Annals of the Academy of Romanian Scientists
Series on Engineering Sciences
ISSN 2066-8570 Volume **17**, Number **1**/**2025**

STOCHASTIC MODELING OF THE HUMAN RESOURCES RISK MANAGEMENT

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Rezumat. *Managementul resurselor umane joacă un rol critic în orice organizație și, prin urmare, instrumentele predictive ale disponibilității forței de muncă ar spori eficiența organizației și ar atenua orice întrerupere în cadrul organizației. Cu toate acestea, resursele umane sunt adesea predispuse la impactul diferitelor incertitudini asociate cu nevoia de forță de muncă calificată cauzată de migrații, recesiune, pandemii, deficit de resurse etc. Prin urmare, o modalitate de a cuantifica aceste incertitudini sunt abordările de modelare stocastică a resurselor umane. . Modelarea stocastică este un instrument puternic care poate prezice cu o anumită probabilitate evenimentele care pot avea loc în cadrul resurselor umane. În cadrul cercetării de față este dezvoltat și propus un model stocastic, bazat pe teoria probabilității, pentru analiza dinamicii resurselor umane și managementul riscului, pentru UE în perioada 2006-2013. Prin urmare, studiile sunt efectuate pentru a investiga corelația dintre factorul de conducere economic și dinamica resurselor umane. Cercetarea arată că abordarea modelării stocastice poate prezice cu o anumită probabilitate dinamica resurselor umane corelată cu factorii economici. De asemenea, studiul arată că modelarea stocastică poate prezice creșterea șomajului în timpul crizelor economice, care au afectat UE în perioada 2008-2013.*

Abstract. *Human resources management plays a critical role in any organization and thus, predictive tools of workforce availability would enhance the efficiency of the organization as well it would mitigate any interruptions within the organization. However, the human resources are often prone to the impact of various uncertainties associated with the need of skilled workforce caused by migrations, recession, pandemics, resources shortage, etc. Therefore, one way to quantify these uncertainties are the stochastic modeling approaches of human resources. The stochastic modeling is a powerful tool that can predict with certain probability the events that may occur within the human resources. In the present research a stochastic model, based on probability theory, is developed and proposed for the analysis of human resources dynamics and risk management, for EU during the period of 2006-2013. Therefore, the studies are performed to investigate the correlation between the economic driving factor and dynamics of human resources. The research shows that the stochastic modeling approach can predict with certain probability the dynamics of the human resources correlated with the economic factors. The study also show that stochastic modeling can predict the increase of unemployment during the economic crises, which affected the EU during the period of 2008-2013.*

Keywords: human resources management, stochastic modeling, numerical modeling, dynamical systems

DOI **10.56082/annalsarscieng.2025.1.19**

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1. Introduction

Human resources management plays a critical role in any organization and thus, predictive tools of workforce availability would enhance the efficiency of the organization as well it would mitigate any interruptions within the organization.

However, the human resources are often prone to the impact of various uncertainties associated with the need of skilled workforce caused by migrations, recession, pandemics, resources shortage, etc. Therefore, one way to quantify these uncertainties are the stochastic modeling approaches of human resources.

The stochastic modeling is a powerful tool that can predict with certain probability the events that may occur within the human resources.

An important environment where the theory of the dynamical system can be used is the simulation and prediction of correlation between jobs and work force availability. In this sense, the European Union (EU) represents an interesting case due the more or less control migration of the work force cause by the expansion of the EU including East-European countries such as Bulgaria and Romania.

Moreover, the uncontrolled migration of populations from the conflict zones also brought numerous uncertainties in the job-workforce correlation over the past decades. Moreover, the impact of the 2008 economic crisis also brought uncertainties to the job-workforce correlation. The hypothesis of this research is that the correlation of the job-workforce availability can be modeled using the theory of the dynamical systems, including uncertainty modeling.

The present research concerns the development of computational models that can predict the correlation of job-workforce availability. We will employ the developed computational model for the analysis of jobs-workforce correlation within EU, for different periods of time between 2006 and 2013.

In the present research a stochastic model, based on probability theory, is developed and proposed for the analysis of human resources dynamics and risk management, for EU during the period of 2006-2013. Therefore, the studies are performed to investigate the correlation between the economic driving factor and dynamics of human resources. The research shows that the stochastic modeling approach can predict with certain probability the dynamics of the human resources correlated with the economic factors. The study also show that stochastic modeling can predict the increase of unemployment during the economic crises, which affected the EU during the period of 2008-2009.

