pillar 0 is a basic (noncontributory) and provides a minimal level of protection; (ii) Pillar I is a mandatory, unfunded, and publicly managed system that is linked to earnings and seeks to replace some portion of income (PAYG); (iii) Pillar II is a mandatory, funded, and privately or publicly managed system; and (iv) Pillar III is a voluntary, funded, and privately managed system in which pension schemes can take various forms (individual, employer sponsored, occupational, etc.) (Holzmann and Hinz, 2005).

However, the diffusion of multi-level pension systems shows cross-national and temporal variations (sometimes it has the nature of "concentration"). For example, the Central and Eastern Europe (CEE) countries transformed the PAYG-system into a three-pillar model (plus a base pillar), while the Latin American countries converted the PAYG-system into a fully-funded private pension system (so-called Chilean model of pension privatization). In Romania, the Pillar II is a mandatory funded private pension system, and in Ukraine, Pillar II has not yet been implemented, but conceptually it is a mandatory funded public pension system; however, in both Romania and Ukraine, the 3rd pillar is a voluntary private pension. In addition, the governments of some countries, faced with tight budgetary pressure, de facto abolished the multi-pillar system. For example, in Hungary in 2010 the mandatory funded Pillar II was excluded, while voluntary and occupational pension schemes of the (Pillar III) remain marginal (Freudenberg et al., 2016; OECD, 2017). In Poland, since 2014 participation in the Pillar II is voluntary (OECD, 2017).

Thus, the question arises: what is the cause and what is the depth of cross-national and temporal differences in the adoption of new pension systems? In this study, we will focus on the spread of voluntary private pensions in CEE countries. We will try to assess differences in behavior patterns regarding membership in voluntary pension systems in CEE countries that have the same institutional structure of pension systems, but belong to different groups (Chawla et al., 2007): "aging, early reformers" (Romania) and "aging, late reformers "(Ukraine). Since private pension provision is a pension innovation in these countries, it is obvious that diffusion theories and models should be the research methodology.

The beginning of diffusion researches is associated with work of Gabriel Tarde "The laws of imitation" (1895/1903), where it is emphasized: "the tendency of all ideas and wants to spread in a geometrical progression" (Tarde, 1903, p. xvii). However, this is an ideal scheme; in a social environment, the curves will be irregular and "they can always be decomposed in the same way into three kinds of linear elements, into inclines, plateaux, and declines" (Tarde, 1903, p. 114).

In modern diffuse research, there are three streams that explain how and why innovation spreads: (i) classic diffusion theory, (ii) institutional diffusion theory, and (iii) cognitive-institutional diffusion theory (Strang and Soule, 1998; Bui, 2015). The key difference between diffuse theories is the underlying causal mechanism of diffusion. In the classical diffusion theory, the causal mechanism is the contagion process, i.e. "point-to-point interactions spread an innovation across a population" (Bui, 2015); contagion implies the commonly observed S-shaped cumulative adoption curve (Strang and Soule, 1998). In the institutional diffusion theory, the underlying causal mechanism is the conformity mechanism, i.e. adoption of innovation is due to (i) imitation of peers or competitors, (ii) context or pressure (coercion of influential institutions), and (iii) compliance with accepted norms. The underlying causal mechanism for cognitive-institutional diffusion theory is a social learning mechanism, i.e. the adoption decision is based on empirical observations on

outcomes among prior adopters (Young, 2009); decision making is caused by both institutional influence and cognitive process at the collective level (Bui, 2015).

However, in reality, diffusion mechanisms often act simultaneously and complement each other during the entire diffusion process, which is manifested in the diffusion of pension innovations. For example, Orenstein (2003, p. 179) empirically proved that, firstly, diffusion of the first pension systems worldwide followed "the usual distribution pattern for adoption of innovations – a few countries are pioneers, followed by a steep increase in the rate of adoption, with a few laggards filling in at the end. When charted cumulatively, this results in an S-curve." Secondly, level of economic development, size, regional example, and activities of global policy advocates have influenced the diffusion of pension innovations around the world. In addition, past decisions on the introduction of public pensions (the Bismarck or Beveridge model) had repercussions for the space of development for private (occupational and personal) pensions (Ebbinghaus and Gronwald, 2011). At the same time, there are empirical studies that link the adoption of pension reforms in Western Europe to a greater extent with the "shock" of the European Monetary Union than with the demographic pressure and the spread of social policy ideas (Hennessy and Steinwand, 2014).

Brooks (2005, 2007) identified institutional mechanisms in the cross-national diffusion of pension privatization (Pillar II), namely, the imitation of peers, the impact of demographic, political, and economic context. In particular, Brooks (2005, p. 283) proved "the diffusion hypothesis that all else being equal, the likelihood of adopting pension privatization in one country will increase systematically with the proportion of peer nations that have adopted some form of private pension reform" using the Cox model; however, the influence of peer dynamics is uneven, with the most powerful impact among Eastern European and Central Asian countries. Gilardi et al. (2006) came to similar conclusions using the expected utility model in studying the diffusion of the Chilean model. But, the empirical analysis does not reveal a significant role for financial coercion by the Word Bank (Brooks, 2007, p. 713).

As for the cognitive mechanisms of pension diffusion, Weyland (2005, 2007) identified three heuristics that promote diffusion and explain the wave diffusion process of the Chilean model in Latin American countries: (i) the availability heuristic explains strong neighborhood effects in diffusion innovation (geographical clustering); (ii) the representativeness heuristic affects the assessment of innovation, giving rise to the S-shaped temporal diffusion pattern; and (iii) the heuristic of anchoring explains the spread of commonality amid diversity (Weyland, 2005, pp. 286-287). It should be clarified that the cultural, political or historical similarity can overcome the effects of geographic proximity (Weyland, 2007, p. 19). For example, as is known, the Bismarck model has spread across the countries of the continental legal system, and the Beveridge model across the countries of the Anglo-Saxon legal system.

Thus, in the literature, we found evidence that institutional and cognitive mechanisms are causal mechanisms for diffusion of pension reforms. However, in this study, as noted above, we will focus on studying the diffusion of voluntary private pension provision (Pillar III) across a population. In this case, the underlying mechanism is contagion (of course, institutional and cognitive mechanisms also act), so we will use the classical diffusion models.

In the early works on modeling classical diffusion, it was revealed that the same adoption data can be represented by either a bell-shaped (frequency) or an s-shaped

(cumulative) curve (Rogers, 1962/1983, p. 243). Besides, Rogers (1962/1983, p. 246) identified five adopter categories and the approximate percentage of individuals included in each: (1) innovators (2.5 %), (2) early adopters (13.5 %), (3) early majority (34 %), (4) later majority (34 %), and (5) laggards (16 %). We will use the Rogers categorization to evaluate and compare the current level of adoption of Pillar III by the population of Romania and Ukraine. Bass (1969), in turn, formalized the theory of Rogers; he developed a new product growth model based on the assumption: "The probability that an initial purchase will be made at T given that no purchase has yet been made is a linear function of the number of previous buyers" (Bass, 1969, p. 216). Bass, unlike Rogers, distinguished only two classes of adopters (innovators and imitators) and stressed that "the important distinction between an innovator and an imitator being the buying influence" (Bass, 1969, p. 217).

