The Basic Competitiveness Factors Shaping the Innovation Performance of Countries

Esma Nur Çinicioğlu[1], Gündüz Ulusoy[2], Şule Önsel[3], Füsun Ülengin[3], Burç Ülengin[4]
[1]Quantitative Methods Division, School of Business,Istanbul University, Istanbul, Turkey
[2]Manufacturing Systems Engineering, Sabancı University, Istanbul, Turkey
[3]Department of Industrial Engineering, Doğuş University, Istanbul, Turkey
[4]Management Engineering Department, Istanbul Technical University, Istanbul, Turkey
esmanurc@istanbul.edu.tr, gunduz@sabanciuniv.edu, sonsel@dogus.edu.tr, fulengin@dogus.edu.tr, ulenginbur@itu.edu.tr

Abstract - **The goal of this research is to use Bayesian Networks to discover the relations among the components of competitiveness and the innovation level of countries.For this purpose, initially the competitiveness performance of 148 countries is analyzed using an integrated cluster analysis and factor analysis framework. This facilitates the basic areas where each cluster group demonstrates a good performance and those where they need improvements relative to the othergroups in order to increase their competition level. Subsequently; a Bayesian Network is constructed using WinMine software based on competitiveness indicators drawn from WEF pillars and sub-pillars. This analysis, in its turn,investigates whether the competitiveness stage to which a country belongs has an important impact on its innovation performance and highlights, which of the basic competitiveness variables has a significant impact in shaping its innovation level.**

Keywords–**Competitiveness, Cluster analysis, Factor Analysis, Bayesian Network, Innovation**

I. INTRODUCTION

Innovation is an important component of competitiveness. It has been shown by [1] that innovative countries had higher productivity and income than the less-innovative ones. It plays a significant role in creating the differences of performance and competitiveness not only among regions and countries but among firms as well [2].

Innovation has been with us for ages but it is only in the last decades that it has become a major policy tool for countries and firms alike for sustainable competitiveness. The main reason for this emphasis on innovation is its major role in income and employment growth [1]. High quality science and research and development (R&D) are not sufficient for the realization of important economic and social objectives. New ideas and inventions being the initial steps leading to innovation are obviously important but they may have little economic and social impact unless they are commercialized. New ideas and inventions are transformed into innovation once they are commercialized.

The literature shows that the research conducted so far generally investigates the current status of a country of interest and highlights the factors influencing the innovation performance. The papers in literature accept thatthere are important relationships between the competitiveness of a country and its innovation performance. Therefore, a subsequent stage of those types of studies should be to understand the relationship between the innovation performance of countries and specify the basic drivers on which they have to focus and, hence, to develop a road map to the policy makers in order to guide them in their decision about the improvement to be realized in order to upgrade their innovation performance. In this study, we aim to understand whether the competitiveness stage that a country belongs, has explanatory information on its innovation level.For this purpose initially a cluster analysis is conducted and each cluster of countries is evaluated in terms of their status with respect to different components that shape their competitiveness level. Subsequently, a Bayesian Network (BN) analysis is conducted to understand the basic competitiveness drivers behind the innovation performance of countries.

II.GLOBAL COMPETITIVENESS of COUNTRIES

World Economic Forum (WEF)defines *competitiveness* as *the set of institutions, policies, and factors that determine the level of productivity of a country.* The level of productivity, in turn, sets the levelof prosperity that can be earned by an economy. Theproductivity level also determines the rates of returnobtained by investments in an economy, which in turn are the fundamental drivers of its growth rates. In otherwords, a more competitive economy is one that is likely to grow faster over time. The concept of competitiveness thus involves static and dynamic components: although the productivity of a country determines its ability to sustain a high levelof income, it is also one of the central determinants of its returns on investment, which is one of the key factors explaining an economy's growth potential[3].Based on Global Competitiveness Index (GCI), released every year in its Global Competitiveness Report, WEF measures the competitiveness of countries, providing a source of data, including public and private sectors, which they can employ to develop policies pertaining to factors leading to higher levels of competitiveness. That is why, in this paper, GCI is selected to analyze the competitiveness level of the countries.

