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Barriers for innovation detected in 400 colombian businesses, based on the innovation "U" coefficient methodology

Barreras para la innovación detectadas en 400 empresas colombianas, a partir de la metodología coeficiente "U" de innovación

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ABSTRACT: The barriers for innovation have been studied for the past 40 years. However, in most of these studies, the subject has been examined in a qualitative way. Consequently, certain tools are required to measure the barriers of innovation inside the organizations. This time, the results of the barriers of an innovation tool is presented; this tool has been developed by researchers from Universidad Pontificia Bolivariana, which was applied to 400 businesses from different areas. The tool is composed by a total of 18 internal and external barriers, and allows the controllable barriers to be determined by identifying the sector and region. Furthermore, there is a coefficient that classifies the businesses in ranges from high, medium and low in terms of innovation´s facilities. The methodology for the calculation of the barriers for innovation in business can be the base to measure innovation obstacles in regions, clusters and sectors, because it provides an indicator of the most representative barriers in each of them. This can be useful to generate some strategies to close or eliminate those barriers through public policies and summons with specific projects.

RESUMEN: Las barreras para la innovación han sido estudiadas desde hace más de 40 años, sin embargo, en la mayoría de estos estudios el tema ha sido abordado de una forma cualitativa, lo que indica que se requieren herramientas que permitan cuantificar el efecto de las barreras para la innovación dentro de las organizaciones. En esta ocasión, se presentan los resultados de la herramienta, coeficiente "U" de innovación, desarrollada por investigadores de la Universidad Pontificia Bolivariana, la cual fue aplicada a 400 empresas de diversos sectores. La herramienta está conformada por un total de 18 barreras internas y externas, y permite detectar las barreras controlantes (o más importantes) por sector y región; así como un coeficiente que clasifica las empresas en rangos de alto, medio y bajo en cuanto a facilidades para innovar. Sin embargo, ha surgido la necesidad de aumentar el número de barreras y de generar otros indicadores por empresa. La metodología para el cálculo de barreras para la innovación en empresas puede ser la base para la medición de los obstáculos de innovación en regiones, cluster y sectores, ya que reflejaría un indicador de las barreras más representativas en cada uno de ellos y sería útil para generar estrategias eliminar esas barreras a través de políticas públicas y convocatorias con proyectos específicos que permitan la eliminación de las barreras para la innovación.

1. Introduction

In recent years, several investigations have been conducted in order to analyze the barriers for innovation inside different businesses or industrial sectors, where the lack of comprehension between the academy and the industry to the joint implementation of innovative projects emerges [1, 2]. The barriers for innovation are presented inside the companies or sectors, but there are also some exogenous barriers that hinder the innovation process [3]. Regarding the exogenous barriers, which the company may face, researchers have followed the effect of government support in biotechnological research in Germany, determining the effect of public research on private companies making it a possible barrier [4].

Although intensive knowledge companies are very dynamic in terms of innovation, they tend to be incremental and focused, and present barriers to improve their innovation

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level [5]. However, they may find companies which stand out thanks to their innovation achievements. These companies must overcome the cultural barriers regarding the innovation that they may find in all the organizational levels [6]. In general, barriers for innovation have been researched in different sectors such as construction and education, amongst others [7, 8]. In the education sector, the barriers for innovation regarding online education have been studied, and they found that the teachers just adapt these tools when it is mandatory [8].

On the other hand, the barriers for innovation that are presented when using R&D teams on separate or integrated environments have found that, in the first case, the teams show a lack of motivation when it comes to exploring new options; meanwhile the groups in a separate environment show interdepartmental collaboration problems [9].

An analysis of the case of Siemens (Australia), highlighting the innovation achievements that were accomplished by the company, concludes that the key to staying is to overcome the cultural barriers regarding the innovation that they may find in all organizational levels [6]. In a study of some companies in a market with mature characteristics, the necessity to change certain general paradigms to overcome and implement a real innovation strategy has been found [10].