In fact, the basic Bass model is applicable to describe the diffusion of a single innovation in a single market, but subsequently caused considerable research in the following directions: (i) multiple purchases (e.g. Leigh and Yorke-Smith, 2011), (ii) new explanatory variables (Kalish, 1985; Kamakura and Ealasubramanian, 1987), (iii) new estimation methods (Xie *et al.*, 1997), (iv) little or no data (Jiang *et al.*, 2006), and (v) applying the Bass model and its modifications in marketing (Mahajan *et al.*, 1990), and for forecasting the diffusion of such products, technologies and services as telecommunications products (Wright *et al.*, 1997), mobile communications (Kumar *et al.*, 2007), financial innovation (Philippas, 2011), photovoltaic solar panels (Islam, 2014), car ownership (Tosa *et al.*, 2015), automotive technologies (Massiani and Gohs, 2015), product and service innovations in Base of the Pyramid markets (Ratcliff and Doshi, 2016) etc.

This study is intended to contribute to the latter direction of research by developing the Bass model to describe the diffusion of voluntary pension provision. However, it should be noted that in previous studies we already studied the effect of the contagion mechanism on the diffusion of voluntary pension in Ukraine; for this, we have developed mathematical based on epidemic SIR-model, which take into account the level of perception by individuals of the new pension product and the level of influence of Pillar III agents (counteragents) (Danich and Yakymova, 2011); these models formed the basis of the cellular automaton model (Yakymova, 2013).

The purpose of this paper is threefold. The first is to adapt the innovation diffusion models to describe and predict the diffusion of private pension provision. We develop the Rogers and Bass diffusion models to test the hypothesis: the contagion mechanism of the classical diffusion theory explains the S-shaped cumulative curve of adoption voluntary pensions, and the institutional and cognitive mechanisms explain deviations from the classical curve. The second purpose is to evaluate the suitability of diffusion models based on the historical data of Romania and Ukraine, and the third is to compare the diffusion parameters of private pension provision in these countries. We use data from Romania and Ukraine, since these countries are neighbors, have the same demographic pressure, but the context is not the same – Romania is an "early reformer" (EU member), and Ukraine is a "late reformer". Our study gives a negative answer to the question of whether the current context could overpower the representativeness heuristic – a common for post-communist countries orientation to state paternalism.

Thus, this study contributes to diffusion theory and pension literature by empirically analyzing the characteristics of the spread of voluntary private pension provision in two CEE countries for the period 2005/2007-2017 using the Rogers and Bass diffusion models.

The remainder of the paper is organized as follows. Section 2 provides a description of methodology. The evaluation results are discussed in Section 3. Finally, a conclusion and an outlook to future work are given in Section 4.

2. METHODOLOGY

This paper uses two diffusion models: (i) the Rogers model and (ii) the Bass model.

First, consider the modeling of the diffusion of voluntary pension provision based on the Rogers model. Suppose that a pension innovation (participation in Pillar III or in a voluntary pension fund) is available in pension market with m persons. If $N(t)$ is the number of the members of a society that have already adopted the innovation up to time t then the number of remaining potential participants will be $m - N(t)$. It can be assumed that the increase in the number of supporters of private pension provision is proportional to the number of interactions between supporters of pension innovations and those who doubt. The number of such interactions will be proportional to the product $N(t)[m - N(t)]$. The number of participants who join Pillar III at time t ($=n(t)$) is equal to the derivative of the function $N(t)$, i.e.,

$$\frac{dN(t)}{dt} = kN(t)[m - N(t)] \tag{1}$$

The discrete analogue is expressed as follows: $N_t - N_{t-1} = kN_{t-1}(m - N_{t-1})$. The solution of the Bernoulli differential equation (1) is the function

$$N(t) = \frac{m}{1 + \exp(\beta_0 - \beta_1 t)} \tag{2}$$

The graph of the function $N(t)$ – cumulative number of participants at time t–is a classical S-shaped curve (aka logistic curve); the graph of the function $n(t)$–noncumulative number of participants at time t–is a bell-shaped curve. The parameter β_1 characterizes the steepness of the middle part of the cumulative curve $N(t)$; the inflection point of the cumulative curve occurs at time $t_{infl} = \beta_0/\beta_1$, which is the time of peak of the noncumulative curve ($t^*(n_t)$).

To estimate the unknown parameters β_0, β_1, and m from discrete time series data, we use a method that is a synthesis of the finite difference method and the Ordinary Least Squares (OLS) method.

The second approach to modeling the diffusion of voluntary pension provision is the application of the Bass model (Bass, 1969). It should be noted that for the universality of the exposition we use the notation adopted in the Rogers model.

The following assumptions characterize the Bass model: (i) diffusion process is binary (potential participant either joins Pillar III or does not join); (ii) constant maximum potential number of participants (m); (iii) eventually, all m will join Pillar III; (iv) no repeat joining, or replacement; (v) the marketing strategies supporting the voluntary pension provision are not explicitly included.

Suppose further that the increase in the number of participants in Pillar III is due to two effects: (i) the effect of advertising (mass-media); (ii) the effect of interpersonal communication (word-of-mouth, WoM).

In this sense, the pension society with m persons can be divided into two categories of individuals: (i) innovators themselves learn and "try" voluntary pension provision; (ii) imitators learn from the first and join Pillar III. The important distinction between an innovator and an imitator is the influence of the participants (Bass, 1969, p. 217). Innovators are not influenced in the timing of their joining by the number of people who have already joined Pillar III, while imitators are influenced by the number of actual participants.

Then, the likelihood of joining Pillar III at time t is a linear function of the number of actual participants: $P(t) = p + \dfrac{q}{m} N(t)$, where p and $\dfrac{q}{p}$ are constants and $N(t)$ is the number of actual participants. Since $N(0) = 0$, the constant p is the probability of an initial joining Pillar III at $t = 0$ and its magnitude reflects the importance of innovators in the voluntary pension provision. The product $\dfrac{q}{m} N(t)$ reflects the pressures operating on imitators as the number of actual participants increases. Bass refers to p as the coefficient of innovation and q as the coefficient of imitation. Based on Bass's derivation (Bass, 1969, p. 217), we get the number of individuals who join Pillar III at time t:

$$n(t) = \frac{dN(t)}{dt} = pm + (q - p)N(t) - \frac{q}{m} N^2(t) \tag{3}$$

The basic Bass model (3) can be transformed and used to decompose the number of participants who enter Pillar III at the moment t into innovators and imitators as follows:

$$n(t) = p[m - N(t)] + q \frac{N(t)}{m} [m - N(t)] = In(t) + Im(t) \tag{4}$$

where $In(t)$ is noncumulative number of innovators at time t and $Im(t)$ is noncumulative number of imitators at time t.

