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Factors Affecting Knowledge Commercialisation in University: A Case Study

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ABSTRACT

Commercialisation is accounted as the third mission of the universities; it is the idea expressing that the universities play a socio-economic role. The current research paper attempts to identify and rank the factors influencing the process of commercializing the research results of Payam-e-Noor University (PNU) to recognise the extent to which the identified factors are influential to pave the way for offering a structural-interpretational model of commercialisation according to the present study's findings. The delineation of a structural-interpretational model based on the investigation of the factors influencing the commercialisation of the researches' results contributes to the managers and decision-makers in the area of knowledge commercialisation to, meanwhile paying attention to the existent factors offered in the influential and basic levels, set the ground for the corroboration and improvement of the statuses of the existent influential factors in higher levels of the model thereby to bring about an increase in the success rate of the commercialisation of the studies' results.

Keywords: Knowledge commercialisation; Knowledge management; Commercialisation of research results.

1. INTRODUCTION

The need to pay attention to the commercialisation of knowledge in universities and to identify the factors influencing it for strategic planning in universities has become an undeniable principle today, which leads to a shift in the role of universities from knowledge producers to producers of capital from knowledge. This role shift takes place with the aim of improving the performance of the national or regional economy as well as generating financial benefits to the university and its staff, and leads to an increase in commercialisation-related activities in the last two decades. The commercialisation of knowledge in any society is influenced by the political, economic, cultural, and social structures of that society, and the relationship among the university, industry, and the government. Debacker and Veugelers (2005) considered the diverse inclination of universities towards the commercialisation of knowledge and, consequently, various commercialisation patterns in academic environments to be the result of various organisational structures in the universities1. Therefore, universities intending to increase their efficiency, effectiveness, and competitiveness in the KC process are forced to reconsider the shape and size of their structures[1]. Pourezzat *et al.* (2010) also considered the presence of professional bureaucratic structures with traditional organisational boundaries to be the reason of reduced KC inclination in universities. They claimed that some appropriate solutions for KC in universities are to change management and structural policies of the universities, to encourage the relationship between universities and the industry, to consider time requirement, and to change the management style. Therefore, in order to develop the commercialisation of university research products, it is necessary to build and reinforce the appropriate culture of the trend at the university[2].

Knowledge commercialisation reduces the dependency of universities on public budget. On the other hand, consideration of the commercialisation of research results and innovations is the manifestation of recognizing the importance of science and technology and the approval of their direct effect on economic, social, cultural, and political development[2]. The adoption of this approach is a promising start in removing the existing barriers to the formation of a knowledge-based economy. The success of academic sections in commercialisation of research results necessitates the provision of important and different prerequisites and requirements in the academic, industry, and the dominant socio-economic environment of the two sectors. Pazhouhesh Jahromi (2016) asserts in his research that, given the current academic philosophy, research commercialisation at universities is necessary in order to fill up the income basket and to provide services to the community. However, despite its necessity, research commercialisation is a difficult process and it might be followed by a lot of failures which are mainly due to the difference in cultural context and the environmental difference between the origin (university) and destination (industry) of the technology3.

The design of KC mechanisms and its operationalisation, in the first phase, requires the identification of factors affecting KC in the universities. To this end, using expert opinions in the present research, we attempted to identify the most

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important barriers to KC in PNU in order to present strategic recommendation and introduce factors affecting KC through the recognition of available grounds in this area. Therefore, in order to fulfill the main purpose of the research as "Identification of barriers to KC in PNU in order to present strategic recommendations in this area", we attempted to find answers to the following questions.

- What are the barriers to KC in PNU?
- How to prioritise barriers to KC in PNU?
- What cause-and-effect relationships do exist between the barriers to KC in PNU?
- What strategic recommendation can be presented for KC in PNU?

2. LITERATURE REVIEW

Commercialisation is a challenging problem in universities since business activities stand in contrast to the traditional role of the universities in the provision of education and research. However, it should be considered as a new goal in gaining economic benefits. The commercialisation of knowledge in universities is influenced by two categories of preventive and progressive factors. Among preventive factors, we can mention challenges and barriers to KC in universities. Many studies have identified the barriers to KC and other minor related issues, such as lack of sufficient capital[3,4], lake of policy[2,5-7], lack of commercialisation culture[5,8,7,9-11], restrictive policies[2,9,12,13], and lack of connection between university and industry[5,14-18,2,19].

Jang, Lee, and Lee (2015) reviewed the progressive factors and barriers to knowledge commercialisation in South Korea. The results of this research showed that marketing and cooperation with the producer have been introduced as the most important factors of commercialisation development. Also, inadequate capital, lack of attention to market conditions and the lack of marketing capabilities were identified as the most important barriers to knowledge commercialisation4.

Biranvand and Seif (2018) using a fuzzy method determined that among the triple factors of context, content and structure, the contextual factors had the highest importance, and among the investigated sub-criteria, the commercialisation culture, the knowledge-base and research quality, and innovative infrastructure sub-criteria had the highest importance. The prioritisation of the investigated indices showed that the indices of developing commercialisation culture and entrepreneurship, processing the results for different purposes, and focusing and considering the market and customer needs, respectively, are listed as having the highest priority. They emphasised that, due to the direct relation of the contextual factors with economy and policies, they have the greatest effect on knowledge commercialisation at universities[8].