Recently, some approaches have described the barriers for innovation that companies have when activities are aimed towards innovation, such as: costs, knowledge, market and regulation factors [11]. On the other hand, the relationship between product, process, and innovation management has been examined, finding that barriers have a different impact on the types of innovation and innovation management [12]. In the last years, researchers such as [13-15] have analyzed the barriers for innovation in Portugal, Brazil and Morocco, respectively.

The barriers for innovation quantitative analysis related to this paper is based on innovation "U" coefficient methodology, and seeks to analyze how susceptible organizations are to the adoption, promotion, leverage, and support of new ideas, projects or activities in the R&D process. The tool was developed within the framework of several research projects and a specialization thesis at the in Universidad Pontificia Bolivariana, Medellin – Colombia and is available in the following webpage: http://barrerasparalainnovacion.com/.

2. Methodology

The "U" innovation coefficient is a methodology based on physical models of heat transfer by conduction and convection. The tool includes a total of 18 barriers, which at first instance are the result of the barriers raised in an evaluation type workshop, or resemble the ones posted in Management Innovation Lab [16]. This raises a similar exercise to the proposed activity regarding this work. These barriers are classified as conduction barriers (tangible barriers) and convective barriers (intangible barriers, money and information). The developed tool allows a quick "U" innovation coefficient inside companies to be determined, based on physical models of heat transfer by conduction and convection [17].

A random sample was extracted from the web application of 400 companies that evaluate ideas or projects through the tool. Then, the information was debugged, detecting outliers. Figure 1 presents the region and sector's participation percentage.

2.1. Information analysis and comparative methods

The comparison between the regions is presented firstly, through a distribution data analysis, using the box and whisker plot, which allows an estimate of the range where more than 75% of the data is concentrated. Then, the mean analysis allows meaningful statistical difference to be established between the mean values of the "U" innovation coefficient. This is done through a test factorial ANOVA, which shows the ratings of the barriers of regions with the highest average "U" innovation coefficient; which generates a confidence level of 95%. An ANOVA test was performed to identify the barriers that have significant statistical difference at a confidence level of 95%. Table 1 shows the ranges and categories with which companies are classified in terms of the coefficient of innovation.

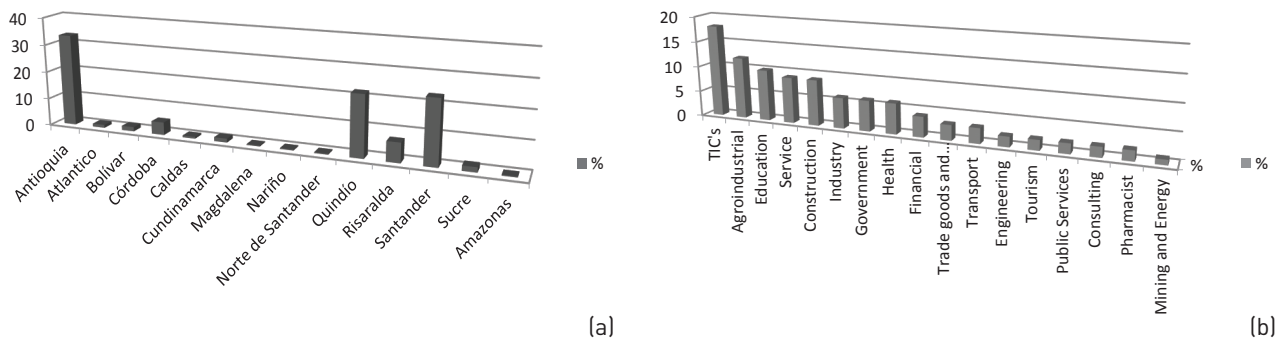

Figure 1 Participation percentage by region (a) and by industrial sector (b) in the study

Table 1 Ranges of the innovation coefficient

Range	Result
>140	High
70-139	medium
<70	Low

Finally, the three most representative sectors were selected, in which the barriers' weights were analyzed, with the purpose of establishing higher barriers in the projects or evaluated ideas. Table 2 shows the relative sum and the rating of the barriers. The qualifications with a rating of 5, indicate than the barrier is in a medium, medium-high or high state.