In estimating the parameters, m, p, and q from discrete time series data is used the discrete analogue of the basic Bass model (3)

$$n_t = \beta_0 + \beta_1 N_{t-1} + \beta_2 N_{t-1}^2 + \varepsilon_t \tag{5}$$

where n_t is noncumulative number of participants (participants' growth) at t, $N_{t\text{-}1} = \sum_{\tau=1}^{t-1} n_\tau$ is cumulative number of participants through period t-1, ε_t is random variable (error term, residual) which account for the differences between the actual, and the predicted values of n_t, and $\beta_0 = pm$, $\beta_1 = q - p$, and $\beta_2 = -\dfrac{q}{m}$ are unknown model parameters.

Here the OLS method is used to estimating the unknown parameters β_0, β_1, and β_2, by transforming a nonlinear form into a linear one; and the Bass model parameters are calculated by the following formulas:

$$\hat{m} = \frac{-\hat{\beta}_1 \pm \sqrt{\hat{\beta}_1^2 - 4\hat{\beta}_0\hat{\beta}_2}}{2\hat{\beta}_2}, \quad \hat{p} = \frac{\hat{\beta}_0}{\hat{m}}, \quad \hat{q} = -\hat{m}\hat{\beta}_2. \tag{6}$$

However, the estimates m, p, and q must be nonnegative (for simplicity, we omit the symbols of the estimates ^ in notation). Therefore, in order for the Bass model to be consistent, it is necessary to fulfill the conditions for OLS estimates: $\beta_0 > 0$, $\beta_1 \geq 0$, $\beta_2 < 0$. The fulfillment of the conditions $\beta_0 > 0$ and $\beta_2 < 0$ allows to avoid the negative square root error when estimating m.

Diffusion depends on the relationships between the parameters p and q. If ($p > 0$, $q = 0$), this is a pure innovation scenario, and diffusion follows a modified exponential. If ($p = 0$, $q > 0$), this is a pure imitation scenario, and diffusion follows a logistic curve. If ($p > 0$, $q < 0$), this is a negative diffusion, and the diffusion curve follows a modified logistic curve concave down.

Negative diffusion of voluntary pension provision will be interpreted by analogy with diffusion in physical systems. In general, negative diffusion coefficient would denote process of "concentration" as opposed to diffusion. That means, it is not a random diffusion process but additional forces are acting opposite to diffusion resulting in concentration or anti-diffusion. First of all, this is the long-term influence of the established patterns of behavior in transition economies, as well as the impact of political and economic crises.

The fraction $\frac{q}{p}$ determines the shape of the diffusion curve. If $\frac{q}{p} > 1$, the noncumulative number of participants $n(t)$ peaks at time $T^* > 0$, which is the point of inflection of the S-shaped curve of cumulative number of participants $N(t)$. If $\frac{q}{p} \leq 1$, $n(t)$ decreases monotonically with time t and $T^* < 0$ (negative peak).

The sum ($p + q$) determines the rate of adoption (or scale of diffusion). According to Rogers (1962/1983, p. 232), "rate of adoption is a numerical indicant of the steepness of the adoption curve for an innovation". The larger the sum ($p + q$), the steeper the diffusion curve and the larger the diffusion scale.

Thus, the following conclusions can be formulated regarding the adoption of pension innovation by the society. The larger the sum ($p + q$), the greater the diffusion rate of voluntary pension provision in society. If $q > p$, the pension innovation is successful; the influence of WoM is greater than the external influences (media). If $q \leq p$, the pension innovation is unsuccessful; the influence of WoM is less than the external influences. If $q > p$, according to Bass model (Bass, 1969, p. 218), the predicted time of peak and magnitude of peak participants' growth (noncumulative number), and cumulative number of participants at the peak time is estimated as follows:

$$T* = \frac{1}{p+q}\ln\left(\frac{q}{p}\right), \; n(T*) = \frac{m(p+q)^2}{4q}, \; N(T*) = \frac{m(q-p)}{2q} \qquad (7)$$

Summing up, it is necessary to distinguish three negative aspects that can be encountered in the practical use of the Bass model: (i) the negative square root error when estimating m; (ii) the negative peak ($q \le p$); and (iii) the negative diffusion ($q < 0$). Both approaches to modeling the diffusion of voluntary pension provision are implemented according to the following scheme:

1. Estimation of model parameters.

2. Assessing the fit of the model. Goodness of fit measures of the model: the adjusted multiple coefficient of determination (Adj. R^2), the overall F-test.

3. Assessing the plausibility of model parameters.

In order to test the plausibility of the Rogers models parameters we use (i) the percentage deviation of m from the total number of participants (m / nth period) and (ii) the percentage deviation of the time of the inflection point of the cumulative curve from the time of peak of the non-cumulative curve ($t*/t_{infl}$). In order to test the plausibility of the Bass models parameters we use (i) the percentage deviation of pm from the number of participants in the 1st period (pm / 1st period) and (ii) the percentage deviation (m / nth period). A value of 100 % indicates the absolute agreement between the estimates of diffusion parameters (β_0, β_1, m or pm) and the time series data.

4. Analysis of the diffusion of voluntary pension provision by the estimated diffusion curve.

5. Testing the predictive ability of the model: a comparison of the timing and magnitude of the predicted and actual joining peaks, and calculating the relative prediction error of the cumulative number of participants. Relative prediction error is defined as:

$$RPE = \frac{\hat{N}_{t+p} - N_{t+p}}{N_{t+p}} \cdot 100\% \qquad (8)$$

The presented modeling methodology was implemented in a spreadsheet.

3. RESULTS AND DISCUSSION

3.1 Data and sample selection

This study uses time series data on total Pillar III membership in Romania (Financial Supervisory Authority, 2017) and Ukraine (National Commission for Regulation of Financial Services Markets, 2017), including by age and gender. We use historical data from the introduction of Pillar III (the first quarter of 2005 for Ukraine and the fourth quarter of 2007 for Romania) until 2017. The study also uses data from 6 out of 10 voluntary pension funds in Romania, since the remaining funds have a short history (Financial Supervisory Authority, 2017). We analyzed the membership in 64 non-state pension funds (NPF) (Administrator of the Pension Fund "Center of Personified Accounting", 2017; National Commission for Regulation of Financial Services Markets, 2017; OtpPension, 2017;

PensionMarket, 2017), but we present the simulation results for only 6 funds. This choice is due to a long history, the availability of comparable information, the diffusion of participants, etc. For example, in the pension fund "Golden Age" the number of participants in 2008-2010 is 19 persons, in 2011 – 173, and in 2017 – 169 persons (PensionMarket, 2017). Obviously, the modeling of such a process is meaningless, and such funds are subject to consolidation (merger). Therefore, we did not use such samples.