2. Modeling and algorithms

In this research we focus on the modeling of the human resources as dynamical system employing the stochastic modeling, which is a predictive method that can estimate the risks and disruptions of the human resources required by the job market. The stochastic model is based on the probability of random variables as detailed in the following. Thus, a random variable X is usually described by its cumulative distribution function (cdf)

$$F(x) = P(X \leq x), -\infty < x < \infty \tag{1}$$

It is worth to note here that a multivariate random variable

$$(X_1, X_2, \dots\dots\dots\dots . X_n) \tag{2}$$

is usually descibed by its joint cumulative distribution function.

$$F(x_1, x_2, \dots\dots\dots\dots . x_n) = P(X_1 \leq x_1, X_2 \leq x_2 \dots\dots\dots . X_n \leq x_n) \tag{3}$$

for all $-\infty < x_i < \infty$, $i = 0,1,2,3, \dots\dots$.

The distribution function F of a random variable X is given by

$$F(\lambda) = \int_{-\lambda}^{\lambda} p(t)\, dt \tag{4}$$

where p is the probability density of X. if X discrete random variable then its mth moment is given by

$$E[X^m] = \sum_i \lambda_i^m P\{x = \lambda_i\} \tag{5}$$

if the series converge absolutely, where λ_i represents a finite set of distinct values such that

$$P\{X = \lambda_i\} > 0 \tag{6}$$

If X is a continuous random variable with probability density $P(\cdot)$, its mth moment is given by

$$E[X^m] = \int_{-\infty}^{\infty} x^m p(x)\, dx \tag{7}$$

if the integral converges absolutely.

If X is a random variable and g is a function, then Y=g(X) is also a random variable. If X is a discrete random variable with possible values $x_1, x_2, x_3, \dots \dots \dots$ then the expectations of g(X) is given by

$$E[X^m] = \sum_{i=1}^{\infty} g(x_i) P\{X = x_i\} \tag{8}$$

if the sum converges absolutely.

If X is a discrete random variable with possible values $x_1, x_2, x_3, \dots \dots \dots$, then the expectation of g(X) is given by

$$E[g(X)] = \int_{-\infty}^{\infty} g(x) P_x(x) dx \tag{9}$$

The general formula, covering both the discrete and continuous cases is

$$E[g(X)] = \int g(x)\, dF_x(x) \tag{10}$$

where F_x is the distribution function of the random variable X. It is worth mentioning here that the integral of equation 10 is the Lebesgue-Stieltjes integral. In this research, the computational model, employed to predict the jobs-workforce correlation, is based on the Lotka-Volterra algorithm. The Lotka-Volterra equations are presented below:

$$\frac{dx}{dt} = \alpha x - \beta xy \tag{11}$$

$$\frac{dy}{dt} = \gamma y - \delta xy \tag{12}$$

The Lotka-Volterra model represents a pair of first-order nonlinear differential equations that can be used to describe the time-dependent dynamics of interacting species. The model is also called the predator-prey model. Thus, in equation 1, x represents the population density of prey, the variable y represents the population density of predator, while dx/dt and dy/dt represent the instantaneous growth rates of the two populations, and t represents the time.

In this research we focus on the modeling of teams as attractors and fractals. As already mentioned, the members of the team are always on the look for new and better opportunities, challenges or career advancements. The incoming or outgoing personal plays a critical role in the successful completion of a research project. Usually, the in and out flow of human resources generate delays in the execution and finalization of the project.

A predictive method that can estimate the team's dynamics would help to minimize the impact of relocation of human resources. Thus, in the following we propose a mathematical framework for the modeling of human resources as dynamical systems. Since the dynamics of the human resources exhibits a random behavior, we propose and develop a model that is based on the Metropolis–Hastings algorithm. Metropolis–Hastings algorithm is a Markov chain Monte Carlo (MCMC) approach.