Table 2 Relative sum to each weighing by sector and region

Sector or region	Barrier					
	1	2	3	4	5	6
Educational	119	230	360	480	600	720
TIC´s	210	420	630	840	1050	1260
Agro-industrial	140	280	420	560	700	840
Antioquia	404	800	1220	1620	2020	2430
Quindío	268	540	810	1080	1340	1610

To evaluate the ideas, projects or activities inside the process of R+D+i, the tool considers a total of 18 barriers, which are classified as: physical, monetary, informational; and time. Table 3 shows the barriers and their qualification.

3. Results and discussion

3.1. "U" Innovation coefficient distribution in different regions

Figure 2 shows "U" innovation coefficient distribution in the referred regions. The figure shows that 75% of data in Antioquia is in the range (40,751; 74,432), in other regions (40,048; 81,307), Quindío (37,497; 69,599), Risaralda (34,087; 67,558) and Santander (37,216; 60,463). That means that in terms of "U" innovation coefficient, Antioquia and the rest of the regions are in the low-medium category; while Quindío, Risaralda and Santander are in the low category. In these regions, the upper "U" coefficients are values outside the data distribution that show that they are not common cases in all regions.

In terms of the "U" innovation coefficient, Table 4 shows that there is no significant difference between the mean values of the coefficient of innovation in each of the regions, at confidence level of 95%. However, Figure 3 shows that Antioquia, Risaralda and Quindío are in a medium-low, although Risaralda leans toward lower values. Meanwhile Santander is in a category of a low innovation coefficient.

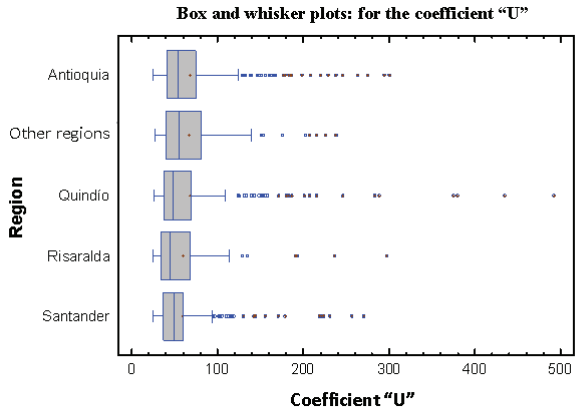

Figure 2 "U" Innovation coefficient distribution in different regions in Colombia

3.2. Barriers to innovation in Antioquia and Quindío

In terms of the mean value, Figure 4 shows that there are no differences between the barrier ratings in Antioquia and Quindío. According to Table 2, the mean value related to the barrier ratings falls between 3 and 5. While Antioquia tends to remain in the medium category with weights between 1318 and 2116, Quindío possesses weights that are between 927 and 1501; thus indicating that they are in the low-medium category. However, in terms of the mean and the mode, the barriers in Antioquia stay in a medium and low-medium category, meanwhile in Quindío, the barriers are in low, medium and high-medium categories.

Antioquia and Quindío present some common barriers such as having time to develop new ideas, keeping the project going despite the organization´s priority changes and the inability to carry the generated costs that come with removing a professional in order to dedicate full time to the development of the idea or project. However, the categorization of barriers and the U coefficient, indicates that Antioquia has a tendency towards medium score values (4 to 6), while Quindío has a tendency toward medium and medium-high values (between 3 and 10). In terms of the barriers, these two regions differ. In Table 4, the upper and middle barriers in each of these regions are shown, taking into account that the higher the barrier, the less prone the region is to innovation.