When composing GCI, the weights of the sub-indices are determined according to the stage of development of countries [4]. There are three stages of development with two transition stages in between leading to 5 groups of countries. These stages of development are based on

Gross Domestic Product (GDP) per capita. GDP per capita is indicated not to be the sole criterion for the determination of the stage of development for economies with a high dependency on mineral resources.

Here the innovation level is represented through the 12th pillar of the WEF model, *Innovation*. When we look into the sub-pillars of *Innovation* we observe that this pillar indeed contains the means and policies for the development of an environment conducive to innovation. It is not a complete list but none of the major means and policies appears to be left out: *Capacity for innovation*; *Quality of scientific research institutions*; *Company spending on R&D*; *University-industry research collaboration*; *Government procurement of advanced technology products*; *Availability of scientists and engineers*; *Utility patents*; and *Intellectual property protection*. Although it is questionable whether patents are the cause or result of innovation, all the sub-pillars indeed have an impact on the level of innovation in a country. When we investigate the variables of *Business sophistication*, on the other hand, we observe the close relationship of several of these variables with various phases of innovation process and its success in the market such as, for example, *Extent of marketing*; *Production process sophistication; Value chain breadth* or *Willingness to delegate authority.* The latter one has been cited as one of the important innovation drivers for manufacturing firms [5].

III.DETERMINATION of COMPETITIVENESS STAGE OF COUNTRIES THROUGH CLUSTER ANALYSIS

As mentioned above, for determining the GCI, WEF separated countries into five groups based on their GDP. But for the purpose of analyzing the innovation level in association with competitiveness indicators it would be rather restrictive to base the grouping of countries only on GDP. For that reason, for the determination of country groupings of the 148 countries included we decided to perform a cluster analysis using the set of pillars and sub-pillars given in the Global Competitiveness Reports of 2010, 2011 and 2012. The set of pillars and sub-pillars used are listed in Table 1.

The list of countries analyzed by WEF differs slightly in the last three years. The total number of different countries present in this study is 148, which corresponds to 425 lines of data set.

TABLE 1
THE SET of PILLARS and SUBPILLARS USED in THIS STUDY

1A Publicinstitutions	6B Quality of demandconditions
1B Privateinstitutions	7A Labor market flexibility
2A Transport infrastructure	7B Efficientuse of talent
2B Electricityandtelephonyinfrastructure	8A Financial market efficiency
3. Macroeconomicenvironment	8B Trustworthinessandconfidence
4A Health	9A Technologicaladoption
4B Primaryeducation	9B ICT use
5A Quantity of education	10A Domestic market size
5B Quality of education	10B Foreign market size
5C On-the-jobtraining	11 Business sophistication
6A Competition	12 Innovation

In the clustering process, different from the WEF model no weights are assigned to pillars and their sub-pillars. Each pillar or sub-pillar has an equal contribution to the overall result. As a result of the clustering process, the countries are grouped under 5 main clusters as listed in Table 2.

Although we do not intend to distinguish among countries within the same group with respect to their competitiveness, still we would like to be able to reach some conclusions concerning the differences in competitiveness between clusters. According to cluster analysis, Cluster 1 is composed of countries at the lowest level of competitiveness while those in Cluster 5 are composed of highly competitive countries. Cluster 2 includes the countries, which still have a low competitiveness level but which can be accepted at the transition level between the first and the third cluster. Finally the countries assigned to Cluster 3 are average performing countries and those in Cluster 4 are in a transition stage between the third and fifth clusters. Each cluster is given a name as stated on the header of Table 2with which it will be referred to from here on.

We will first introduce some observations from a visual inspection of the clusters of countries using a graphical representation of the levels of the same 22 pillars and sub-pillars employed in the clustering of the countries (Figure 1).