The Metropolis–Hastings algorithm generates a collection of states according to a desired distribution $P(x)$. This is accomplished when the Markov process convergences asymptotically to a stationary distribution of $\pi(x)$ such that $\pi(x) = P(x)$. Thus,

$$P(x'|x)P(x) = P(x|x')P(x') \tag{13}$$

which can be rewritten in the form

$$\frac{P(x'|x)}{P(x|x')} = \frac{P(x')}{P(x)} \tag{14}$$

Defining the conditional probability as $g(x'|x)$ of proposing state x' given x and the acceptance distribution $A(x', x)$ is the probability to accept the proposed state x'. The transition probability can be written as the product of them:

$$P(x'|x) = g(x'|x)A(x', x) \tag{15}$$

Similarly, we have

$$\frac{P(x')}{P(x)} \frac{g(x|x')}{g(x'|x)} = \frac{A(x', x)}{A(x, x')} \tag{16}$$

Based on the Metropolis acceptante ratio

$$A(x', x) = \min\{1, \frac{P(x')}{P(x)} \frac{g(x|x')}{g(x'|x)}\} \tag{17}$$

A second approach employed in the current research is the Henon attractor/map which is a discrete-time dynamical system. The motivation for this model stems from the fact that it can predict the chaotic behavior of the individual which may occur due to external perturbations. The Henon system of equation is defined as

$$\begin{cases} x_{n+1} = 1 - ax_n^2 + y_n \\ y_{n+1} = bx_n \end{cases} \tag{18}$$

The Henon map depends on two parameters a and b which for a chaotic map have the values $a = 1.4$ and $b = 0.3$.

3. Results and discussion

As already mentioned, this research concerns the prediction of the correlation between jobs and workforce availability, within EU, for the period of time between 2006 and 2023. The correlation between the jobs and workforce availability is assessed through the unemployment rate, within EU, during the period of 2006 and 2023, based on the publically available data. Based on the Eurostat data, the unemployment data in quarter of 2006 was around 8.4%. This means that there were less jobs available than the workforce and this is also represented in the Lotka-Volterra mathematical model. Thus, Figure 1 presents the jobs-workforce availability during the fourth-quarter of 2006. The fourth quarter of 2007 presented an increase in the job availability compared with the Q4 of 2006 and thus, a reduction of the unemployment rate to about 7.5%.

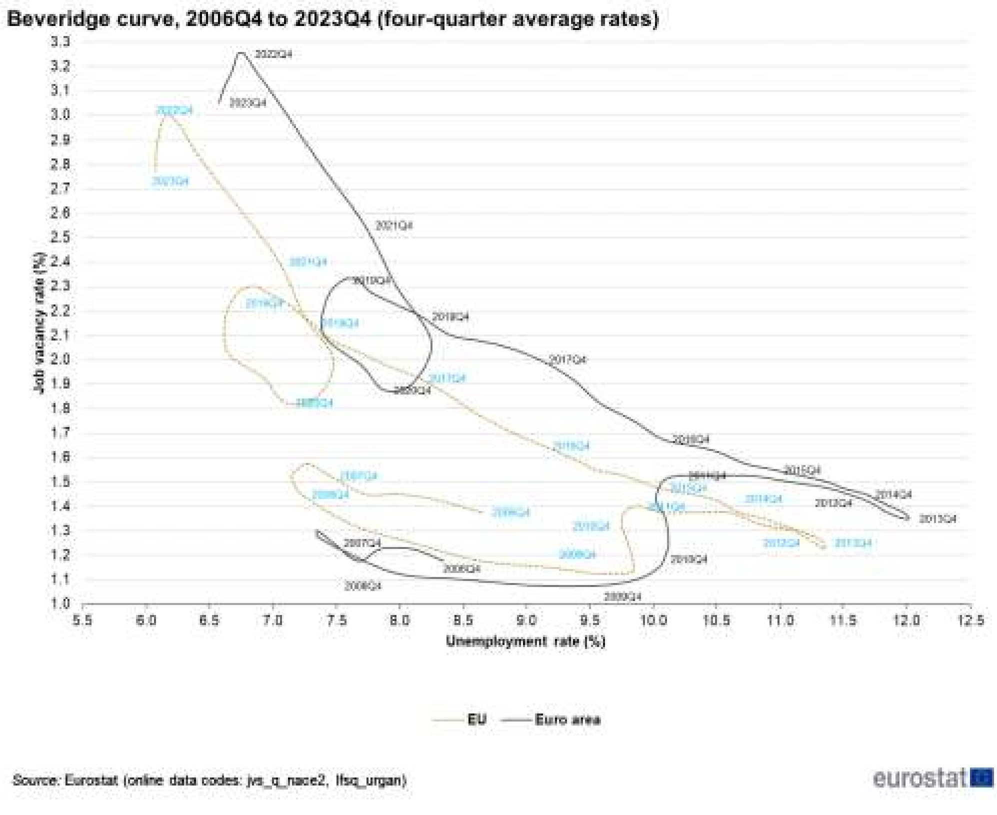

Fig. 1. Beveridge curve, fourth-quarter; 2006-2023 [19]