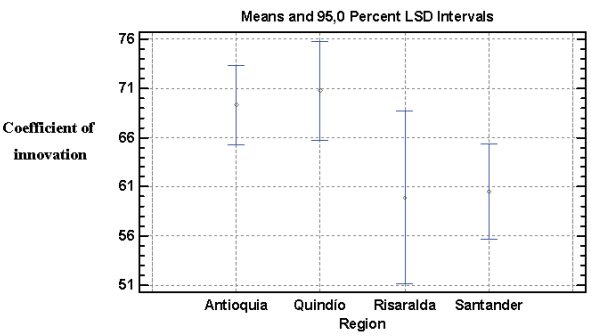

Figure 3 Confidence intervals for each region with a probability occurrence of 95%

Table 3 Barriers for innovation

Code	Barrier	Classification
B1	Having time to develop new ideas	Time
B2	Getting access to data and critical information required to develop new ideas	Information
B3	Turn the idea into a convincing business to sustain with authority in front of the sponsor	Physical
B4	Dealing with objections that reflect inflexible mental models inside the organization	Information
B5	Finding a proper sponsor	Physical
B6	Feeling encouraged to keep going with the idea, regardless of the problems that may come across	Information
B7	Staying in touch with experts in different areas of the company that can help develop the idea	Physical
B8	Getting financial support in the early stages of the Project or the idea	Money
B9	Knowing the risks and the organizations' regulations	Information
B10	Keeping the momentum despite the early problems	Physical
B11	Keeping the project despite the organization´s priority changes	Physical
B12	Mental short-term and early result versus the long-term plans that may occur	Information
B13	Counting on the support of human talent for the development of the project.	Physical
B14	Inability to carry with the generated costs, while obliged to lay off a professional in order dedicate full time for the idea or project	Money
B15	Low budget to deploy the idea or project	Money
B16	Lack of skilled staff to develop the idea or project	Physical
B17	Does not have the staff that guides the equipment purchased properly, required in the idea or project	Physical
B18	Fear of the impact between technology and human resources, in management or the possible dismissal of the organization´s staff	Physical

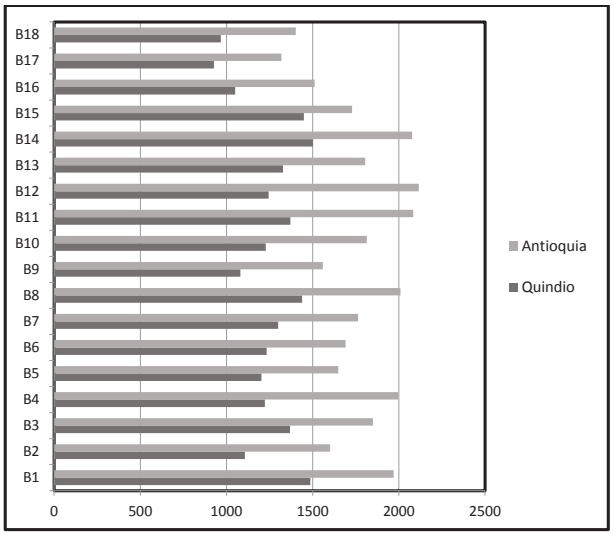

Figure 4 Weights of the barriers in Antioquia and Quindío

In terms of the barrier's weight, Table 5 shows that there is statistical significant difference at a confidence level of 95%, according to the P-value. In this regard, if the value of the barrier weight is low, the coefficient of innovation will be higher, which in comparative terms, gives an idea of how regions are more prone to innovation in respect to the others.

Figure 5 shows that Antioquia is noticeably different from other regions, with the lowest weight barrier, which equals to a higher coefficient of innovation; followed by the region of Quindío. Meanwhile Risaralda and Santander are the regions that have more difficulties to innovate because they have the highest weight barrier in respect to the others.

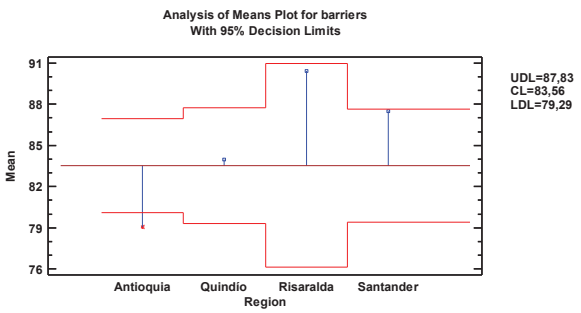

Figure 5 Mean Analysis for barriers with a probability occurrence of 95%

Table 4 ANOVA Table for Coefficient of Innovation by Region

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between groups	21905.1	3	7301.71	2.12	0.0961
Within groups	3.56554E6	1035	3444.97		
Total (Corr.)	3.58745E6	1038			