For a correct cross-country comparison of the diffusion of voluntary pension provision (total Pillar III membership), we used the time series of the number of participants as a percentage of the population aged over 15 years (15+), calculated as follows: $N_\%(t) = N(t)/p_{15+}(t) \cdot 100$, where $N(t)$ is cumulative number of participants at time t and $p_{15+}(t)$ is population aged 15+ at time t (population data available from Countrymeters, 2017 and State Statistics Service of Ukraine, 2017). In other words, p_{15+} is the aggregate of potential Pillar III participants, namely the working age population and the retirement age population; the ILO (International labor Organization) standard for the lower age limit is 15 years. Figure no. 1 demonstrates, in fact, an equal small-scale diffusion of voluntary pension provision in both Romania and Ukraine (in the first quarter of 2017, 2.35% in Ukraine and 2.57% in Romania). At the same time, diffuse dynamics varies: (i) in Romania this is a steady growth; (ii) in Ukraine the diffusion process is essentially unstable. Next, we use diffuse models to explain and predict these processes both at the macro level (by countries) and at the micro level (by pension funds).
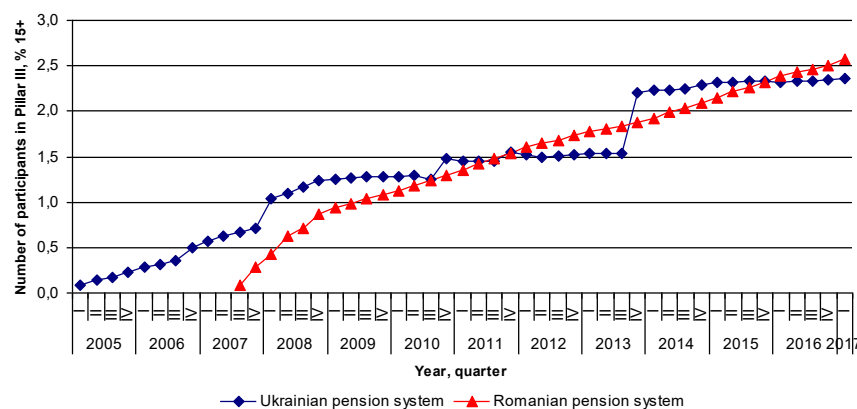
Source: author's computations

Figure no. 1 – Actual cumulative number of participants in Pillar III of the Ukrainian and Romanian pension systems

3.2 Empirical results and discussion

Throughout the research process, two models were estimated: the Rogers model and the Bass model. First, diffusion of voluntary pension provision (total membership in Pillar III) was analyzed using the Rogers model. The estimation results are shown in Table no. 1 and Figure no. 2. These results seem to support the extension of the Rogers model for voluntary pension provision in both Romania and Ukraine. The adjusted R^2 and F values indicate that Rogers's models are well-fitting. However, the significance of the parameter

estimates of the Ukrainian model is lower due to fluctuations in the actual data caused by economic and political crises. Cyclic fluctuations could be removed from the time series (e.g., using the Hodrick-Prescott filter as in Yakimova (2018)), but in this case we are interested in the pure diffusion of voluntary pension provision.
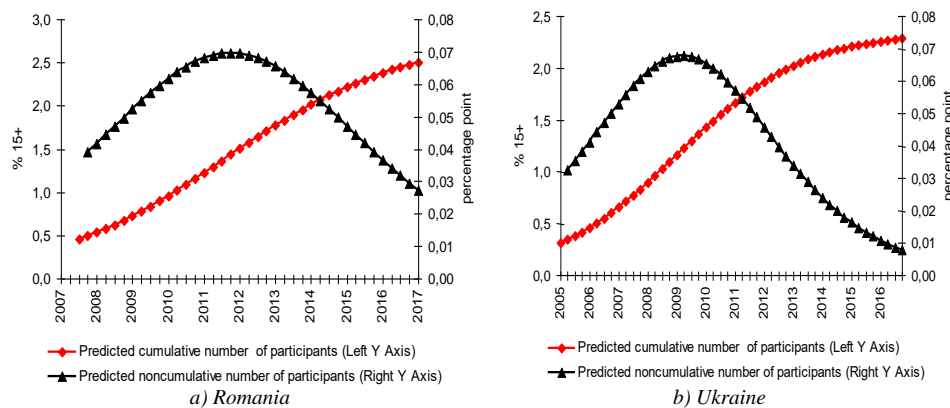
Table no. 1 – The Rogers model estimates for Romania and Ukraine

Country	Goodness of fit		Parameter estimates			Plausibility of parameters (%)		Predictive ability (%)
	Adj. R^2	F	m	β_0	β_1	t^*/t_{infl}	m/nth period	RPE
Romania	.9568	410.17	2.7992	1.7436	.0995	102.7	108.8	-2.67
Ukraine	.8905	192.08	2.3517	1.9919	.1153	104.2	99.9	-2.59

Note: Critical value F (.05; 2; 35) = 3.27 for Romania and F (.05; 2; 45) = 3.20 for Ukraine
Source: author's computations

As for the plausibility of the Rogers models parameters, the values of all percentage deviations are close to 100 %. The predicted time of the curve inflection point is 17.5 quarter in Romania and 17.3 quarter in Ukraine. This result is consistent with the predicted peak curve non-cumulative number of participants (deviations are equal to 102.7 % and 104.2 % respectively). It is interesting that the predicted peak of participants' growth is in the 18th quarter both in Romania and in Ukraine; the growth of participants in Romania is .0696% of the population ages 15+, and in Ukraine .0678%. The actual peak of participants' growth in Romania was .0665% in the 16th quarter and in Ukraine .0744% in the 15th quarter. However, in Ukraine there is also a second actual peak in the 36th quarter with a magnitude of .660 % (this is the reaction of society to the way out of the economic crisis).

a) Romania   *b) Ukraine*
Source: author's computations
Figure no. 2 – The Rogers model estimates: cumulative and noncumulative number of participants in Pillar III of the Romanian and Ukrainian pension systems

The key criteria for the predictive ability of the model are how well the model predicts samples that were not used to estimate of model parameters. Forecasting by models gave the relative prediction error not exceeding 3% (see Table no. 1), although it is alarming that

both forecasts are underestimated. Nevertheless, the Rogers model can be used for short-term forecasting of the diffusion of voluntary pension provision (or other pension product).