This increase in the job availability is also captured well by the mathematical model as shown in Figure 2. However, the fourth quarter of 2008 saw a decay in the jobs availability compared with Q4 of 2007. It is worth mentioning here that this is due to the economic crisis which has already started in USA. However, the effects of the economic crises were felt later in the EU. Therefore, although we saw a decline in the jobs available within the EU, they were still in a reasonable range.

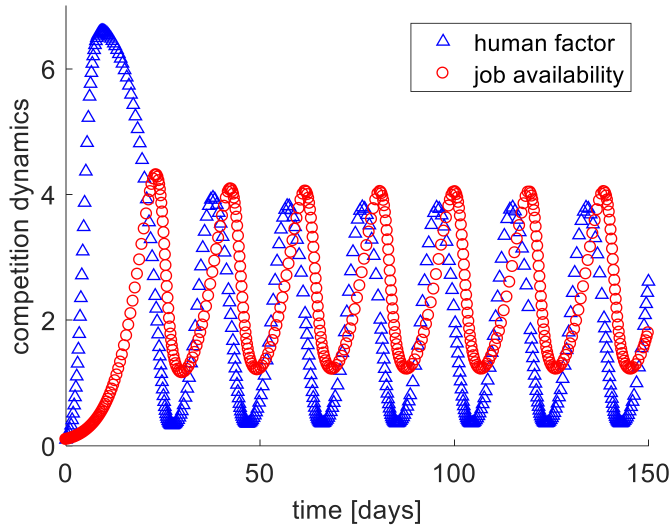

Fig. 2. Jobs-workforce availability; 2006

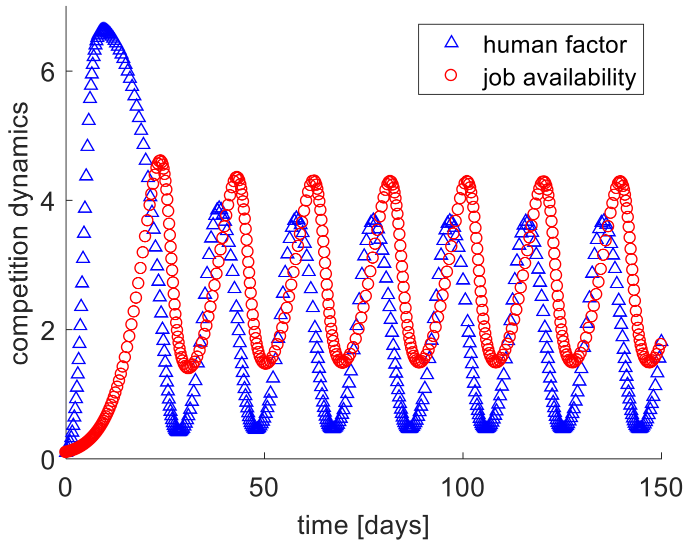

Fig. 3. Jobs-workforce availability; 2007

The unemployment rate in the fourth quarter of 2008 was still in a reasonable range of 7.5%, as shown in Figure 3.