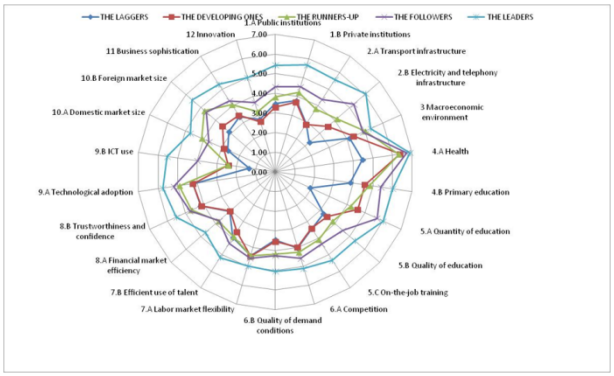

Fig. 1. Country cluster performances in 22 pillars and sub-pillars of GCI considered in the clustering of countries

A general observation is that the clusters are embedded into each other with relatively few exceptions. Particularly the Leaders encompass all the others in all pillars and sub-pillars. There is an increasing difference in case of *Innovation* between consecutive clusters from the Laggers to the Leaders, which can be taken as an indication of the impact of *Innovation* on the competitiveness. A sub-pillar, which distinguishes the Leaders from the other clusters, is the *Labor market flexibility*. Although all the other clusters converge in case of the *Labor market flexibility,* the Leaders display a higher level than the other clusters. The largest differences between the Leaders and the Followers in the levels of pillars and sub-pillars occur in *Public institutions*, *Private institutions*, *Transport infrastructure*, *On-the-job training*, and *ICT use*.

The Developing Ones differ from the Laggers particularly in *Electricity and telephony infrastructure*, *Health*, *Primary education*, *Quantity of education*, and *ICT use*. Runners-Up, on the other hand, differ from the Developing Ones particularly in *Transport infrastructure,On-the-job training, Technological adoption, Domestic market size*, and *Foreignmarket size*. The Followers differ from the Runners-Up in *Electricity and telephony infrastructure*, *Primary education*, *Quantity of education*, *Quality of education*, *ICT use*.

TABLE 2
COMPETITIVENESS STAGE OF THE COUNTRIESBASED ON WEF'S PILLARS AND SUB-SPILLARS

Cluster 1 LAGGERS	Cluster 2 DEVELOPING ONES	Cluster 3 RUNNERS-UP	Cluster 4 FOLLOWERS	Cluster 5 LEADERS
Angola	Albania	Azerbaijan	Argentina	Australia
Bangladesh	Algeria	Brazil	Bahrain	Austria
Benin	Armenia	Brunei Darussalam	Barbados	Belgium
Botswana	Belize	China	Chile	Canada
Burkina Faso	Bolivia	Colombia	Croatia	Denmark
Burundi	Bosnia &Herzigovina	Costa Rica	Cyprus	Finland
Cambodia	Bulgaria	Egypt	Czech Rpb.	France
Cameroon	Cape Verde	El Salvador	Estonia	Germany
Chad	Dominican Republic	Guatemala	Greece	Hong Kong SAR
Côte d'Ivoire	Ecuador	Honduras	Hungary	Japan
Ethiopia	Georgia	India	Iceland	Luxembourg
Gabon	Guyana	Indonesia	Ireland	Netherlands
Gambia, The	Jamaica	Iran	Israel	New Zealand
Ghana	Kyrgyz Republic	Jordan	Italy	Norway
Guinea	Lebanon	Kazakhstan	Korea, Rep.	Singapore
Haiti	Libya	Kuwait	Latvia	Sweden
Kenya	Macedonia, FYR	Mauritius	Lithuania	Switzerland
Lesotho	Moldova	Mexico	Malaysia	Taiwan,China
Liberia	Mongolia	Morocco	Malta	UK
Madagascar	Nicaragua	Panama	Montenegro	US
Malawi	Paraguay	Peru	Oman	
Mali	Romania	Philippines	Poland	
Mauritania	Serbia	South Africa	Portugal	
Mozambique	Suriname	Sri Lanka	Puerto Rico	
Namibia	Syria	Thailand	Qatar	
Nepal	Tajikistan	Trinidad and Tobago	Russian Fed.	
Nigeria	Venezuela	Tunisia	Saudi Arabia	
Pakistan		Turkey	Seychelles	
Rwanda		Vietnam	Slovak Republic	
Senegal			Slovenia	
Sierra Leone			Spain	
Swaziland			Ukraine	
Tanzania			U. Arab Emirates	
Timor-Leste			Uruguay	
Uganda				
Yemen				
Zambia				
Zimbabwe				

Several cluster methods are used and the best cluster configuration is obtained using agglomerative clustering and Ward as distance measure between different clusters. In addition to the visual inspection based on dendogram, a variance analysis -ANOVA- is conducted initially followed by the Scheffe test used as a post-hoc test in order to decide whether there are significant differences concerning the WEF competitiveness indicators among the clusters of countries. The ANOVA test showed that there are significant differences between the means of the clusters. As a result, it was possible to reveal the similarity and differences among clusters with respect to different indicators(for technical details of cluster analysis see [6].