Zahra *et al.* (2018), in a review article, studied the causes of knowledge commercialisation failure. Given the study findings, it became evident that the lack of confidence of decision-makers in knowledge-based economy, the lack of mutual cooperation between universities and industry, lack of financial support, lack of familiarity with market conditions and a long interruption between knowledge generation and turning it into products, are among the most important factors of knowledge commercialisation failure[9].

Clayton *et al.* (2018) examined the contributing factors to the success or failure of knowledge commercialisation. Given the study results, it became clear that there are several factors determining the success or failure of knowledge commercialisation projects. These factors include physical space (incubators, accelerators, and co-working space), specialised service providers, business networks, communications, organisational sponsor, and organisational funding. The rest of their paper discussed the effect of each factor on the success or failure of knowledge commercialisation[20].

Hamilsky and Powell (2018) investigated the progressive and preventive factors of knowledge commercialisation. Given the research results, factors such as investment in research and development, governmental support, the relationship among universities, research institutes and industry, and the use of experts' opinion have been introduced as the most important propagators of knowledge commercialisation. On the contrary, the weak relationship between industry and university, cultural factors, weaknesses in laws and regulations, and inadequate intellectual capital support have been identified as the most important barriers to knowledge commercialisation[7].

Biranvand *et al.* (2019) investigated the effects of different variables on the intention to commercialise knowledge: including psychological empowerment, self-efficacy, university policies, social capital, perceived behavior control, attitude towards commercialisation. They stated that, based on correlation coefficient values, there was a significant relationship between the intention to commercialise knowledge and the variables of psychological empowerment, perceived behavior control and attitude toward commercialisation at the level of 0.01, and the social capital variable at the level of 0.05. Moreover, they found that there was no significant relationship between the intention to commercialise knowledge and the self-efficacy and university policy variables[3].

3. METHODOLOGY

The present research is an applied research in terms of objectives and it is conducted using confirmatory factor analysis. Data were collected through the review of previous studies and using Delphi method. Fuzzy Delphi method was used for validation and variable screening; and fuzzy AHP was used for prioritizing barriers to KC. In addition, fuzzy DEMATEL technique and interpretive-structural modeling were used for development of the model and identification of the relationship between variables. The research questionnaire, which was based on fuzzy DEMATEL technique, aimed to identify the cause-effect relationship pattern among the research variables. A pairwise comparison questionnaire was used to prioritise the factors.

The statistical population of the study consisted of knowledge commercialisation experts at PNU. Accordingly, 30 participants were selected using purposive sampling with respect to the research approach; these participants met at least one of the following criteria:

- Individuals who have commercialised their research findings or they had the intention to commercialise but failed to do so.
- Individuals who are familiar with the commercialisation

of university research, the process of obtaining a patent, and academic enterprises.
- Individuals who have accomplished at least one of the phases of the process of research commercialisation.

4. RESEARCH FINDINGS

To evaluate the specified research objectives, barriers to commercialisation were first identified using research findings, and then, they were prioritised so that the driving and dependency power of each index could be measured through the interpretive-structural equation modeling. Determining the driving and dependency power of the indices helps to partition them in the proposed model.

4.1 Identification of Barriers to KC

In the first step, we identified and screened barriers to KC in the universities. Based on literature review and specialised interviews, 28 indices were identified. In the next step, fuzzy Delphi method is used for identifying and screening the ultimate indices. Based on fuzzy 7 point scale (Table 1), the fuzzy mean and the defuzzified output values relevant to the indices are calculated (Table 2). The defuzzified values above 0.7 are acceptable; hence, any index scored less than 0.7 is eliminated.

Table1. Fuzzy 7 point scale for rating the indices

Definitive equivalent	Language variable	Fuzzy Number Scale
1	Absolutely trivial	(0, 0, 0.1)
2	Very trivial	(0, 0.1, 0.3)
3	Trivial	(0.1, 0.3, 0.5)
4	Average	(0.3, 0.5, 0.75)
5	Important	(0.5, 0.75, 0.9)
6	Very important	(0.75, 0.9, 1)
7	Absolutely important	(0.9, 1, 1)

4.1.1 Calculation of the Fuzzy Mean of Expert Opinions

To find the sum of the respondents' opinions and to compute the fuzzy mean of their opinions, the following equation is used:

$$F_{AGR} = \left(\min\{1\}, \left\{ \frac{\sum m}{n} \right\}, \max\{u\} \right)$$

Each triangular fuzzy number, i.e. the sum of expert opinions for the jth index, is represented as follows:

$$t_j = \left(L_j, M_j, U_j \right)$$

$$L_j = \min\left(X_{ij} \right)$$

$$M_j = \sqrt[n]{\prod_{i=1}^{n} X_{ij}}$$

$$U_j = \max\left(X_{ij} \right)$$

The subscript *i* refers to the expert, thereby:

- X_{ij}: The value of the i^{th} expert's assessment of the j^{th} criterion
- L_j: The minimum assessment value obtained for the j^{th} criterion
- M_j: The geometric mean of the value of experts' assessment of the j^{th} criterion function
- U_j: Maximum assessment value obtained for the j^{th} criterion

