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An Empirical Analysis about Technological Development and Innovation Indicators

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Abstract

Researches on technological development and innovation indicators that are used as different criteria for measurement such as multivariate statistics methods have increased rapidly in the field of social sciences since 1990s. The concept of indicators is an interesting field of science, which are used to inform us about things that are difficult to measure. Indicators for technology development and innovation may be defined as statistics, which measure quantifiable aspects of technological development and innovation creation. In this research, indicators help us to describe technological development and innovation clearly and enable us to have a better understanding of the impact of policies and programs on technological development and innovation and on the society and the economy in general. The objective of the present paper is to examine whether technological development indicators, which are used as a proxy for economic growth, innovation and the development level of countries, are influenced by the used variables in this analysis. The study is conducted by using a very large data set. It covers a monthly time period of 1996 and 2011. The study includes a variety of variables such as research and development expenditure (RDE), high-technology exports (HTE), long-term unemployment (LTU), patent applications-residents (PA), patent applications-nonresidents (PAF), health expenditure (HE), GNI per capita (PPP), share of women employed in the non-agricultural sector (SWE), stocks traded (ST), internet users (IU), scientific and technical journal articles (STJ). The empirical results which were obtained by using MDS (Multidimensional Scaling) and HCA (Hierarchical Cluster Analysis) methods suggest that the variables of RDE, PA, HE, PPP, SWE, IU and STJ have significant impacts on technological development and innovation and should be reviewed all together.

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Keywords : Technology Development, Innovation, Multidimensional Scaling (MDS).

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1. Introduction

Since the beginning of the recent financial crisis in 2008, the world economy tries to move from initial recovery to more sustained expansion. Governments all around the world have applied looser fiscal and monetray policies, which initiated a period of recovery. However, fiscal or monetary policies are not alone sufficient for the economies to enter into a more lasting expansionary period. Policymakers have recently recognized that more investment is needed for a sustainable growth rate. States try to remove barriers and governments cut taxes to increase the level of gross domestic product (GDP). It is obvious that these measures will create only a one-time increase in the level of GDP and technological progress is needed to have a long-term, sustainable rate of change in the level of economy.

One of the most important findings that belong to 1950s is that a substantial share of economic growth such as more than one third is due to technological progress. By the beginning of 1990s, many economists and analysts were not very optimistic about the sustainability of economic growth. However, contrary to their opinions, by the middle of 1990s, productivity increased and technological progress accelerated thanks to advances in computer and software technologies.

One successful example to economic development is China. As Zhang et al., (2012) point out, one of the most important reasons why China could realize such great achievements in terms of economic growth is the scientific progress and innovation. In today's tough competitive environment, countries have to benefit from scientific innovation resources more than ever before. As Zhang et al., (2012) state, there is a significant relationship between scientific innovation and economic growth. In China and in several other Asian countries like Korea, Taiwan and Singapore, aggressive technology acquisition and efficient use of these technologies in production processes played a significant role in the economic development of these countries. In order to increase their international competitiveness, the mentioned states further developed these acquired technologies by improving their research and development (R&D) capabilities. Consequently, as the scientific innovation contributes more to economic growth, governments give more importance to technological investments.

In general, R&D is considered as an expensive, risky and time-consuming activity for most companies. As Whangtomkum et al. (2003) point out, companies prefer technology transfer rather than R&D. Thus they believe that they can enhance their technological capacity, knowledge generation, diffusion and application in a low cost, less risky and more efficient manner. Although technology transfer enables corporations to develop new products to meet the needs of their customers, it is impossible to survive in such a tough competitive environment without making sufficient level of investments in technology and innovation.

Innovation and technology are the key elements of sustainable economic growth in today's global economy. As Gurbiel (2002) states, appropriate economic policies should be set, which provides the strengthening of the cooperation between main players such as innovators, companies, state agencies and financial institutions to ease the flow of information technology between them. Based on this premise, the aim of this study is two-fold. First, to assess technology development indicators and their roles on the formation of a proper technology and innovation strategy. Secondly, to suggest some policy recommendations for improving technological performance of newly developing countries and to make some suggestions for further research.