Analyzing the estimates of model parameters, we can draw three conclusions. First, since the estimates $\beta_{1rom} < \beta_{1ukr}$, the middle part of the curve of the cumulative number of participants in Pillar III is steeper in Ukraine, that means a faster rate of diffusion in this period. Figure no. 2 confirms this conclusion. Secondly, based on the estimates $m_{rom} = 2.7992$ and $m_{ukr} = 2.3517$ and the classification of adopters by Rogers (1962/1983, p. 246) ("the first 2.5 percent of the individuals to adopt an innovation—the innovators"), we can conclude that in Ukraine the participants in Pillar III are only innovators, and in Romania there are already early adopters.

Third, the differences in diffusion parameters, however, are not significant; representativeness heuristic and the neighborhood effect explain the post-socialist behavior pattern (orientation to public paternalism) and predetermine equivalent patterns of collective behavior in these countries. It should be clarified that the representativeness heuristic is the individual's ability to make intuitive assessments based on established stereotypes, while neglecting other important information. Pension stereotypes in Romania and Ukraine have developed in the socialist countries with the Bismarck pension system. As noted above, the basic pension system significantly influences the current pension decisions, regardless of the institutional context; for example, Germany (the birthplace of the Bismarck model) faced a similar challenge. In order to overcome this heuristic, government used a nudging mechanism through subsidies. Now Pillar III consists of voluntary, subsidized individual plans. The so-called Riester-Rente (2001) serves the purpose to encourage low-income workers to additionally save (Guardiancich, 2010). However, Riester-Rente did not meet all the expectations associated with its implementation, and "it had lost momentum in recent years". However, 16m people (22.3 % of the population aged 15+) had opted for a Riester-Rente, and no other voluntary pension saving system in the world came close to this level of participation (Rust, 2016). This approach has also been chosen in Italy, Sweden, Poland and the United Kingdom (Arza, 2008).

The next part of the paper focuses on the analysis of simulation results using the Bass model. Note that the Bass model was applied to the original datasets, measured in thousand persons (for total number of participants in Pillar III) or persons (for pension funds). Therefore, the graphs of the noncumulative number of participants in Pillar III in relative (change in the share of population ages 15+ in percentage points) and absolute (in thousand persons) terms are fundamentally different (see Figure no. 2 and Figure no. 3). Figure no. 3 shows that the functions of the noncumulative number of participants are decreasing, but they have different concavity. This is explained by the peculiarities of population dynamics in these countries. The functions of population ages 15+ are also decreasing, but for Romania the function is concave up, while for Ukraine it is concave down.

The estimation results are shown in Table no. 2 and Table no. 3. The estimation procedure generally yielded plausible parameter estimates, with a few exceptions. First, for the time series of the Romanian Pillar III (except for participants aged 16-29, "AZT VIVACE", and "PENSIA MEA") and participants of the Ukrainian Pillar III over the age of 60 (60+), it was not possible to avoid obtaining a negative square root error when estimating m.

a) Romania   *b) Ukraine*
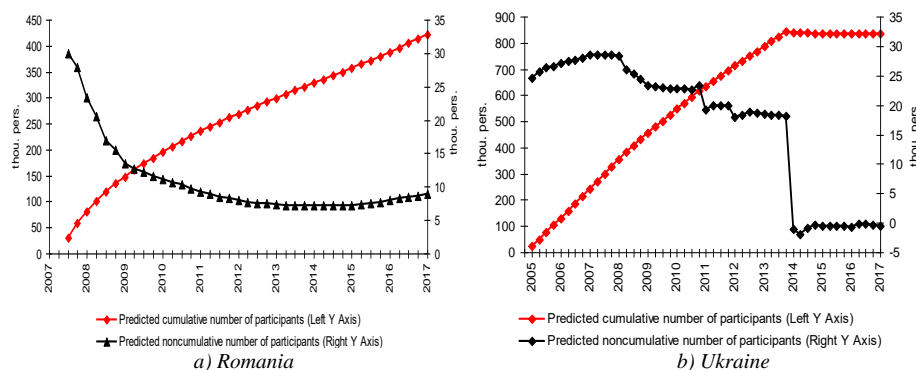
Source: author's computations

Figure no. 3 – The Bass model estimates: cumulative and noncumulative number of participants in Pillar III of the Romanian and Ukrainian pension systems

Secondly, the values of the adjusted R^2 for noncumulative models (OLS estimation) are generally lower than the corresponding values for the cumulative curves. The explanation of the low performance of these models can be found in significant fluctuations in the actual time series n_t. It is likely that a greater temporal aggregation can reduce the influence of these fluctuations.

Thirdly, negative adjusted R^2 is obtained, which indicates the extreme poor performance of the corresponding models. For example, in the model "Age 16-29" (Romania) this is explained by significant fluctuations in the growth of participants at the initial stage (typical phenomenon) and in the period 2010-2013 (consequences of the crisis). The global financial and economic crisis has led to a decline in the Romanian economy, loss of jobs, and a reduction in the disposable incomes of the working population (Baltac and Dinca (Nicola), 2013). But it turned out that participants aged 30-44 years less than others were affected by the crisis: the smallest fluctuations and, accordingly, the largest adjusted R^2 for the OLS estimation model. In the "Age < 25" model, the negative adjusted R^2 for the cumulative curve is explained by the decrease in the number of participants due to the global financial crisis of 2008; a significant increase in 2013 and a decline since 2014, i.e. due to political and economic crises in Ukraine. We arrive at the obvious conclusion that the basic Bass model is not able to take into account the fluctuations caused by external factors–crises.

The negative adjusted R^2 explains the improbable estimates of m or pm and a large relative prediction error. Similar unsatisfactory estimates were received for the Open NPF "IFD Kapital" both for depositors-individuals and legal entities. In the Open NPF "OTP Pension" in March 2013 the number of participants increased by 190.9%; this jump explains the negative adjusted R^2 for the OLS estimation model. The model was applied to time series data "before the jump" (27 data); we got rid of negative adjusted R^2, but this model can not be used for forecasting.

It should be noted that, according to the Bass model (Bass, 1969, p. 221), the first period should be defined as the period in which the number of joined participants equal or exceed pm for the first time, i.e. $n(0) = pm$. As noted by Zabkar and Zuzel (2002, p. 216), "this seems somewhat circular; before an estimate of pm can be produced, a starting period must be chosen and the Bass model estimated. The Bass model can then be re-estimated

after dropping any initial periods in which sales are less than pm, but this will result in a different estimate for *pm*. Instead, it seems more sensible to follow the practice of choosing as the initial period the point from which obvious sales "take off" occurs".