4.1.2 Defuzzification of Values

The DEMATEL technique was introduced by Fontela and Gabus in 1976. In fact, the DEMATEL technique has two major functions. Considering the interdependent relationships, the advantage of this technique over network analysis technique is its clarity and transparency in reflecting the interdependent relationships among a wide range of components; so that experts are able to better express their opinions on the (direction and severity of) effects among the factors. It is worth noting that the matrix derived from the DEMATEL technique (the matrix of interdependent relationships) is actually a part of the super-matrix; in other words, the DEMATEL technique does not operate independently but as a subsystem of a larger system such as the ANP. Its second function is to identify and structure complex factors into cause-effect groups. This is one of its most important functions and one of the most important reasons why it is widely used in problem solving processes. Dividing a broad set of complex factors into cause-effect groups, the DEMATEL technique provides the decision-maker with a better understanding of the relationships. This leads to a better understanding of the status of the factors and their role in the inter-effect. Generally, the triangular and trapezoidal fuzzy numbers can be summed up by a crisp value which is the best corresponding mean. This operation is called defuzzification. There are several defuzzification methods. In the present study, the center-of-area method is used for defuzzification, as follows:

$$DF_{ij} = \frac{\left[\left(u_{ij} - l_{ij} \right) + \left(m_{ij} - l_{ij} \right) \right]}{3} + l_{ij}$$

The fuzzy mean and the defuzzified output of the values relevant to the indices, extracted from the review of the previous sources, are presented in Table 2.

4.2 Prioritisation of the Indices of KC

The fuzzy AHP has been used to prioritise the identified indices. Thus, 28 indices were identified and classified into 6 main criteria (Table 4). The main criteria are: legal barriers, human resource barriers, economic barriers, structural and policy barriers, communication and information barriers, and cultural barriers. Some sub-criteria (indices) are defined for each main criterion based on the main criteria mentioned in the literature and the experts' interviews. The criteria and barriers (indices) of the research are named using a numerical index to be easily detected and studied during the research.

The analysis was carried out in 3 steps, as follows:
- Prioritizing the main barriers based on the objective through a pairwise comparison;

Table 2. Results obtained from index screening

Code	Indexes	L	M	U	Crisp	Results
S01	Weak legal framework for supporting ideas of people at the university	0.58	0.75	0.88	0.74	Accept
S02	Inefficiency and ineffectiveness of the rules and regulations for commercialization of research	0.59	0.77	0.89	0.75	Accept
S03	Lack of regulation for the apportionment of financial gain from commercialization among scholars	0.62	0.80	0.92	0.78	Accept
S04	Lack of intellectual property rights and ownership rights resulted from joint research with industry	0.57	0.74	0.88	0.73	Accept
S05	Lack of effective policies to improve the quality of academic research	0.67	0.83	0.93	0.81	Accept
S06	Low intention towards commercialization	0.68	0.85	0.95	0.83	Accept
S07	Lack of skilled and expert human resources	0.60	0.78	0.90	0.76	Accept
S08	Weakness of the university in providing high motivation for human capital	0.61	0.80	0.92	0.78	Accept
S09	Inadequate knowledge of the faculty members	0.60	0.78	0.91	0.77	Accept
S10	The inadequacy of the scholar's share in the commercialization revenues	0.61	0.79	0.91	0.77	Accept
S11	Poor fund management in the university	0.66	0.82	0.92	0.80	Accept
S12	Weakness of universities in wealth creation	0.59	0.77	0.90	0.75	Accept
S13	Lack of financial resources and facilities for commercialization of research results	0.62	0.80	0.92	0.78	Accept
S14	Lack of university sponsorship for researchers to exploit production know-how	0.72	0.87	0.95	0.85	Accept
S15	Lack of organized organization for the commercialization of academic research	0.65	0.81	0.92	0.79	Accept
S16	Lack of bureaucratic flexibility	0.60	0.78	0.91	0.76	Accept
S17	Absence of university entrepreneurial missions	0.59	0.75	0.87	0.74	Accept
S18	Lack of a research leading university document	0.67	0.83	0.93	0.81	Accept
S19	Lack of effective policies to improve the quality of academic research	0.62	0.79	0.91	0.77	Accept
S20	The absence of up-to-date and effective idea banks and databases in the university	0.62	0.80	0.92	0.78	Accept
S21	Weakness in mutual recognition of university and industry	0.63	0.81	0.92	0.78	Accept
S22	Weakness in the mutual recognition between university and industry	0.64	0.81	0.93	0.79	Accept
S23	Lack of communication and networks between investors, industry activists and academics	0.65	0.83	0.94	0.81	Accept
S24	Weakness of university in providing consulting services to the community	0.61	0.79	0.91	0.77	Accept
S25	Weak research culture	0.59	0.77	0.90	0.75	Accept
S26	Existence of cultural differences between university and industry	0.55	0.75	0.89	0.73	Accept
S27	Weakness of entrepreneurship culture	0.65	0.80	0.90	0.78	Accept
S28	Uncompromising collective sensitivity to the commercialization of knowledge generated at universities	0.57	0.75	0.88	0.73	Accept

Accordingly, 28 indices have been approved and studied as barriers to KC in PNU.

