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FUZZY ESTIMATING METHOD FOR QUANTITATIVE IMBALANCE OF DEMAND AND SUPPLY OF INFORMATION TECHNOLOGY SPECIALISTS

The paper is devoted to an attempt of modelling supply and demand interaction processes in the labour market for information technology experts (IT professionals). Paper considers the labor market conditions and the evolution of the approaches to supply-demand balancing in the labour market of IT professionals. The method is proposed for estimating the degree of supply and demand imbalance for IT professionals based on fuzzy mismatch scale. The algorithm of fuzzy classification of states of imbalance is proposed.

Keywords: labour market for IT professionals, labor market conditions, supply-demand balancing, quantitative imbalance index, fuzzy mismatch scale, fuzzy classification of states of imbalance.

Introduction

The supply and demand mismatch in the labour market today is one of the most pressing problems in the world. In the field of information technology, this problem is even more complicated. High dynamics of the ICT sector, global informatization, rapid technological change, rapid obsolescence of knowledge and, consequently, of the content and structure of IT professions and specialties cause the imbalance in volume and structure of incoming and outgoing flows in the labour market for IT professionals. This in turn leads to supply and demand mismatch for the latter both in professional qualification and quantitative perspective [1–5]. Depending on the qualitative and quantitative aspects the imbalance of supply and demand for IT professionals has different forms, can be viewed at different levels (microfocus or macrofocus) and requires the use of appropriate approaches to its reduction.

Despite the understanding by the countries of the need to adopt policies to eliminate the imbalance of supply and demand for IT professionals, within which the new technologies and tools are developed and implemented, the issues of supply and demand for IT professionals, development of appropriate approaches and methods of their modelling, support of management decisions in coordination of supply and demand in the labour market for IT professionals that take into account the specifics of this sector of the economy [6–9], the preferences of its main actors and the nature of the imbalance are undersold in the scientific literature.

Conditions of labour market for IT professionals

The interaction of supply and demand for IT professionals set the conditions of the respective labour market segment. Labour market conditions are a real situation emerging in the labour market during the interaction of supply and demand (purchase and sale of labour power) influenced by numerous factors (political, socio-economic, demographic, and others.) [10, 11].

It is characterized by ratio of supply and demand. From the perspective of labour market conditions three of its states are traditionally distinguished: balance, labour shortage and labour surplus. In practice, both general and structural equilibrium (balance, coordination) of labour supply and demand are difficult to achieve. Labour market conditions have a direct impact on the remuneration of labour (wages), which in turn varies depending on the markets conditions.

Let's consider the labour market situation in the context of information technology segment. Thus,

1) if at the time t the demand vector $V(t)$ exceeds the supply vector $S(t)$, i.e. total demand for IT professionals in various IT professions and specializations is higher than the total supply

in the terms of the considered IT professions and specializations $V(t) > S(t)$, then there is a shortage of IT professionals in a labour market;

2) if at the time t the supply vector $S(t)$ exceeds the demand vector $V(t)$, i.e. the total supply of IT professionals in various IT professions and specializations is higher than the total demand for IT professionals in the terms of the considered IT professions and specializations $V(t) < S(t)$, then there is a surplus of IT professionals in a labour market;

3) if at the time t supply $S(t)$ and demand $V(t)$ vectors coincide, i.e. the number and structure of supply of IT professionals is equal to the number of relevant IT jobs, which require IT professionals of designated qualifications and specialization, then one may say about the ideal situation of balance $V(t) = S(t)$ in the labour market.

Description of the labour market situation by means of the above mentioned three situations doesn't reveal a wide range of interrelations between supply and demand for IT professionals. For example, the gap (imbalance) between supply and demand may be quite wide (critical) or, on the contrary, not significant. The character of the growth or decrease of imbalance trend from the perspective of supply and demand needs to be focused on, i.e., both the dynamics of supply and trend of shift in demand shall be revealed. The variety of possible conditions of demand and supply causes a corresponding multitude of different situations in the labour market for IT professionals. This, in turn, determines for each case the necessity for a prompt appropriate managerial decision towards reducing the imbalance of supply and demand.