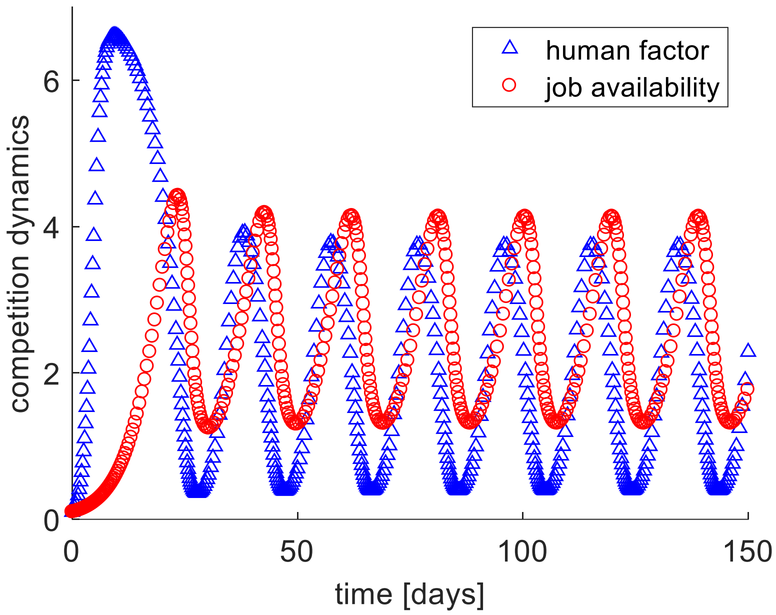

Fig. 4. Jobs-workforce availability; 2008

As already mentioned, the jobs availability within the EU felt the impact of the economic crises at a later time and thus, the fourth-quarter of 2009 saw a large jump in the unemployment rate reaching almost 10%. The correlation of the jobs-workforce availability for the fourth-quarter of 2009 is presented in Figure 4 and it shows a large discrepancy between the jobs-workforce availability. Therefore, as predicted by the mathematical model there were much less jobs than the workforce available which lead to 9.75% unemployment rate. However, this was just the beginning of a period of about 9 years of high unemployed throughout the EU. However, it is important to mention here that this not only the result of the economic crisis but also the impact of the uncontrolled migration of the population of North Africa and Middle-East. However, the fourth-quarter of 2010 did not bring too much hope to the EU unemployment rate and thus, the unemployment continued to increase to more than 10%.

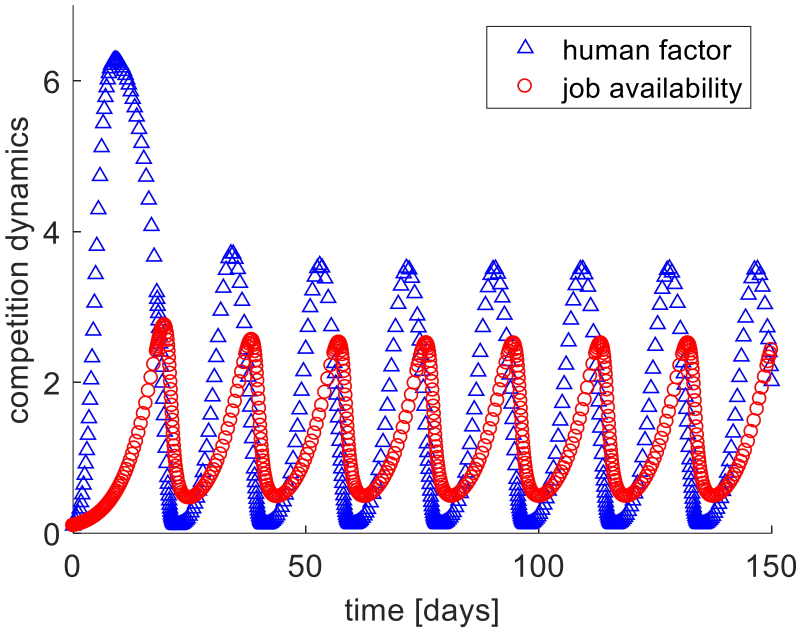

Fig. 5. Jobs-workforce availability; 2009

This also reflected in the large discrepancies in the mathematical model, between the jobs available and workforce available, as seen in Figure 5. As shown by the mathematical results, a significant difference between the jobs available and workforce available is observed, Figure 6. The fourth-quarter of 2010 exhibits an interesting phenomenon, in the sense that although there was an increase in the jab vacancy as shown in Figure 7, there was still in increase in the unemployment rate. This interesting behavior of the unemployment rate can be associated with the lack of workers required skills by the employer. Therefore, although there were jobs available, the job seekers did not meet the hiring criteria. Another explanation of this phenomenon may be the fact that the jobs available might have been low-paid jobs and thus, it did present too much interested.

The fourth-quarter of 2012 experienced a significant increase of the unemployment rate from 10.5% in the fourth-quarter of 2011 to more than 11.5% in Q4 of 2012. The job vacancy also saw a slight decay from 1.52% in the fourth-quarter of 2012 to 1.45% in the fourth-quarter of 2013. The rate of unemployment is also reflected in the mathematical model where the work-force available exceeds the jobs available, as shown in Figure 8.