- Prioritizing the sub-criteria in the relevant cluster through a pairwise comparison;
- Calculating the ultimate weight of indices.

Saaty's 9 point scale is used for pairwise comparison of the components. In the present study, a fuzzy method is used to quantify the values (Table 3).

The geometric mean method is used to find the sum of expert opinions in the fuzzy AHP.

$$F_{AGR} = \left(\prod(l), \prod(m), \prod(u)\right)$$

After forming the matrix of pairwise comparisons, the eigenvector is calculated. First, the fuzzy expansion of each row is computed. Each element of pairwise comparison matrix $\tilde{X}\tilde{X}$ is represented as $\tilde{x}_{ij}\tilde{x}_{ij}$. The fuzzy extension of each row is represented by $\tilde{S}_i\tilde{S}_i$. Therefore, the fuzzy expansion of each row will be calculated as follows:

$$\tilde{S}_i = \sum_{j=1}^{n} x_{ij}$$

Then, the fuzzy summation is computed as the sum of the

Table 3. Triangular fuzzy pairwise comparison

Definition	Fuzzy equivalent	Revers fuzzy equivalent
Equally Preferred	(1, 1, 1)	(1,1,1)
Moderate	(1, 2, 3)	$\left(\frac{1}{3},\frac{1}{2},1\right)$
Moderately Preferred	(2, 3, 4)	$\left(\frac{1}{4},\frac{1}{3},\frac{1}{2}\right)$
Moderate	(3, 4, 5)	$\left(\frac{1}{5},\frac{1}{4},\frac{1}{3}\right)$
Strongly Preferred	(4, 5, 6)	$\left(\frac{1}{6},\frac{1}{5},\frac{1}{4}\right)$
Moderate	(5, 6, 7)	$\left(\frac{1}{7},\frac{1}{6},\frac{1}{5}\right)$
Very strongly Preferred	(6, 7, 8)	$\left(\frac{1}{8},\frac{1}{7},\frac{1}{6}\right)$
Moderate	(7, 8, 9)	$\left(\frac{1}{9},\frac{1}{8},\frac{1}{7}\right)$
Extremely Preferred	(9, 9, 9)	$\left(\frac{1}{9},\frac{1}{9},\frac{1}{9}\right)$

elements in the column of preferences:

$$\sum \tilde{S}_i = \sum_{i=1}^{n}\sum_{j=1}^{n} x_{ij}$$

To normalise the preferences of each criterion, the total values of that criterion must be divided by the sum of all preferences (column elements). Since the values are fuzzy, the fuzzy summation of each row is multiplied by the inverse of summation. The inverse of summation must be calculated.

if $\tilde{F} = (l,m,u)$ then $\tilde{F}^{-1} = \left(\frac{1}{u},\frac{1}{m},\frac{1}{l}\right)$

Therefore, according to the calculations, the ultimate weight of each index of the model is calculated using fuzzy AHP (Annexure 1). Given the results obtained in this phase, the most important indices in terms of the order of priority are as follows: weak legal framework for supporting ideas of people at the university, inefficiency and ineffectiveness of the rules and regulations for commercialisation, researchers' low intention towards commercialisation, the inadequacy of the scholar's share in the commercialisation revenues, weak research culture, lack of regulation for the apportionment of financial gain from commercialisation among scholars, and weakness of universities in wealth creation.

5. INTERPRETIVE-STRUCTURAL MODELING

In this phase, we determine the driving and dependency power of the prioritised indices using interpretive-structural modeling. Interpretive-structural modeling (ISM) is a methodology for establishing and understanding the relationships among elements of a complex system. In other words, interpretive-structural modeling is an interactive process in which a set of different and interrelated elements are structured into a comprehensive systematic model. ISM methodology contributes to ordering the complex relationships among elements of a system. ISM helps to identify the internal relationships of variables; and it is an appropriate technique for analyzing and interpretive-structural modeling to prioritise and analyse the impact of one variable on other variables. It can also prioritise and quantify the elements of a system, which will greatly help managers better implement the designed model. The following process must be followed to implement the ISM technique to obtain the internal relationships and priorities of the elements in a system ISM is a method for creating and understanding the relationships among the elements of a complex system in which a set of different but relevant elements are structured in a systematic comprehensive model. Interpretive-structural equation methodology helps establish order in the complex relationships among the elements of a system and helps managers prioritise and partition the elements of a system. To develop an ISM, we first calculate the structural self-interaction matrix and then the reachability matrix of indices studied in the research.

5.1 STRUCTURAL SELF-INTERACTION MATRIX

Structural Self-Interaction Matrix (SSIM). The first step in interpretive-structural modeling is to find the internal relationships between indices. The matrix obtained in this step shows that a specific variable affects which variables and is affected by which variables. Typically, we use notation represented in Table 4 to identify relationship patterns between elements.