The intention to accelerate and provide sustainable economic growth and competitiveness put to the forefront over recent years the balancing (coordination) issues and forecasting of supply and demand in the labour market as extremely important strategic tasks. The need for training and development of IT staff having professional skills relevant to labour market needs, requires the development of new, more flexible approaches and methods for harmonizing supply and demand for IT professionals.

The evolution of the approaches towards determination of staff demand and supply-demand balancing in the labour market

The continuously varying economic situation, the movement of countries towards innovation-driven growth of the economy cause the change in the requirements for IT-profile jobs, expand of IT professions and specializations content and introduction of new ones. This in turn leads to the formulation of new competence requirements to IT professionals (the profile of professional skills) by employers, and causes a need to determine the demand for competence of the latter by way of qualification requirements for IT profile jobs. The competences considered through the prism of formal qualifications of IT professionals are a tool aggregating professional profiles, individual experience, personal and other qualities of the latter, as well as determine their employment opportunities, career growth, self-confidence, etc.

The competences are also important factors and mechanism in the development and harmonization of labour, education and economic development policies. The challenges faced by the labour market for IT professionals specify new demands to the educational system. The essence of these requirements reduces to creating conditions that allow determining the qualifications of graduates by recognizing learning outcomes as set of skills and knowledge obtained during the mastering of educational programs, relevant to the employer's qualification requirements to IT profile workplace rather than by recognizing of a course taken.

The urgency of the problem of noncompliance of electronic skills (professional knowledge, expertise, experience, etc.) of IT professionals formed by educational institutions with e-skills that are in demand in the labour market, contributed to launching of a number of initiatives and research in this field [12–16].

Naturally, for each type of imbalance or their combination there will be different decisions on the development of appropriate control actions towards balancing of supply and demand for IT professionals. Thus, depending on the current labour market situation and in accordance with the anticipated needs of forming an innovative economy the control actions may be directed towards harmonization of:

- a) quantitative characteristics (eliminating shortage or excess of IT personnel);
- b) qualitative characteristics (obsolescence of professional skills);
- c) the level of training of IT professionals (superior or insufficient skills);
- d) the structure of training of IT professionals (deficit or surplus of IT professionals of certain specialization, obsolescence of one and the emergence of other IT professions and specialties);
- e) various combinations of the above mentioned types of imbalance.

In the study of processes of supply and demand balancing it is also necessary to identify the level of the imbalance assessment. It can be:

- 1) microfocuss, that includes individual level (IT specialist), the level of employer (company);
- 2) macrofocuss, that includes the levels of industry (sector, segment) or the entire economy.

In [17, 18] the methods of labour market for IT professionals governance at a micro level are proposed, based on the fuzzy multicriteria methods of IT professionals selection and fuzzy pattern recognition.

The method of evaluating the degree of supply and demand imbalance using fuzzy mismatch scale

For the general characteristics of supply and demand ratio in the labour market for IT professionals in a time interval $[t_1, t_2]$:

1. the scope and pattern of demand for IT professionals in the terms of IT professions and qualifications we shall describe with the vector

$$V[t_1, t_2] = \{V_1[t_1, t_2], V_2[t_1, t_2], \dots, V_N[t_1, t_2]\},$$

representing the variety of IT vacancies by the branches of the national economy in a timeframe $[t_1, t_2]$, where N is a number of IT professions available in the labour market;

2. the scope and pattern of supply for IT professionals in designated timeframe in terms of IT professions we shall describe with the supply vector

$$S[t_1, t_2] = \{S_1[t_1, t_2], S_2[t_1, t_2], \dots, S_N[t_1, t_2]\}.$$

3. we introduce the concept of "quantitative imbalance index", which defines the ratio of the number of unemployed IT professionals who are seeking for a job (supply) to the number of IT-profile jobs:

$$\delta = S[t_1, t_2] / V[t_1, t_2] \text{ if } S[t_1, t_2] < V[t_1, t_2]$$

and

$$\delta = V[t_1, t_2] / S[t_1, t_2] \text{ if } S[t_1, t_2] > V[t_1, t_2].$$

Typically, the actual data for the evaluation of supply and demand come from various sources. This information is not perfect, far from complete and is not lacking in subjectivity and inconsistency. Therefore it seems to be natural to consider the index of "supply and demand imbalance" as a linguistic variable.