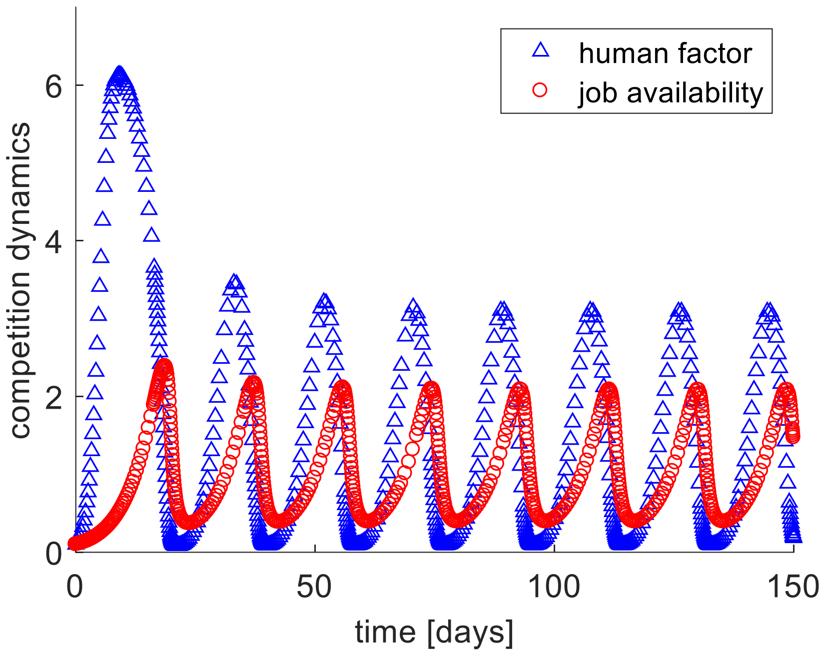

Fig. 6. Jobs-workforce availability; 2010

The fourth-quarter of 2011, brought a farther increase of the unemployment rate with the EU and thus, the unemployment rate raised to almost 10.5%. It is worth mentioning here that the fourth-quarter of 2011 also brought up an interesting phenomenon, similar to the Q4 of 2010, in the sense that although there was an increase in the jobs availability from 1.2% in 2010 to 1.5% in 2011, the unemployment remained high. There might be two different factors that cause interesting non-correlation. One of the factors might be due to the fact that although there more jobs available in fourth-quarter of 2011 than same quarter of 2010 the workforce available did not meet the employer requirements. The other factor may be associated with the uncontrolled migration which could have shifted artificially the correlation of the jobs-workforce availability. This suggests that there was more workforce available than the jobs available, despite the increase in jobs availability. In other words, the uncontrolled migration may have brought more workforce in the market than the newly created jobs.