Due to the fact that there are high levels of correlations among the 22 variables, instead of using each variable individually, a dimension reduction is realized based on factor analysis.The factor analysis results are given in Figure 2 and the factor groups which constitute the basis of these clusters are given in Table 3.

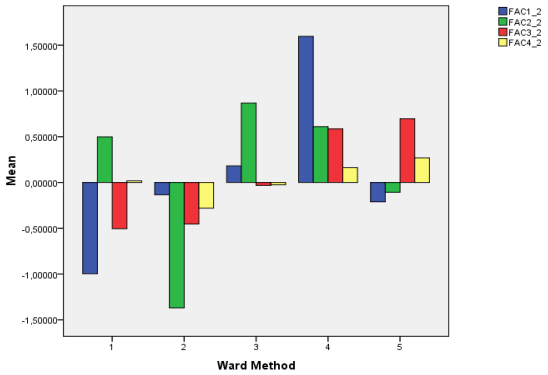

Fig. 2. Results of the Ward method

When Figure 2 and Table 3 are analyzed in detail, it can be seen that the "Laggers" display a very low performance on all the factors except the first one, even where it still shows a low but stable performance. In other words, the countries assigned to this group have low performance in market size, macroeconomic environment, health and primary education, electricity and telephony infrastructure (Table3).These countries do not have an efficient infrastructure; they have poor health leads and even basic education. The lack of knowledge of the workers will make it much more difficult to adapt to more advanced production processes. These countries primarily based on unskilled labor and natural resources and low productivity reflected in low wages.

The Developing Ones have only a positive performance on Factor 2, which is especially related with the basic requirements for the competitiveness of a country while they have low performance in the first and third factors and stable performance with respect to 4th factor. This shows that although these countries were able to reach a better infrastructure, health and primary education level etc. than the first group, they still need improvements in the quality of their public and private institutes as well as their transportation infrastructure. They also have a low performance in the majority of the indicators titled as Efficiency Enhancers by WEF. In other words, they neglect the importance of vocational and continuous on – the-job-training and they do not provide an efficient use of talents. Their domestic as well as foreign market size is small, which shows that their trade openness is in general low and they are not export-driven economies except a few natural resource exporters. The quality of the country's overall business network and the quality of individual firms' operations and strategies are low. Therefore they lack sophisticated business practices which are conducive to higher efficiency in the production of goods and services.

TABLE 3
FACTORS and RELATED VARIABLES

Variables	Loadings	Variables	Loadings
FACTOR 1		FACTOR 2	
1A Public institutions	.882	2B Electricity and telephony infrastructure	.885
1B Private institutions	.837	4A Health	.852
11 Business sophistication	.822	4B Primary education	.765
12 Innovation	.811	5A Quantity of education	.732
2A Transport infrastructure	.798	9B ICT use	.696
5B Quality of education	.791	FACTOR 3	
5C On-the-job training	.788	10A Domestic market size	.915
6A Competition	.786	10B Foreign market size	.867
6B Quality of demand conditions	.778	FACTOR 4	
7B Efficient use of talent	.763	3. Macroeconomic environment	.763
8A Financial market efficiency	.757	7A Labor market flexibility	.697
8B Trustworthiness and confidence	.744		
9A Technological adoption	.725		

The Runners-Up have positive performance in the third and fourth factors and have stable performance in the first two factors. This shows that those countries have large market sizes which allow the firms to exploit economies of scale. The macroeconomic environment as well as flexibility of the workers is also better than the first two groups. They have stable accomplishments in the areas considered to be basic factors underpinning competitiveness. In other words, although these countries have a high potential for international trade potential due to their market sizes, they have to make further improvements in the areas considered to be basic factors underpinning competitiveness such as transport and electricity infrastructure, public and private institutes, health, primary education etc. In fact, it is necessary to underline that Brazil, China, Mexico and Turkey belong to this group.