Depending on the degree of the supply and demand perturbation (mismatch) each imbalance gradation can be verbally expressed with such linguistic terms as optimal imbalance,

minimum imbalance, allowable imbalance, ultimate imbalance and complete imbalance of supply and demand. It is proposed to describe the range of variation of supply and demand imbalance for IT professionals in the form of a mismatch scale that consists depending on the degree of superiority of demand over supply, or, on the contrary, of supply over demand, the two segments, which we call the area of positive demand in the case of the superiority of the latter over the supply and, otherwise, the area of positive supply.

Information on the imbalance degree in the mismatch scale is expert assessments in the form of membership function of the fuzzy sets derived by experts through mapping of above mentioned verbal gradations (values) of the linguistic variable of "supply and demand imbalance" onto the universal fuzzy scale represented by the interval $[0,1]$. Here, the point 0 corresponds to unacceptable value of quantitative imbalance characteristics, i.e. reflects a complete imbalance of supply and demand, and point 1 corresponds to the equilibrium of supply and demand, i.e., reflects the ideal ratio of the latter.

For a formal description of verbal parameters the experts determined the appropriate linguistic and fuzzy variables, the basic sets and membership functions of fuzzy variables, in setting which the direct and indirect methods are used [19–22].

Under the direct method the membership degrees of $x \in X$ elements may be defined by one expert or a group of experts. In the case of one expert he put the each of $l = \overline{1, m}$ verbal gradations of linguistic variable "supply and demand imbalance" in correspondence with the degree of membership $\mu_l(x) \in [0,1]$, which in his view corresponds in the best way with to the semantic interpretation of a fuzzy set.

Figure 1 graphically illustrates the mismatch scale that reflects the supply and demand imbalance. As is clear from the figure, each of these areas of imbalance changes $[E, A]$ and $[E^*, A^*]$ represents the interval $[0,1]$, divided according to the possible mismatch degree of supply and demand in a number of segments – areas of deviation from the standard imbalance value.