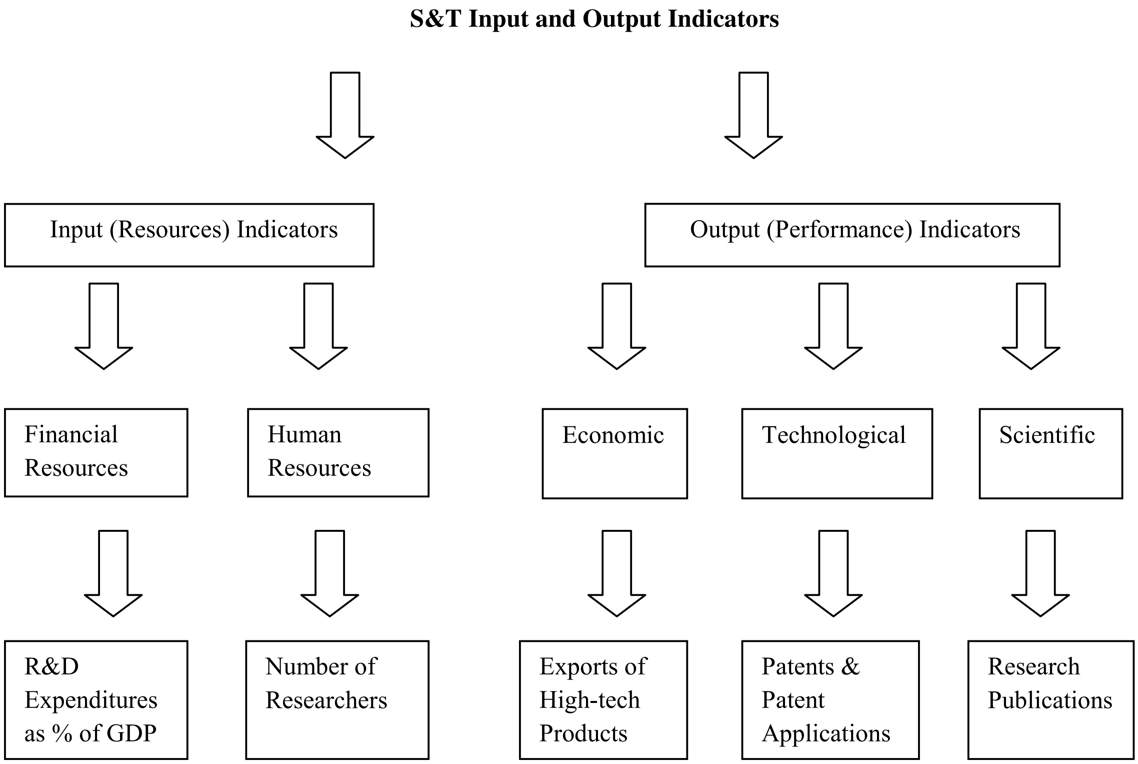
This study differs in several ways from the previous studies in literature. First, we provide a more in-depth, comprehensive and up-to-date assessment of technological development resources and performance indicators by focusing on Turkey. Second, we extend our analysis to compare the case of Turkey with all of the technological development indicators. Third, different from the studies in the Turkish literature, we provide a more comprehensive analysis by including both technological development input and output indicators by using more up-to-date data.

The reminder of the study is organized in the following way. We discuss the literature focusing on the science and technology (S&T) indicators in section 2. We describe the data set, methodology and the results of both Multidimensional Scaling (MDS) and the Hierarchical Cluster Analysis (HCA). At the same time we present multivariate statistics methods used in the empirical analysis with a focus on the multidimensional visual presentation to control for technological development and innovation, which are potentially correlated with observed and unobservable characteristics. Section 4 is the conclusion part of the study.

2.Literature Review

The literature identifying the important role that science and technology (S&T) plays in promoting economic growth and development in both developing and industrialized countries is highly rich. The New Growth Theory, an important theoretical development in the 1980s represented by Romer (1986) and Lucas (1988) states that technological progress depends on research or human capital and the advance in S&T is the most important factor on the economic growth and the social development. 'National system of innovation' , a frequently used modern term, which emphasizes the interaction between technical and institutional innovative development, has a major impact on the S&T performances of countries. Lundvall (1992) states that 'national system of innovation' includes all aspects of the economic structure and institutional set-up that has an impact on learning. Additionally, Freeman and Soete (1997) define 'national system of innovation' as "the many national or international interactions between various institutions dealing with science and technology as well as with higher education, innovation and technology diffusion". They underline that understanding the interactions between such institutions is also important for analyzing the growth dynamics of science and technology especially at a time when such growth dynamics differ among countries.