Table 4. Symbols and notations for the relationship between variables

	V	A	X	O
	Variable i affects j	**Variable j affects i**	**Two-way relationship**	**No relation**
(i, j)	1	0	1	0
(i, j)	0	1	1	0

The structural self-interaction matrix is formed using the dimensions and indices of the research and their comparison and using four modes of conceptual relations. The reachability matrix is obtained from the conversion of SSIM into a binary matrix in which all elements are 1 and 0. In the reachability matrix, the main diagonal elements are assumed 1. Moreover, secondary relationships must be controlled to provide assurance. That is, if A leads to B and B leads to C, then A must lead to C. It means, if a direct effect is taken into account on the basis of the secondary relations but it does not occur in practice, the table should be corrected and the secondary relation should also be presented.

One possible strategy for calculating various paths from i to j is the access matrix T. Access matrix T became compatible with the following laws of Boolean:

0 + 0= 0

Table 5. The driving and dependency power of the research variables

Code	Indexes	Driving Power	Dependence Power
S01	Weak legal framework for supporting ideas of people at the university	2	5
S02	Inefficiency and ineffectiveness of the rules and regulations for commercialization of research	2	4
S03	Lack of regulation for the apportionment of financial gain from commercialization among scholars	1	6
S04	Lack of intellectual property rights and ownership rights resulted from joint research with industry	9	11
S05	Lack of effective policies to improve the quality of academic research	5	11
S06	Low intention towards commercialization	2	9
S07	Lack of skilled and expert human resources	1	8
S08	Weakness of the university in providing high motivation for human capital	7	10
S09	Inadequate knowledge of the faculty members	20	6
S10	The inadequacy of the scholar's share in the commercialization revenues	5	7
S11	Poor fund management in the university	21	8
S12	Weakness of universities in wealth creation	13	4
S13	Lack of financial resources and facilities for commercialization of research results	3	8
S14	Lack of university sponsorship for researchers to exploit production know-how	12	8
S15	Lack of organized organization for the commercialization of academic research	2	7
S16	Lack of bureaucratic flexibility	9	6
S17	Absence of university entrepreneurial missions	16	6
S18	Lack of a research leading university document	4	11
S19	Lack of effective policies to improve the quality of academic research	6	7
S20	The absence of up-to-date and effective idea banks and databases in the university	21	5
S21	Weakness in mutual recognition of university and industry	1	8
S22	Weakness in the mutual recognition between university and industry	6	3
S23	Lack of communication and networks between investors, industry activists and academics	7	7
S24	Weakness of university in providing consulting services to the community	7	7
S25	Weak research culture	3	8
S26	Existence of cultural differences between university and industry	7	11
S27	Weakness of entrepreneurship culture	6	8
S28	Uncompromising collective sensitivity to the commercialization of knowledge generated at universities	6	5

$0 + 1 = 1$; $1 + 0 = 1$

$1 + 1 = 1$

Therefore, to calculate the access matrix (T):

$T=(I+D)^{n-1}$; t_{ij} = {1, if there is a path from variable 1 to variable 2, 0; otherwise}

In interpretive-structural modeling, there are effective and reciprocal interactions between criteria; and the relationships between the criteria of different levels are well illustrated, which provides a better understanding of the decision space at the managers' disposal. To determine the key criteria, the driving and dependency power of the criteria are formed on the ultimate access matrix. Table 5 shows the power-dependency diagram for the understudied variables.

6. FINDING THE RELATIONSHIPS AND LEVEL PARTITIONING THE DIMENSIONS AND INDICES

To find the relationships and to partition the criteria, the output and input sets should be extracted for each criteria of the access matrix.

- Reachability set (row elements, outputs, or those that affect): Reachability set of a variable is a set of variables that can be reached through this variable.
- Antecedent set (column elements, inputs, or those that are affected): Antecedent set of a variable is a set of variables through which this variable can be reached.

To find the relationships and to partition the criteria, the output and input sets should be extracted for each criteria of the access matrix. For the variable Ci, the reachability set (output or those that affect) includes variables that can be reached through the variable Ci. The antecedent set (input or those that are affected) includes variables through which the variable Ci can be reached as shown in Table 6.

Once the reachability and antecedent sets are determined, intersection of the two sets is calculated. The first variable