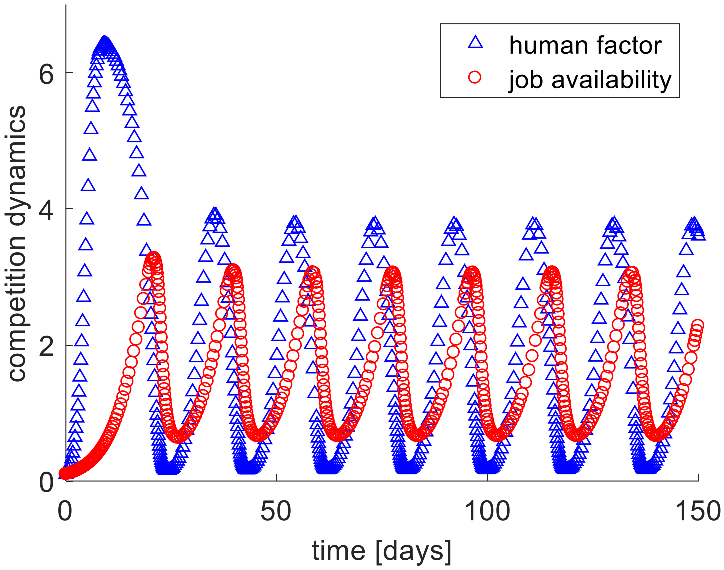

Fig. 7. Jobs-workforce availability; 2011

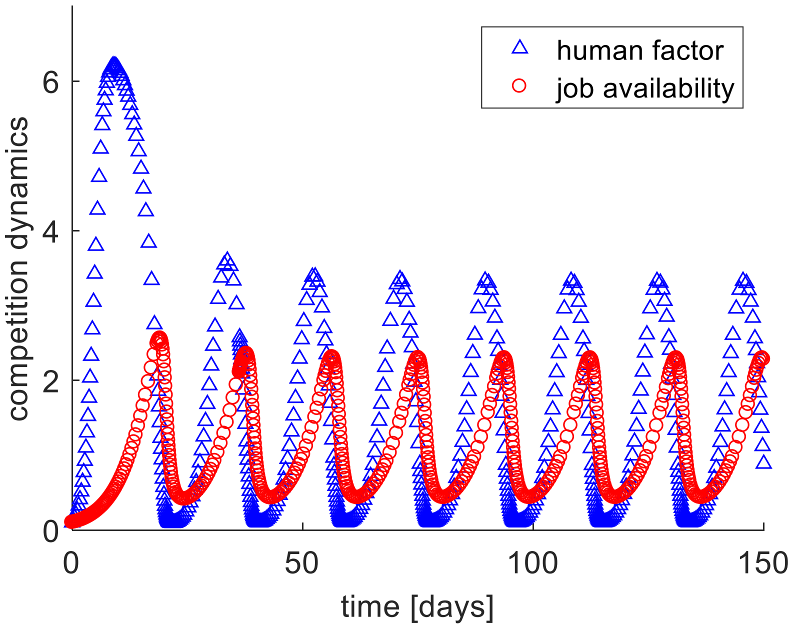

Fig. 8. Jobs-workforce availability; 2012

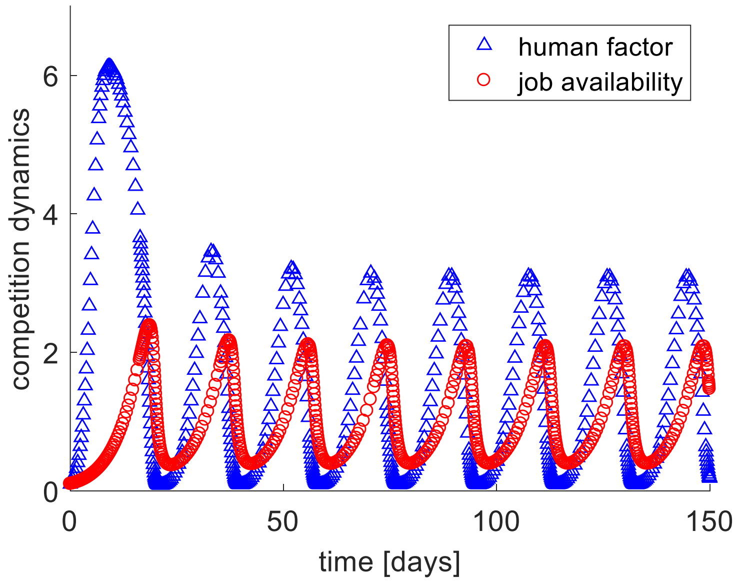

Fig. 9. Jobs-workforce availability; 2013

The Eurostat data shows that the fourth-quarter of 2013 experienced the largest unemployment rate over the period 2006-2023. Therefore, the unemployment rate was more than 12% in fourth-quarter of 2013. The job vacancy also saw a decrease compared with the fourth-quarter of 2011 and 2012. However, the job vacancy was higher than the period of 2006-2010. The explanation for the high unemployment rate in spite of relatively high job vacancy may be again the lack of skills required for the jobs available. It might happened that the job seekers did not possess the necessary skills required by the employers. The difference between jobs available and workforce available is also reflected by the mathematical model, in Figure 9.

5. Conclusions

A stochastic model using the theory of probability is developed and employed for the prediction of the relationship between the workforce resources and job availability. The study shows that the stochastic modeling is a powerful tool that can be used successfully in the prediction of the dynamics of human resources while establishing a correlation with the job availability. The stochastic modeling of the human resources dynamics is a promising predictive approach that can help in enhancing the management of human resources and thus, minimizing the risk of skilled work force.

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