Table no 2 – The Bass model estimates (Ukraine and Romania)

| Pillar III, voluntary pension funds	Adj. R^2 for n_t	Coefficient of innovation	Coefficient of imitation	Market potential	pm/1st period (%)	m/nth period (%)	Adj. R^2 for N_t	RPE (%)	Comments
Romania									
Pillar III, Total	.5838	n.a.	n.a.	n.a.	n.a.	n.a.	.9966	1.02	n.a.
By age									
16-29	.2504	0,1478	0,0801	33968.10	171.9	111.0	.2152	3.19	unsuccessful
30-44	.5768	n.a.	n.a.	n.a.	n.a.	n.a.	.9987	-.04	n.a.
45+	n.	n.a.	n.a.	n.a.	n.a.	n.a.	.9937	1.38	n.a.
By gender									
male	.6043	n.a.	n.a.	n.a.	n.a.	n.a.	.9993	.95	n.a.
female	.5336	n.a.	n.a.	n.a.	n.a.	n.a.	.9997	1.11	n.a.
AZT VIVACE									
monthly	.7827	.1615	-.0778	19935.58	185.2	97.9	.6313	-.21	negative
quarterly	.5891	.2733	-.0346	19993.38	114.4	98.1	.9932	-.42	diffusion
"take-off"	.9931	n.a.	n.a.	n.a.	n.a.	n.a.	.9996	.14	n.a.
PENSIA MEA									negative
monthly	.7981	.1971	-.1159	10086.14	111.11	101.82	.9655	.33	diffusion
quarterly	.8122	.2603	.1336	10048.72	146.20	101.04	.9982	.65	unsuccessful
Ukraine									
Pillar III, Total	.0257	.0297	.0651	828.74	70.3	99.4	.8890	-.32	successful
By age									
< 25	.0573	.1050	.0099	34.41	104.2	192.2	n.	19.51	unsuccessful
25-49	.0248	.0221	.0842	524.03	59.2	100.5	.9088	.22	successful
50-60	.0374	.0307	.0263	239.72	68.7	107.9	.8720	-.19	unsuccessful
60+	.0211	n.a.	n.a.	n.a.	n.a.	n.a.	.9797	-.75	n.a.
Europe	.7625	.0037	.4570	135198.75	80.8	101,1	.9754	.38	successful
PensionCapital									
all data	.5626	.1385	.2040	578.90	471.5	102,1	.9460	.36	successful
"take-off"	.7704	.2360	.0124	581.9764	106.5	102.6	.8633	2.82	unsuccessful
Social									
standard"	.1666	.0295	.1040	5226.27	115.1	119.2	.6818	2.69	successful
Magistral	.0034	.0255	.3408	326385.98	157.2	99.97	.7423	-.01	successful
OTP Pension									
all data	n.	.0118	.1365	32340.98	764,2	107.4	.1457	-1.75	successful
first 27 data	.2828	.1000	.0653	9821.148	1963.4	99.8	.9628	-	unsuccessful
"take-off"	.4889	n.a.	n.a.	n.a.	n.a.	n.a.	.9246	-	n.a.
IFD Kapital									
depositors-									negative
individuals	.0975	.4844	-.1838	11.29	91.1	141.1	n.	n.d.	diffusion
legal entities	.8217	1.112	-.7032	9.60	97.1	120.0	n.	n.d.	

Note: n.a. = not available (a negative square root error when estimating *m*); n. = negative adjusted R^2; n.d. = no data available

Source: author's computations

An attempt to apply the "take-off" technique to the time series "OTP Pension" resulted in a negative square root error. The application of this technique to the time series "Pension Capital" shows a change in the type of diffusion; now the pension innovation is defined as unsuccessful, since the coefficient of innovation exceeds the coefficient of imitation; at the same time, the goodness of fit of the non-cumulative model was improved, but the fit of the cumulative model deteriorated.

This technique, however, can not always be applied. For example, the Professional Pension Fund "Magistral" shows two leaps in the number of participants (in December 2010 and in March 2014). Probably employers use the nudge mechanisms (coercion or automatic joining the pension fund) to overcome the heuristics of representativeness, availability, and anchoring. But in this case, the process of joining the fund is a partially controlled process; therefore it cannot be described by the classical diffusion model.

Another way to improve the relationship between pm and 1st period is data aggregation. For example, quarterly aggregation produced more plausible parameter estimates for "AZT VIVACE"; the fit of the cumulative curve improved, but forecasting is possible only quarterly (see Table no. 2 and Figure no. 4). An attempt to improve the 114.4 ratio by applying the "take-off" technique resulted in a negative root error when estimating m, but at the same time the goodness of fit of the models has improved (see Table no. 2 and Figure no. 5).
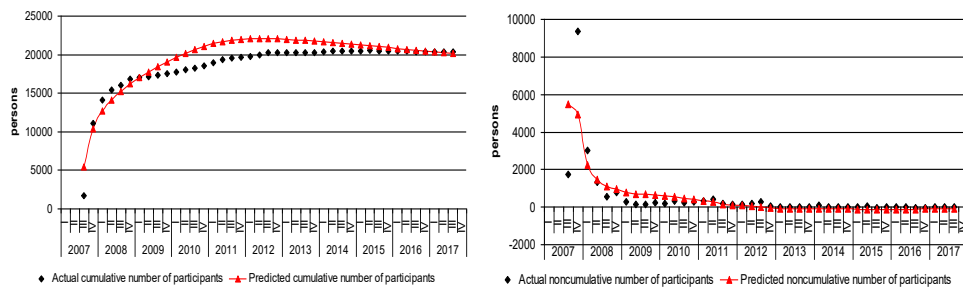
Source: author's computations

Figure no. 4 – Actual number of participants and Bass model estimates for "AZT VIVACE": quarterly aggregation
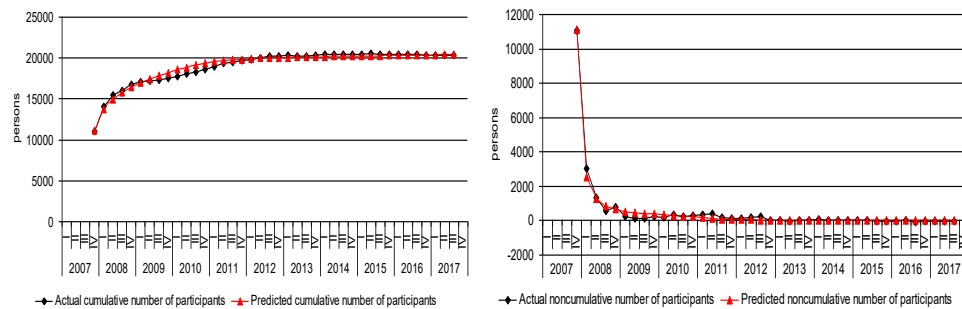
Source: author's computations

Figure no. 5 – Actual number of participants and Bass model estimates for "AZT VIVACE": quarterly aggregation and "take-off" technique

However, the quarterly aggregation of data "PENSIA MEA" worsened this ratio and, accordingly, the predictive ability of the model. But at the same time, the assessment of diffusion has changed from "negative diffusion" to "unsuccessful product", i.e. aggregation of data allowed us to reveal the diffusion mechanism: the influence of WoM (contagion) is less than external influences. Thus, the aggregated data, eliminating intra-quarter fluctuations, helps to identify the general mechanism of diffusion.