Table 6. Level partitioning based on input and output sets

Level	Output or those that affect	Input or those that are affected
C01	S01,S02	S01,S02,S11,S15,S20
C02	S01,S02	S01,S02,S11,S17
C03	S03	S03,S09,S11,S12,S17,S20
C04	S04,S05,S06,S08,S18,S23,S24,S25,S26	S04,S09,S10,S11,S14,S16,S18,S20,S23,S24,S25
C05	S05,S08,S13,S15,S21	S04,S05,S08,S09,S12,S17,S20,S23,S24,S27,S28
C06	S06,S07	S04,S06,S09,S10,S11,S23,S24,S27,S28
C07	S07	S06,S07,S08,S09,S12,S17,S20,S26
C08	S05,S07,S08,S10,S13,S15,S21	S04,S05,S08,S10,S12,S20,S23,S24,S27,S28
C09	S03,S04,S05,S06,S07,S09,S10,S11,S12,S13,S14,S16,S17,S18,S19,S21,S23,S24,S26,S27	S09,S11,S12,S13,S17,S19
C10	S04,S06,S08,S10,S14	S08,S09,S10,S11,S14,S20,S22
C11	S01,S02,S03,S04,S06,S09,S10,S11,S12,S13,S14,S15,S16,S17,S18,S19,S20,S23,S24,S25,S27	S09,S11,S12,S13,S14,S16,S17,S20
C12	S03,S05,S07,S08,S09,S11,S12,S16,S17,S19,S21,S26,S28	S09,S11,S12,S17
C13	S09,S11,S13	S05,S08,S09,S11,S13,S17,S20,S26
C13	S04,S10,S11,S14,S15,S16,S19,S23,S24,S25,S27,S28	S09,S10,S11,S14,S16,S19,S20,S22
C14	S01,S15	S05,S08,S11,S14,S15,S20,S26
C15	S04,S11,S14,S16,S23,S24,S25,S27,S28	S09,S11,S12,S14,S16,S22
C16	S02,S03,S05,S07,S09,S11,S12,S13,S17,S18,S19,S20,S22,S23,S25,S27	S09,S11,S12,S17,S20,S22
C17	S04,S18,S21,S26	S04,S09,S11,S17,S18,S20,S23,S24,S26,S27,S28
C18	S09,S14,S19,S25,S27,S28	S09,S11,S12,S14,S17,S19,S20
C19	S01,S03,S04,S05,S07,S08,S10,S11,S13,S14,S15,S17,S18,S19,S20,S21,S22,S24,S25,S26,S27	S11,S17,S20,S22,S26
C20	S21	S05,S08,S09,S12,S18,S20,S21,S26
C21	S10,S14,S16,S17,S20,S22	S17,S20,S22
C22	S04,S05,S06,S08,S18,S23,S26	S04,S09,S11,S14,S16,S17,S23
C23	S04,S05,S06,S08,S18,S24,S26	S04,S09,S11,S14,S16,S20,S24
C24	S04,S25,S26	S04,S11,S14,S16,S17,S19,S20,S25
C25	S07,S13,S15,S18,S20,S21,S26	S04,S09,S12,S18,S20,S23,S24,S25,S26,S27,S28
C26	S05,S06,S08,S18,S26,S27	S09,S11,S14,S16,S17,S19,S20,S27
C27	S05,S06,S08,S18,S26,S28	S12,S14,S16,S19,S28
C28	S01,S02	S01,S02,S11,S15,S20

which is obtained from the intersection of the two sets and is equal to the reachability set (outputs) will be in the first level. Therefore, the elements of level 1 will be the most affectable elements in the model. After determining the level, the criterion whose level has been identified is removed from the entire set and then we form the input and output sets again; next, we obtain the subsequent variable level. Consequently, the variables are partitioned into 6 levels:

- Level 1 variables: S01, S02, S03, S07, S13, S20
- Level 2 variables: S06, S15, S18
- Level 3 variables: S05, S08, S26
- Level 4 variables: S04, S23, S24, S25, S27, S28
- Level 5 variables: S10, S14, S16, S19
- Level 6 variables: S09, S11, S12, S14, S17, S21, S22

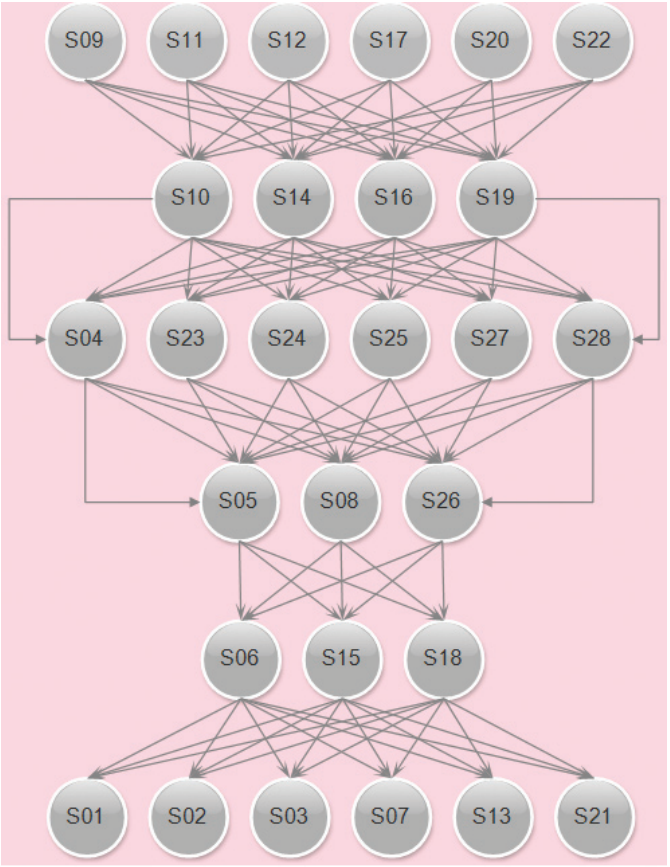

Figure 1. The interpretive-structural model.

7. CONCEPTUAL MODEL DEVELOPED BY INTERPRETIVE-STRUCTURAL TECHNIQUE

The ultimate pattern of the identified variable levels is illustrated in Fig. 1. In this graph, the significant relationships between the elements of each level and the elements of the level below and the significant internal relationships between the elements of each row are considered.