Table 5 ANOVA Table for barriers by Region

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between groups	16669.8	3	5556.62	5.37	0.0011
Within groups	1.0709E6	1035	1034.69		
Total (Corr.)	1.08757E6	1038			

Table 6 Analysis of Variance for cal - Type III Sums of Squares

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Main Effects					
A:Region	95.2219	1	95.2219	9.66	0.0019
B:Barriers	2233.77	17	131.398	13.33	0.0000
Interactions					
AB	599.2	17	35.2471	3.57	0.0000
Residual	97084.8	9846	9.86033		
Total (corrected)	99989.6	9881			

Table 7 Score Comparison of the barriers in Antioquia and Quindío

Barriers	F-Ratio	P-Value
B1	3.21	0.0735
B2	13.37	0.0003
B3	0.09	0.7606
B4	2.34	0.127
B5	0.52	0.4708
B6	3.57	0.0595
B7	0.89	0.3463
B8	2.04	0.1538
B9	9.68	0.002
B10	1.67	0.1964
B11	2.01	0.157
B12	5.38	0.0207
B13	3.44	0.0643
B14	7.28	0.0072
B15	6.78	0.0095
B16	0.02	0.8819
B17	5.5	0.0194
B18	3.05	0.0815

In general, the barriers in both Antioquia and Quindío have a central value that is between 3 and 5. However, Table 6 shows that there is a statistically significant difference between the two regions, amid all the barriers grouped together and between the scores of the barriers in both regions; with a confidence level of 95%.

Meanwhile, Table 7 shows that there are similarities and differences between the barriers, finding differences in those related to information (B2, B9, B12) and money (B14, B15). It can be noted that the regions differ and that these regions are faced barriers.

Table 8 shows the main barriers founded in Antioquia, such as dealing with objections that reflect inflexible mental models inside the organization; getting financial support in early stages of the Project or the idea. This is what makes the project last despite the organization´s priorities changes, etc.

3.3. Barriers to innovation present in three economic sectors

Figure 6 shows the weighted sum associated to the rated values. Each barrier in different project or ideas explored by each company belongs to the three most representative

Table 8 Mean barriers in Antioquia

Region	Category	Code	Barriers
ANTIOQUIA	Medium	B1	Having time to develop new ideas
		B4	Dealing with objections that reflect inflexible mental models inside the organization
		B8	Getting financial support in early stages of the Project or the idea
		B11	Keeping the Project despite the organization´s priorities changes
		B12	Mental short-term and early results versus the long-term plans
		B14	Inability to carry with the generated costs, while obliged to lay off a professional in order dedicate full time for the idea or project
	Medium-high	B1	Having time to develop new ideas
		B13	Counting with human talent to support the development of the project
		B3	Turn the idea in a convincing business to sustain with authority in front of the sponsor
		B8	Get financial support in early stages of the Project or the idea
		B11	Keeping the Project despite the organization´s priority changes
		B14	Inability to carry with the generated costs, while obliged to lay off a professional in order dedicate full time for the idea or project
		B15	Lack of a budget to deploy the idea or project