Unfortunately, the modeling of all other Romanian time series gave a negative square root error. The Bass model was estimated on the original data (monthly), on aggregated data (quarterly), and using the "take-off" technique to aggregated data (except "AZT MODERATO", as there was no "take-off" of joining to the fund), but the estimates were similar in this sense. Table no. 3 shows the OLS estimation results. Consistency conditions for all models except "PENSIA MEA" are not satisfied, since $\beta_1 < 0$ and $\beta_2 > 0$, although it tends to zero. The adjusted R^2 values for the OLS estimation noncumulative curves are high or medium, except for "NN OPTIM" and "BCR PLUS"; p-value greater than .05 for only two estimations β_2 for "NN OPTIM" and "AZT VIVACE" (quarterly). At the same time, the adjusted R^2 values for all cumulative curves are high. Thus, the obtained models can be used to forecast the cumulative number of participants, but can not be used to predict the time and magnitude of peak participants' growth.

Negative numerical results and the forms of diffuse curves can be explained using the micromodeling approach of Chatterjee and Eliashberg (1990). The potential participant studies the flow of information on voluntary pension provision. The variance reflects the variability in the information about performance of Pillar III or any pension fund. The more contradictory information is, the less its impact on the individual. Thus, the variance of the flow of information is the inverse measure of the level of perception of pension innovation. Comparing our diffuse curves (for example, Figure 3, Figure 4, and Figure 5) and empirical results on the impact of information variability on the diffuse curve (Chatterjee and Eliashberg, 1990, p. 1067), we conclude that in Romania the flow of information has a large variance, and innovators do not affect simulators, i.e. $q < p$ or $q < 0$. However, it is necessary to further investigate this issue, since the neighborhood effect and representativeness heuristic would have to predetermine equivalent cognitive processes in Romania and Ukraine.

In addition to the negative square root error, negative diffusion was obtained for "AZT VIVACE" and "PENSIA MEA" (Romania), and "IFD Kapital" (Ukraine) (see Table no. 2). This indicates a contraction of pension funds and a diffusion curve concave down. Indeed, the number of participants in the "AZT VIVACE" fund decreased from 20 540 persons in June 2015 to 20 370 persons in May 2017; in "IFD Kapital" the number of depositors–legal entities decreased from 16 in March 2011 to 8 in January 2016, and the number depositors–individuals decreased from 30 in September 2010 to 8 in January 2016 (later data are not available). In these cases, the causal mechanism of negative diffusion is both the institutional context and social learning, i.e. cognitive process described above.

In studying parameter estimates of the Bass model, we found that $p + q$ ranged from .057 (for total number of participants ages 50-60 in Pillar III of the Ukrainian pension systems) to .461 (for Open NPF "Europe", Ukraine); for total number of participants $p + q$ equal to .095. This means that, on the whole, the rate of diffusion of voluntary pension provision in Ukrainian society is very low; and lower than for individual pension funds (i.e. regions, enterprises, industries). In Romania, this value is equal to .2279 for the youngest age cohort (in Ukraine two times lower – .1149) and .3939 for "PENSIA MEA".

**Table no. 3 – The Bass model OLS estimates (Romania)**

Pillar III, voluntary pension funds	Aggregation level	Noncumulative curve, n_t				Adj. R^2 for N_t
		Adj. R^2	β_0	β_1	β_2	
Pillar III, Total	monthly	.5736	13475.99*	-.0732*	1.2E-07*	.9946
	quarterly	.5838	29984.85*	-.1424*	2.2E-07*	.9966
	quart. "take-off"	.8204	44542.35*	-.2609*	4.4E-07*	.9923
AZT MODERATO	monthly	.6836	4916.47*	-.3018*	4.7E-06*	.9429
	quarterly	.8866	8221.85*	-.4391*	6.0E-06*	.9867
AZT VIVACE	monthly	.7827	3219.44*	-.2393*	3,9E-06	.6313
	quarterly	.5891	5464.53*	-.3079**	1.7E-06***	.9932
	quart. "take-off"	.9931	11151.58*	-1.0483*	2.5E-05*	.9996
BCR PLUS	monthly	.3110	2679.46*	-.0422*	2.3E-07*	.9929
	quarterly	.2703	6560.38*	-.0932*	5.3E-07**	.9991
	quart. "take-off"	.6569	9189.52*	-.1674*	9.9E-07*	.9990
NN OPTIM	monthly	.0465	2413.83*	-.0306**	1.6E-07**	.9948
	quarterly	.0581	6350.33*	-.0778**	4.5E-07***	.9989
	quart. "take-off"	.5831	17559.82*	-.3604*	2.0E-06*	.9942
NN ACTIV	monthly	.7472	2769.88*	-.1689*	2.7E-06*	.9586
	quarterly	.7023	5132.00*	-.2798*	4.2E-06*	.9975
	quart. "take-off"	.9388	12707.40*	-.8372*	1.4E-05*	.9930
PENSIA MEA	monthly	.7981	1987.81*	-.3130*	1.1E-05*	.9655
	quarterly	.8122	2615.51*	-.1267***	-1.3E-05***	.9982

Note: *p-value < .01, **.01 < p-value < .05, ***p-value > .05

Source: author's computations

Table no. 2 also shows that the pension innovations are not always successful (the term diffusion theory). This happens when the coefficient of imitation is less than the coefficient of innovation ($q < p$), that is, individuals do not imitate the behavior of innovators and do not repeat the behavior of opinion leaders. Unfortunately, such a situation has developed in youngest age cohorts in both Romania and Ukraine. This means that in the youth environment, the process of spreading the voluntary pension provision began to fade almost from the very beginning. The lack of success of the pension innovation is the result of the synergistic effect of the financial crisis and unmotivated youth.