Considering the amount of effectiveness and affectability of each variable in relation to variables in the analysis, the level partitioning of the variables and graph of the relationships between them is shown in Fig. 1. The variables of Level 1 are the most affectable and have the least effect; the variables of Level 6 are the least affectable and have the most effect on the process of KC in PNU.

8. DISCUSSION AND CONCLUSIONS

The knowledge-based economic system would be beyond our reach if we have no knowledge-based industry and entrepreneurial universities. An established relationship between industry and higher education and its continuity based on their coexistence and mutual cooperation can build a knowledge-based economy via the mediating role of the government. The establishment of knowledge-based enterprises, science and technology parks, and entrepreneurship centers in the universities will be effective if the commercialised product or knowledge is in demand in Iran and international markets. The concept of KC is not just about a single brand registration and holding a production license for the product; it is the ability to make money from the knowledge produced by a research project.

The design of KC mechanisms and its operationalisation, in the first phase, requires the identification of factors affecting KC in the universities. To this end, in the present research, having identified the barriers to KC through the study of previous sources, we classified them into 6 main criteria. The fuzzy AHP was used to prioritise the 6 criteria. The main criteria were listed in terms of their order of importance: legal barriers, economic barriers, human resource barriers, cultural barriers, structural and policy barriers, and communication and information barriers. Moreover, previous research results showed that among barriers of commercialisation, the legal barrier comes first on the list of priorities[10,15,17,18]. The ultimate weight of each index was calculated using fuzzy AHP; and the indices were listed in terms of their order of importance, as follows: weak legal framework for supporting ideas of people at the university, inefficiency and ineffectiveness of the rules and regulations for commercialisation, researchers' low intention towards commercialisation, the inadequacy of the scholar's share in the commercialisation revenues, weak research culture, lack of regulation for the apportionment of financial gain from commercialisation among scholars, and weakness of universities in wealth creation. The results obtained from the prioritisation of barriers identified in this research along with managerial decisions can help improve the status quo.

Given the interpretive-structural model developed based on partitioning the indices in the present research, the following variables are the most affectable: weak legal framework for supporting ideas of people at the university, inefficiency and ineffectiveness of the rules, and regulations for commercialisation, lack of regulation for the apportionment of financial gain from commercialisation among scholars, lack of skilled and expert human resources, lack of financial resources and facilities for commercialisation of research results, and the weakness in the mutual recognition between university and industry. In other words, these variables are dependent variables of the model. On the other hand, the fundamental and effective variables of the model are inadequate knowledge of the faculty members, poor fund management in the university, weakness of universities in wealth creation, absence of university entrepreneurial missions, the absence of up-to-date and effective idea banks and databases in the university, and the lack of effective communication between students and industry sector's activists.

Paying attention to the effective variables can help us improve the variables in the affectable levels of the proposed model and, as a result, improve the KC. Regarding the variable levels represented in the model (Fig.1), it is recommended that university administrators should take measures to eliminate the barriers to KC based on effectiveness and affectability level of the variables in order to improve the KC at PNU.

REFERENCES

1. Debackere, K. & Veugelers, R. The role of academic technology transfer organisations in improving industry science links. *Res. Policy*., 2005, **34**(3), 321-42.