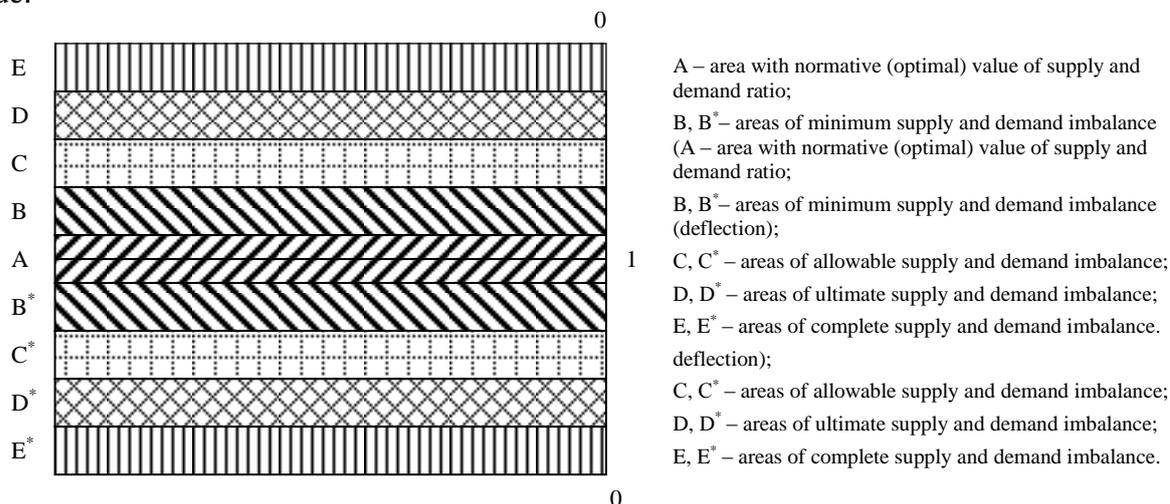


Fig.1. Graphic illustration of supply and demand imbalance degree

To formalize the parameters that determine the imbalance degree of supply and demand at some instant, we use the functions introduced in [23] to assess the measure of the uncertainty by

the functions $s(S_j)$ called fuzzy measures and representing a real number which the expert put in correspondence with each S_j event.

For $\forall i$ function $s(S_j)$ characterize the expert's degree of certainty that $s(S_j) \in \Psi_s$. Thus, the range of imbalance change depending on its manifestation degree, i.e. semantic interpretation of verbal gradations, can be divided via method of expert assessment into several fuzzy intervals, reflecting the variation range of the membership functions of the fuzzy sets of verbal gradations of linguistic variable "supply and demand imbalance" δ_i , defined in the set of real numbers R_δ as a function $\mu_{\delta_i} : R_\delta \rightarrow [0,1]$.

Thus, for example, from the expert point of view the range of the membership degrees in the interval $[0.8, 1]$ may match the normative value of supply and demand imbalance, and the complete imbalance of supply and demand may occur in case of falling of membership functions values within the interval $[0; 0,2)$ (table 1).

Table 1

Variation range of membership functions of fuzzy sets of verbal gradation of supply and demand imbalance, including from a perspective of certain IT professions and specialties

	Terms – verbal (fuzzy) assessment of linguistic variable "supply and demand imbalance" gradations	Range of terms variation on the imbalance scale
Supply and demand imbalance	Optimal (normative) supply and demand imbalance	$[0,8; 1]$
	Minimum imbalance	$[0,6; 0,8)$
	Allowable imbalance	$[0,4; 0,6)$
	Ultimate imbalance	$[0,2; 0,4)$
	Complete supply and demand imbalance	$[0; 0,2)$

Let us set the normative value of imbalance (the optimal supply and demand ratio) at the time moment t^m (or in certain time segment) through

$$\delta^{t^m}_{norm} = S^{t^m}_{norm} / V^{t^m}_{norm}, \text{ if } S^{t^m}_{norm} < V^{t^m}_{norm},$$

and

$$\delta^{t^m}_{norm} = V^{t^m}_{norm} / S^{t^m}_{norm}, \text{ if } S^{t^m}_{norm} > V^{t^m}_{norm}, .$$

If the current values of supply and demand are known and, respectively, their ratio (current imbalance), i.e.

$$\delta^{t^m}_{cur} = S^{t^m}_{cur} / V^{t^m}_{cur},$$

then the membership functions on the imbalance scale may be determined through the following formula:

$$\mu_l(x) = 1 - \left| \delta^{t^m}_{cur} - \delta^{t^m}_{norm} \right|. \tag{1}$$

As it's clear from the Figure 1, the supply and demand imbalance may vary in a wide range: from the normative value of supply and demand ratio to their total imbalance. The closer

is the value of the current imbalance to the normative the more favorable is the range of variation the values of the membership functions of the current state fall in.

This approach to assessing the labour market situation allows making fuzzy classification of its states according to the degree of supply and demand imbalance.

The algorithm of fuzzy classification of states of imbalance

Fuzzy classification of imbalance states depending on its intensity at a particular time moment can be determined according to the following algorithm:

1. To define a set of verbal parameters of linguistic variable of "supply and demand imbalance" reflecting the classes of fuzzy state of imbalance.

2. For each class of fuzzy mismatch states to determine the variation range of the membership functions of the fuzzy sets of gradation imbalance.

3. To generate the appropriate control actions in the form of production rules for each class of fuzzy imbalance states in accordance with the values of membership functions within their variation range and using expert knowledge.