In contrast to the Runners-Up, the Followers show positive performance in the first and second factors and stable performances in the third and fourthfactors. This shows that these countries have accomplished the necessary improvements in the basic requirements as well as most of the efficiency enhancers but they suffer from market size and macroeconomic environment as well as flexibility of their labor force. In fact, it is necessary to highlight that Greece, Italy and Portugal, where currently macroeconomic stability has been the primary concern and the public debt is said to have reached unsustainable levels, belong to this group.

Finally, the Leaders have positive performance in all the factors. They have notable strengths related to innovation, technological readiness and labor market flexibility. Their public institutions are among the most effective and transparent in the world. Governance structures enhance business confidence; they also have excellent infrastructure, very stable macroeconomic environment and high quality of education. In fact, this group also includes the EU countries which are also the leaders of innovation according to Innovation Union Scoreboard [7]. Innovators according to the Innovation Union Scoreboard are in the Followers cluster in term of competitiveness. This shows that there is an important relation between the competitiveness level and the innovation performance of a country.

III. THE BASIC DRIVERS FROM COMPETITIVENESS TO INNOVATION

In this study, we propose a methodology based on BN method for investigating the complex structure of the relationship among innovation and a set of competitiveness indicators as well as providing an interactive and visual decision support systemto the policy makers to guide them in their search for means of improving the innovation level of their country in this fierce global competitive environment. BN is a directed acyclic graph where nodes represent the variables and the arcs represent the conditional dependencies between the variables[8].

In order to learn the corresponding BN, the data is first transformed into a form where each variable is discretized to have seven states, each having equal width of range. Additionally, a new variable called *cluster* is included in the data set which indicates the cluster to which the country belongs. Hence, the final data used to learn the BN includes 23 variables in total. WinMine program is used to learn the structure of the BN from data [9]. Using WinMine we first divide the data into a 70/30 percent train and test split. All of the 23 variables are used both to predict and to be predicted. As the next step of the research the same BN is created using the Netica software. This way wewill be able to enter evidence for variables and observe the change in the posterior probabilities consequently. The BN created using the Netica software and the marginal probabilities of the variables in the network can be seen in Figure 3.

After creating the BN structure from the data set, a sensitivity analysis is performed to determine the variables which have the biggest effect on the innovation variable. The results of the sensitivity analysis are in terms of variance reduction rates corresponding to indicators. Variance reduction is the expected reduction in the variance of the output variable due to the value of an input variable. The variable with the greatest variance reduction rate is expected to be the one to alter the beliefs of the target variable at most. The details of the sensitivity analyses are given in Table 4 below.

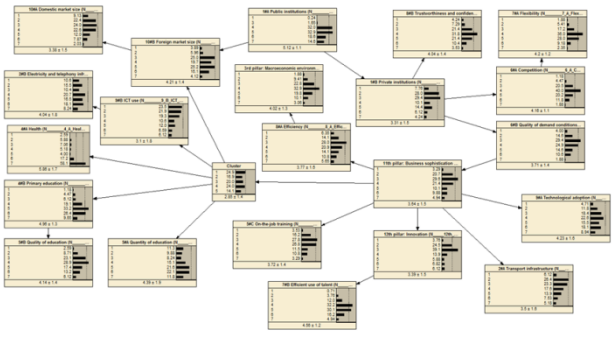

Figure 3.The BN created using Netica software

As can be seen in Table 4, the BN analysis show that, the competitiveness cluster to which a country belongs is an important indicator of its innovation level. Additionally, regardless of the cluster stage, the basic competitiveness indicators which have primary impact on shaping their innovation level *Business sophistication*, *On-the job-training*, *Quality of demand conditions*and*Efficient Use of Talent*.