doi: 10.1016/j.respol.2004.12.003
2. Pourezzat, A.A.; Gholipour, A. & Nadirkhanloo, S. Representation barriers to academic entrepreneurship and knowledge commercialisation at University of Tehran. e*J. Sci. Technol. Policy*, 2010, **2**(4), 65-76.
3. Biranvand, A.; Seif, M.H.; Safa, S. & Mazloumian, S. An investigation into the effective factors on the intention to commercialisation of knowledge in a university: A case study. *Libr. Philo. Pract. (e-journal)*, 2019.
4. Jung, M.; Lee, Y. & Lee, H. Classifying and prioritizing the success and failure factors of technology commercialisation of public R&D in South Korea: Using classification tree analysis. *J. Technol. Transfer*, 2015, **40**(5), 877-98. doi: 10.1007/s10961-014-9376-5.
5. Costa, Neto EC da.; Perin, M.G. & Ferreira, G.C. Transferência de conhecimento: A perspectiva empresarial. *Rev. Gest. Tecnol.*, 2019, **19**(2), 195-216. doi: 10.20397/2177-6652/2019.v19i2.1503.
6. Heidari, E. & Pourezzat, A.A. Studying and sorting the challenges and barriers of knowledge commercialisation using Q-Methodology. *J. Sci. Technol. Policy*., 2011, **4**(1), 49-62.
7. Hmieleski, K.M. & Powell, E.E. The psychological foundations of university science commercialisation: A review of the literature and directions for future research. *Acad. Manag. Perspect.,* 2018, **32**(1), 43-77. doi: 10.5465/amp.2016.0139.
8. Biranvand, A. & Seif, H. Prioritizing the effective factors on knowledge commercialisation using fuzzy analytic hierarchy process: A case study. *Libr. Philos. Pract. E-J.* 2018.
9. Zahra, S.A.; Kaul, A. & Bolivar, M.T. Why corporate science commercialisation fails: Integrating diverse perspectives. *Acad. Manag. Perspect.,* 2018, **32**(1), 156-76. doi: 10.5465/amp.2016.0132.
10. Irani, F.N.H., Hayak, K. & Asetmal, E.K. Identifying and prioritizing barriers to commercializing researches and innovations in east Azerbaijan University with AHP techniques and providing appropriate strategies. *Eur. J. Sustain. Dev.,* 2018, **7**(2). doi: 10.14207/ejsd.2018.v7n2p121.
11. Abbasi, Esfanjani H. & Foruzandeh, Dehkordi L. Identify and explanation the factors that affects in commercialisation of university research using triangulation model. *J. Sci. Technol. Policy,* 2015, **6**(4), 1-15.
12. Jahed, H. Explaining of individual factors influencing commercialisation of research results; the case of Islamic Azad University of Science and Research Branch. *J. Sci. Technol. Policy*, 2011, **4**(1), 1-17.
13. Vick, T.E. & Robertson, M. A systematic literature review of UK university–industry collaboration for knowledge transfer: A future research agenda. *Sci. Public Policy*, 2018, **45**(4), 579-90. doi: 10.1093/scipol/scx086.
14. Biranvand, A. Identification of affected factors on the knowledge commercialisation in the Iranian integrated universities under MSRT to present practical suggestions: The case of study UI. [Phd Desertation]. [Isfahan]: University of Isfahan; 2018.
15. Rajalo, S. & Vadi, M. University-industry innovation collaboration: Reconceptualisation. *Technovation*, 2017, **62**(63), 42-54. doi: 10.1016/j.technovation.2017.04.003
16. Abasi, H. Designing the model for commercialisation of university research using structural equation modeling- partial least squares method (SEM-PLS). *Inst. Trade Stud. Res.*, 2017, **21**(82), 1-21. http://pajooheshnameh.itsr.ir/article_23754_en.html. [accessed on 20-06-2019].
17. Pazhouhesh, Jahromi A. Designing and explanation of a university researches results commercialisation model (Case: Tehran State Technical Colleges) [Phd Desertation]. [Tehran]: University of Tehran; 2016.
18. Bruneel, J.; D'Este, P. & Salter, A. Investigating the factors that diminish the barriers to university–industry collaboration. *Res. Policy*, 2010, **39**(7), 858-68. doi: 10.1016/j.respol.2010.03.006.
19. Clayton, P.; Feldman, M. & Lowe, N. Behind the scenes: Intermediary organisations that facilitate science commercialisation through entrepreneurship. *Acad. Manage. Perspect.*, 2018, **32**(1), 104-24. doi: 10.5465/amp.2016.0133.

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Annexure '1'

Indices of KC in PNU presented in the ultimate order of priority

Main criteria	W	Code	Indexes	W1	W2	Priority
Legal barriers	0.231	S01	Weak legal framework for supporting ideas of people at the university	0.293	0.0676	1
		S02	Inefficiency and ineffectiveness of the rules and regulations for commercialization of research	0.271	0.0626	2
		S03	Lack of regulation for the apportionment of financial gain from commercialization among scholars	0.216	0.0500	6
		S04	Lack of intellectual property rights and ownership rights resulted from joint research with industry	0.114	0.0265	19
		S05	Lack of effective policies to improve the quality of academic research	0.106	0.0244	21
Human resource barriers	0.184	S06	Low intention towards commercialization	0.310	0.0568	3
		S07	Lack of skilled and expert human resources	0.245	0.0450	9
		S08	Weakness of the university in providing high motivation for human capital	0.258	0.0474	8
		S09	Inadequate knowledge of the faculty members	0.187	0.0343	15
		S10	The inadequacy of the scholar's share in the commercialization revenues	0.264	0.0529	4
Economic barriers	0.231	S11	Poor fund management in the university	0.171	0.0344	14
		S12	Weakness of universities in wealth creation	0.241	0.0483	7
		S13	Lack of financial resources and facilities for commercialization of research results	0.181	0.0362	13
		S14	Lack of university sponsorship for researchers to exploit production know-how	0.144	0.0288	18
Structural and policy barriers	0.132	S15	Lack of organized organization for the commercialization of academic research	0.279	0.0368	11
		S16	Lack of bureaucratic flexibility	0.286	0.0377	10
		S17	Absence of university entrepreneurial missions	0.171	0.0225	22
		S18	Lack of a research leading university document	0.154	0.0203	25
		S19	Lack of effective policies to improve the quality of academic research	0.110	0.0145	28
Communication and information barriers	0.114	S20	The absence of up-to-date and effective idea banks and databases in the university	0.271	0.0308	16
		S21	Weakness in mutual recognition of university and industry	0.190	0.0216	23
		S22	Weakness in the mutual recognition between university and industry	0.228	0.0259	20
		S23	Lack of communication and networks between investors, industry activists and academics	0.176	0.0200	26
Cultural barriers	0.139	S24	Weakness of university in providing consulting services to the community	0.135	0.0153	27
		S25	Weak research culture	0.369	0.0514	5
		S26	Existence of cultural differences between university and industry	0.261	0.0363	12
		S27	Weakness of entrepreneurship culture	0.217	0.0301	17
		S28	Uncompromising collective sensitivity to the commercialization of knowledge generated at universities	0.153	0.0213	24