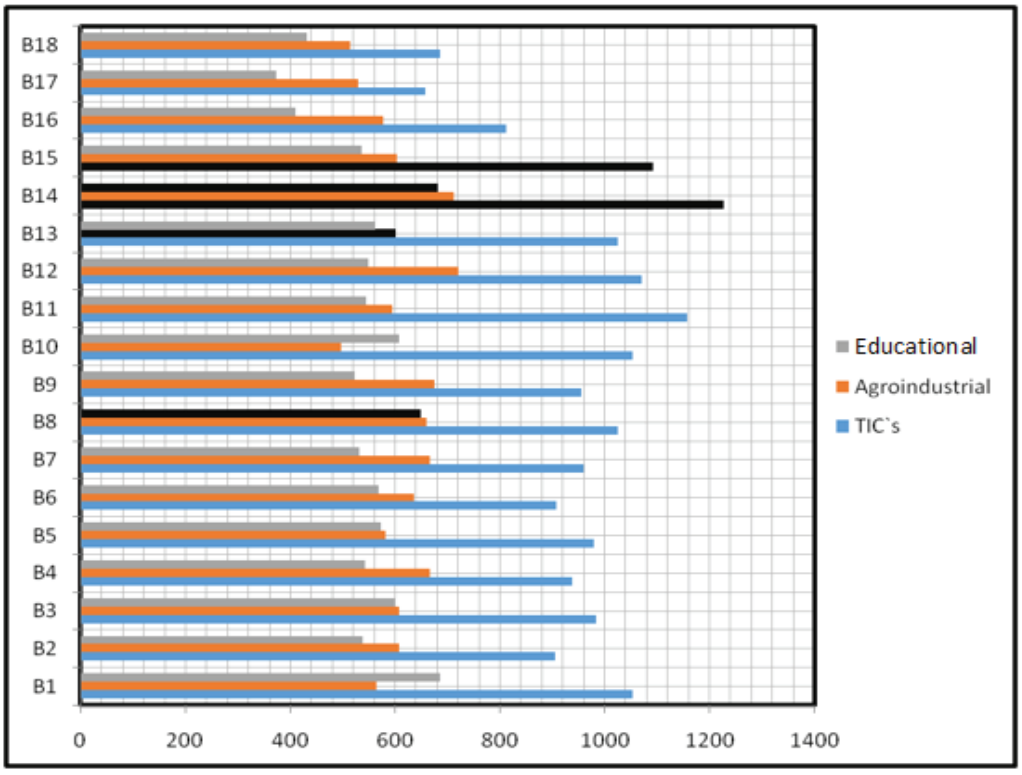

Figure 6 Barriers' weights in three sectors

Table 9 Medium-high barriers present in the covered sectors

Sector	Medium-high barriers	
	Code	Barriers
Educational	B8	Get financial support in the early stages of the project or the idea
TIC`s	B14	Inability to carry with the generated costs, while obliged to lay off a professional in order dedicate full time for the idea or project
	B14	
	B15	Lack of a budget to deploy the idea or project
Agro-industrial	B13	Get human talent that supports the idea and works on developing the idea or project

sectors of the sample. In general terms, the figure gives an idea of the central values of each barrier and the distribution data of the ratings. In this logic, the TIC´s sector is in a range of (657; 1226), which means that the barriers are focused in values from 3 to 5. The Agro-industrial sector is in the range of (497; 720), which is equivalent to central values between 3 and 5; the education sector is in a range of (347; 685), between 3 and 6. It is obvious that the barriers in the three sectors are in a low-medium category, because the lowest weight prevails. However, in modal terms, it is possible to find barriers that can be in a high category. Under these circumstances, the figure shows that the barriers that may consider medium-high category are in black color.

Table 9 shows the barriers contemplated in Figure 6. It is regardless that the medium-high barriers in the educational sector and TICs correspond to related barriers with the monetary resource, meanwhile in the Agro-industrial sector, a physical barrier stands out, related to the human resource.

4. Conclusions

The comparative analysis shows that Antioquia and the rest of the regions have a low-medium "U" innovation coefficient. Quindío, Risaralda, Santander are in a low category. Although it is unrelated, the central value in all regions is in a low category, which means that in statistical terms, the regions do not differ significantly. However, once the probability limits are established, Antioquia, Quindío and the rest of the regions have a certain similarity, but differ regarding the mode with Risaralda and Santander.

The three most representative sectors in the sample present a general distribution in the ratings, where the values between 3 and 6 stand out. In general, it means that the three sectors have a trend towards innovation. However, the higher barriers are economic type resources and staff availability.