TABLE 4
SENSITIVITY ANALYSIS RESULTS

Indicator	Variance Reduction %
11Business sophistication	82.90
5C On-the-job training	70.20
6B Quality of demand conditions	68.60
Cluster	62.90
7B Efficient use of talent	61.20
9A Technological adoption	59.70
2A Transport infrastructure	57.00
8A Financial market efficiency	50.5
9B ICT use	48.00
1B Private institutions	46.80
2B Electricity and telephony infrastructure	38.70
1A Public institutions	36.30
4B Primary education	34.30
5A Quantity of education	32.00
6A Competition	31.60
8B Trustworthiness and confidence	24.40
5B Quality of education	24.40
4A Health	20.80

The fact that *Business sophistication* is the most influential indicator is an indication of its close relation to innovation. Its components such as the use of best and efficient process technologies, the use of sophisticated marketing tools and techniques, competition through unique products and processes, being present across the entire value chain including product design, and willingness to delegate authority all relate directly to the various stages of innovation process. *On-the-jobtraining*, the secondmostinfluentialindicatoraimstoensure a constantupgrading of workers' skills. It is interestingtonotethat*On-the-jobtraining*appears as a moreinfluentialfactorthan*Quantity of education*and*Quality of education*.This is in line with Reference [10] claim that regardless of the institutional education level, workers around the world can be adequately trained on-the-job for high productivity and hence, competitiveness.

Furthermore, it is also necessary to underline that the cluster to which the country belongs is the fourth important indicator of its innovation level. This shows that the group at which a country is assigned according to the cluster analysis has an important influence on its innovation level.

IV. CONCLUSIONS

A representation of the multi-faceted interaction of science, technology and the economy is extremely useful for understanding the sources of and processes leading to technological innovation. This study clusters 148 countries according to the pillars and sub-pillars used in Global Competitiveness Reports and conduct a factor analysis in order to highlight the basic factors that each cluster has to focus on in order to improve their competitiveness stage. Finally the BN analysis highlights that, regardless of its stage of competitiveness, "business sophistication", "on the job training", "quality of demand conditions" especially explain the position of country in terms of innovation index the competitiveness cluster to which a country belongs has an important impact on its innovation level. But it also highlights that the competitiveness cluster to which the country belongs is an important indicator of its innovation level. Therefore these findings provide an important initial step for the further research. Thus, the next step of this analysis will be to specify the relative importance of each of these basic competiveness components changes depending on the competitiveness stage of the country under consideration. This will provide an important road map for each country in different competitiveness stage, the basic competitiveness components that they have to focus in order to improve their innovation level

ACKNOWLEDGMENT
This research was partly supported by Istanbul University Research Fund project number 7264

REFERENCES

[1] J. Fagerberg, "What do we know about innovation? Lessons from the TEARI project", Centre for Technology, Innovation and Culture, University of Oslo, TEARI project. Report No. 1. , 2004
[2] G. Günday, G. Ulusoy,K.Kılıç,L.Alpkan, "Effects of innovation types on firm performance", International Journal of Production Economics, 133, 662-676, 2011.
[3] World Economic Forum, *The Global Competitiveness Report 2012–2013*, Switzerland, 2012.
[4] X. Sala-i-Martin, B. Bilbao-Osorio, J. Blanke, M. Drezeniek, M.D. Hanous, T. Geiger, Mia I. Paua F "The Global Competitiveness Index: 3 prioritizing the economy policy agenda", 2008
[5] G. Günday, G. Ulusoy, K.Kılıç, L. Alpkan, "Modeling Innovation: Determinants of innovativeness and the impact of innovation on firm performance", Proceedings of 4th IEEE International Conference on Management of Innovation & Technology (ICMIT), 766-771, Piscataway, New Jersey, 2008.
[6]J. F. Hair, W.C. Black, B. J. Babin,R.E. Anderson, "Multivariate Data Analysis" Prentice Hall; 7th edition February, 2009.
[7] Innovation Union Scoreboard (IUS), The Enterprise & Industry online magazine, ISBN 978-92-79-23174-2, Belgium, 2011.
[8] F.V. Jensen,"Bayesian Networks and Decision Graphs",Springer-Verlag, NewYork,2001.
[9] D. Heckerman, D. M.Chickering, C. Meek, "Dependency networks for inference, collaborative filtering and data visualization", Journal of Machine Learning Research, 1, 49–75, 2000
[10]W.W. Lewis, "The Power of Productivity", The University of Chicago Press, Chicago, 2004.