4. For each estimated time slice to determine the mismatch (deflection) between the current and the standard value of imbalance using formula (1).

5. In accordance with the mismatch of supply and demand and the value of the corresponding membership functions to set the class to which the investigated state of imbalance refer.

6. Depending on the class in which demand and supply deflection rates fall, the activation of condition-action rule from the knowledge base, corresponding to the desired management decisions.

For example, the control actions generated in the form of condition-action rules in an open knowledge base, depending on the class into which they are incorporated, may relate to elimination of discrepancies between supply and demand in the context of filling quantitative shortage of IT professionals, including in particular IT occupations and professions, or coordination of structural imbalance of IT professionals. Then production rules may affect the qualitative aspects of the supply and demand imbalance associated with obsolescence of IT skills, with emerging and the need to eliminate the factors suppressing the IT sector growth. Another class of control rules can be associated with policies in the field of continuing education and training (retraining, upgrade qualifications, additional education) aimed at suppressing the supply and demand mismatch. Yet another class of rules may reflect measures on expanding and creating new innovative IT-profile jobs, developing the necessary human resources, adaptation of IT education system to the IT professionals market needs, developing mechanisms for coordination of stakeholders' activity in the labour market for IT professionals etc.

Conclusion

Approaches that are proposed in the article towards modelling supply and demand interaction in the labour market for IT professionals and management of their quantitative mismatch at the macro level, transaction scheme of intellectual management of IT professionals labour market, evaluating methods of the structural imbalance in the labour market for IT professionals, the degree of supply and demand imbalance based on fuzzy mismatch scale, fuzzy classification algorithm of imbalance states, the approaches to the formation of a knowledge base in the form of production rules that describe the dependence of the adoption of one or another management decision on the value of supply and demand mismatch are one of the possible options for matching supply and demand in the quantitative terms and can support various person concerned in making informed decisions on management of imbalance in the labour market for IT professionals.

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İnformasiya texnologiyaları mütəxəssislərinə olan tələb və təklifin kəmiyyət disbalansının qeyri-səlis qiymətləndirilməsi metodu

Məqalədə, əmək bazarında informasiya texnologiyaları mütəxəssislərinə (İT-mütəxəssislər) olan tələb və təklifin qarşılıqlı əlaqəsi proseslərinin modelləşdirilməsi məsələləri tədqiq edilmişdir. İT-mütəxəssislər segmentində əmək bazarının konyekturasına və tələb-təklifin uzlaşdırılması istiqamətində mövcud yanaşmaların təkamülünə baxılmışdır. Qeyri-səlis uyğunsuzluq şkalası əsasında İT-mütəxəssislərə olan tələb və təklifin disbalans dərəcəsinin qiymətləndirilməsi metodu təklif edilmişdir. Disbalansın vəziyyətinin qeyri-səlis klassifikasiyası alqoritmi işlənmişdir.

Aşar sözlər: İT-mütəxəssislər əmək bazarı, əmək bazarının konyekturası, tələb və təklifin uzlaşdırılması, qeyri-səlis uyğunsuzluq şkalası, kəmiyyət disbalansı göstəricisi.

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Метод нечеткой оценки количественного дисбаланса спроса и предложения на специалистов по информационным технологиям

В статье исследованы вопросы моделирования процессов взаимодействия спроса и предложения на рынке труда специалистов по информационным технологиям (ИТ-специалистов). Рассмотрены конъюнктура рынка труда, эволюция подходов к согласованию спроса и предложения на сегменте ИТ-специалистов. Предложен метод оценки степени дисбаланса спроса и предложения на ИТ-специалистов на основе нечеткой шкалы рассогласованности. Разработан алгоритм нечеткой классификации состояний дисбаланса.

Ключевые слова: рынок труда ИТ-специалистов, конъюнктура рынка труда, согласование спроса и предложения, нечеткая шкала рассогласованности, показатель количественного дисбаланса.