A study of the barriers by region explains the value of the "U" innovation coefficient. Even though for this case, there are no significant differences between the core indicators of both regions, it is clear that the trend of the ratings in each of the barriers is presenting the differences or similarities that may occur, in this case, between Antioquia and Quindío.

5. References

1. E. Rigby, A. McCoy and M. Garvin, "Toward Aligning Academic and Industry Understanding of Innovation in the Construction Industry", *International Journal of Construction Education and Research,* vol. 8, no. 4, pp. 243-259, 2012.
2. E. Pellicer, C. Correa, V. Yepes and L. Alarcón, "Organizational Improvement Through Standardization of the Innovation Process in Construction Firms", *Engineering Management Journal,* vol. 24, no. 2, pp. 40-53, 2012.
3. D. Simon and D. Rehn, "Innovation in China's semiconductor components industry: The case of Shanghai", *Research Policy,* vol. 16, no. 5, pp. 259-277, 1987.
4. S. Jasanoff, "Technological innovation in a corporatist state: The case of biotechnology in the Federal Republic of Germany", *Research Policy,* vol. 14, no. 1, pp. 23-38, 1985.
5. I. Booyens, N. Molotja and M. Phiri, "Innovation in High-Technology SMMEs: The Case of the New Media Sector in Cape Town", *Urban Forum,* vol. 24, no. 2, pp. 289-306, 2013.
6. F. Zhao, "Technological and organisational innovations: Case study of Siemens (Australia)", *International Journal of Innovation and Learning,* vol. 3, no. 1, pp. 95-109, 2006.
7. M. Christie and R. Garrote, "Barriers to innovation in online pedagogy", *European Journal of Engineering Education,* vol. 34, no. 3, pp. 273-279, 2009.
8. J. Rutkowski and K. Moscinska, "Barriers to innovation in e-pedagogy: A case study", in *13th International Conference on Computers and Advanced Technology in Education*, Maui, USA, 2010, pp 146-151.
9. C. Mirow, K. Hoelzle and H. Gemuenden, "The ambidextrous organization in practice: Barriers to innovation within research and development", in

68th Annual Meeting of the Academy of Management, Anaheim, USA, 2008, pp 1-6.
10. K. Vandenbempt and P. Matthyssens, "Barriers to strategic innovation in industrial markets", *Advances in Business Marketing and Purchasing,* vol. 13, pp. 701-723, 2004.
11. P. D'Este, S. Iammarino, M. Savona and N. Tunzelmann, "What hampers innovation? Revealed barriers versus deterring barriers", *Research Policy,* vol. 41, no. 2, pp. 482-488, 2012.
12. A. Madrid, D. Garcia and H. Auken, "Barriers to Innovation among Spanish Manufacturing SMEs", *Journal of Small Business Management,* vol. 47, no. 4, pp. 465-488, 2009.
13. A. Cordeiro and F. Vieira, "Barriers to innovation in smes: an international comparison", in *II Conferência Internacional de Integração do Design, Engenharia e Gestão para a inovação,* Florianópolis, Brazil, 2012, pp. 10.
14. H. Righi, F. Salum, R. Reis and R. Pereira, "The Barriers to Innovate in Brazil", in *22nd International Conference on Management of Technology* (IAMOT), Porto Alegre, Brazil, 2013, pp. 17.
15. N. Lagziri, H. Achelhi, M. Bennouna and P. Truchot, "Barriers as determinants of innovation in Morocco: The case of Tangier-Tetouan region," *International Journal of Innovation and Applied Studies*, vol. 4, no. 1, pp. 203-221, 2013.
16. Management Innovation Lab, *Harvard Business Review Blog Network*, 2007. [Online]. Available: http://blogs.hbr.org/hbr/hamel/flatmm/miw_tool.pdf. Accessed on: Feb. 12, 2007.
17. J. Zartha, B. Arango, D. Coy, J. Gonzalez and E. Jaramillo, "Methodology to calculate the integral coefficient of Innovation 'U' in organizations", in *22nd International Conference on Management of Technology* (IAMOT), Porto Alegre, Brazil, 2013, pp. 17.