Figure no. 6 illustrates the dynamics of the structure of the predicted noncumulative number of participants in Ukrainian Pillar III as a whole and for two age cohorts. In the Ukrainian voluntary pension system, the number of imitators exceeds the number of innovators since the 14th quarter (2nd quarter of 2008). This means that the voluntary pension provision was accepted by the society. However, the crisis of 2008 suspended the growth of participants, and the crisis of 2014 (including the annexation of territories) caused the outflow of participants, i.e. external context transformed diffusion process into concentration process (see Figure no. 6(a)).

a) total

b) age cohort 25 – 49

c) age cohort 50 – 60
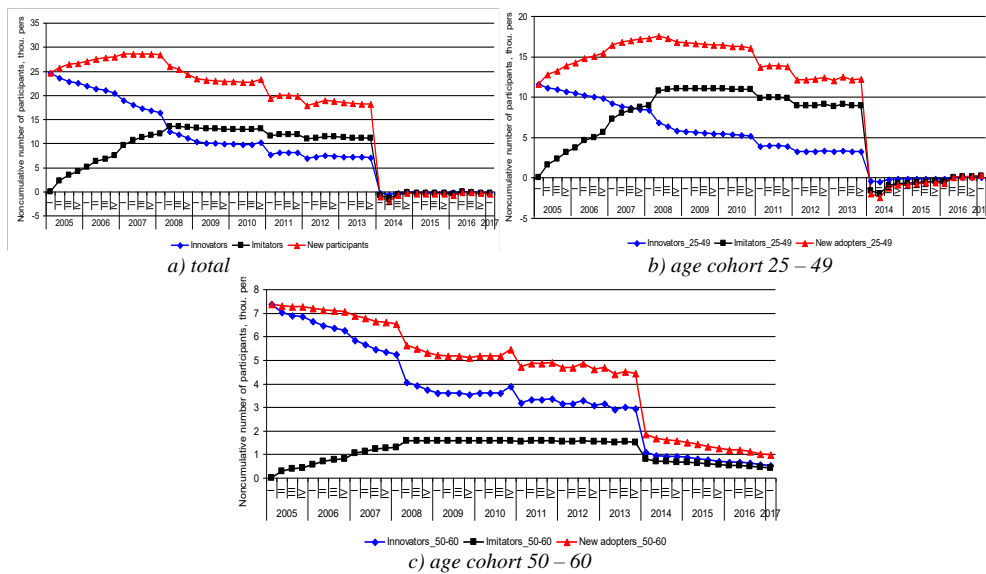
Source: author's computations

Figure no. 6 – Dynamics of the structure of the predicted noncumulative number of participants in Pillar III of the Ukrainian pension system

As for pension behavior by average age cohorts, (i) for cohort 25-49, the number of imitators exceeds the number of innovators since the 12th quarter, i.e. the 4th quarter of 2007 (see Figure no. 6(b)), and (ii) for cohort 50-60, the number of imitators did not exceed the number of innovators for the whole period of the system's existence (see Figure no. 6(c)). Thus, individuals under the age of 25 and over 50 have not accepted a new type of pension provision.

To test the predictive ability of models, we calculated the timing and magnitude of the predicted joining peaks (for successful pension innovations, i.e., for models with $q > p$) and the relative prediction error of the cumulative number of participants (see Table no. 3). The predication results are shown in Table no. 4.

Table no. 4 – Comparison of predicted time and magnitude of peak with actual data for successful pension innovations

Pillar III, voluntary pension funds	Time of peak (periods)		Magnitude of peak (persons)		RPE (%)
	Actual	**Bass**	**Actual**	**Bass**	
Pillar III, Total	9	8.3	28763	28581.2	-.32
Europe	12	10.4	28000	15698.2	.38
Magistral	8	7.1	46	32124.6*	-.01
OTP Pension	7	16.4	1225	1302.8	-1.75
Pension Capital	3	1.2	155	83.2	.36
Social standard	12	9.4	619	223.8	2.69

Note: *The second actual peak in the 11th quarter is 86 616 persons

Source: author's computations

The Bass model for the time series "Pillar III, Total" (Ukraine) shows the best prognostic abilities; other models have unsatisfactory deviations of the predicted parameters of the peaks from their actual values. Part of the reason is that the process of diffusion of voluntary pension provision in the whole country has the characteristics of a random process. Whereas, pension funds use certain methods with respect to individuals (company employees), i.e. the diffusion process is controlled. In this case, the Bass model does not give good peak forecasts, but can be used for short-term forecasting of the cumulative number of participants. Table no. 4 shows that the maximum relative error is only 2.69 %, which is not exceeding 5.00 %. The Professional Pension Fund "Magistral" illustrates this point particularly vividly. The value of *RPE* = -.01 % is explained by the low volatility for the last four years, but the Bass model does not predict the leaps.

4. CONCLUSIONS AND PERSPECTIVES

The presented paper broadens the diffuse models discussion. This study empirically proved that the adapted diffuse models of Rogers and Bass can be used to describe and predict the spread of voluntary private pension provision. We also found confirmation that the underlying diffuse mechanism for the spread of voluntary private pension provision is a contagion mechanism in combination with institutional and cognitive mechanisms.

The modeling results showed that the historical pension data of Romania and Ukraine follow the typical diffusion curve of innovation from the Rogers model (the contagion mechanism explains the S-shaped cumulative curve); diffusion parameters are almost identical, but in Ukraine the Pillar III participants are only innovators, and in Romania there are already early adopters. This gives grounds for a conclusion about similar patterns of pension behavior in post-socialist countries. The neighborhood effect and representativeness heuristic explain the identical state-oriented behavioral stereotype in various current institutional contexts: sustainable behavioral patterns have emerged in socialist countries with a generous Bismarck pension system. It is important to emphasize that the basic pension system significantly influences the current pension decisions regardless of the institutional context; therefore, developed countries, in which the Bismarck model was originally adopted, also faced similar problems (Germany, France, Italy, Greece, etc.). To overcome this heuristic, the German government used the nudge mechanism, namely encouragement: Pillar III was transformed into state-subsidized voluntary private pension schemes, the so-called Riester reform of 2001. However, at present, this approach is costly for the CEE countries (this is especially true for Ukraine).

The Bass model confirmed these findings, but beyond that, its advantage is the ability to predict time. The advantage of the Bass model is its ability to predict the time and magnitude of the peak of participants' growth, determine the success of innovation, and identify innovators and imitators. For the data of Ukraine, the Bass model basically gave significant results. At the same time, it is important to note that during the crisis and when using the nudge mechanisms (coercion or automatic joining the pension fund), Bass models are not always well-fitting, since classical diffusion is significantly deformed due to the impact of these institutional mechanisms; but when new pension schemes are introduced or new pension funds are opened, models can be used in "guessing by analogy".

However, the use of the Bass model for Romania was not always successful. We did not manage to avoid the negative square root error for all historical data except for

participants aged 16-29, as well as pension funds "AZT VIVACE" and "PENSIA MEA". Nevertheless, OLS estimation models demonstrate high performance and can be used to draw useful inferences or to predict future observations.

The question remained open: why is the condition of consistency of Bass models not satisfied for most time series in Romania? Therefore, future research should focus on the study of this issue, as well as on methods of eliminating inconsistencies and limitations in the use of the Bass model (e.g., for long-term pension processes, the diffusion parameters are not constant in time). It is also necessary to study the impact of economic fluctuations and cognitive biases on the diffusion of private pension provision by introducing new exogenous factors into the diffusion model.

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