Fig. 1. S&T Input and Output Indicators According to the Major Literature



The S & T input and output indicators according to the major literature is presented in Figure 1. As Dasgupta and David (1994), Foray (1999), Mytelka (2001) and Cooper (1991, 1994) point out, the literature on technological development generally distinguishes between input (resources) and output (performance) indicators. The input (resources) indicators are divided into financial and human resources. As a financial input (resources) indicator, R&D expenditure as percentage of GDP is the most widely used indicator for evaluating and comparing technological development in different countries. There are also human resources indicators such as the number of science and technology graduates and the number of researchers employed in R&D. It is one of the most important resources for economic growth and social development. Meanwhile, the scientific literature shows that investment in R&D and R&D personnel working in the field are the main indicators for the level of innovation (Venckuviene et al., 2014). Performance indicators, on the other hand, can be classified according to three parameters such as economic, technological and scientific (Nour, 2012). As an economic indicator, percentage of high-tech exports in total exports of a country is a beneficial means of economic performance. Patents and patent applications is the most frequently used indicator to measure technological development. Finally, research publications such as technical journal articles are useful scientific technology output indicators to assess the relative performance of a given country and to compare it with other countries over a certain period of time. Table 1 indicates human and financial S&T input (resources) indicators and economic, technologic and scientific S&T output (performance) indicators of the OECD member countries.

Gurbiel (2002) defines innovation as everything new, which is the result of practical primary usage of a certain idea. We can distinguish between product and process innovations. Product innovations are products that are considered new either by the manufacturer or the customer. Process innovations are new processes, which reduce the cost of production or which facilitate the production of new products (Harmsen, Grunert & Declerck, 2000).

The innovation potential of a certain country is the sum of several macro and microeconomic factors that encourages the process of innovation within the country. R&D expenditure is one of these key factors in the innovation and technological progress of any country, which provides long-term economic development. While new products and processes can be formed thanks to R&D expenditures, the deacrease in the amount of R&D budgets have a negative effect on the number of patent applications in general (Gurbiel, 2002). Prior research also emphasizes the strong relationship between expenditure on R&D and new product announcements (Hipp, Tether and Miles, 2000 ; Tidd, 2001) R&D expenditure in a firm level also has a positive impact on the future investment capability either by minimizing costs or by boosting profits. A firm's R&D efforts not only contribute to generation of new knowledge, but also improve the relationship between several entities such as research institutions, universities and industries. Diverse literature on technology development and innovation underlines the importance of cooperation and networks across these entities (Gertler & Levitte, 2005 ; Okada, 2007 ; Kale and Little, 2007 ; Roy and Banerjee, 2007).

While technological innovation functions as a critical tool in gaining competitive advantage, patents are important instruments for the protection of innovation process. As Kale and Little (2007) point out, strengthening of patent laws is so important that it provides transformation of organizations from imitators to innovators. Because innovation and technology development is such a costly, time consuming and risky process, companies use patents as tools to block innovations from competitors and to obtain the extra value of their innovative efforts (Sampath, 2007). Thus, innovative companies can be amply rewarded with a stronger financial and market position and bargaining power through increased sales (Jenssen and Randoy, 2006).

As Meyer (2008) states, one of the crucial aspects of innovation management and technology development is the capacity to form and implement a proper technology strategy. Companies or states, which do not see the need to develop a technology strategy or which do not constantly review or monitor their strategies, lag behing their major competitors. For instance, Chinese government implements a variety of regulatory reforms and policy changes, which aim to assist knowledge creation and enhance innovative capabilities of the companies. Finland is another country with a sound technological strategy, which has become one of the most innovative countries of the European Union (EU). Finland has a huge number of R&D personnel employed by the public research institutions and private companies. Undoubtedly, technology strategies of corporations cannot work in isolation from national policies of countries. Several government policies to encourage innovation philosophy include R&D subsidies and tax instruments to lower costs of innovation, limiting complicated bureaucratic procedures, building and financing technology transfer institutions such as business incubators and technology parks and attracting venture capital investors (Gurbiel, 2002). Accordingly, structural change of the entire economy and sustainable growth is almost impossible without proper state policies and strategies on technology and innovation. Thus, implementing correct policies will strengthen the competitiveness of newly developing countries and bring economic success to them.

Table 1 : World Development Indicators : Science and Technology (OECD Member Countries)

OECD Member Countries	Researchers Full Time Equiv. per Million People (2012)	Scientific & Technical Journal Articles (2011)	Expenditures for R&D as % of GDP (2012)	High-tech Exports as % of Manufactured Exports (2012)	Patent Applications Filed (Residents) (2012)	Patent Applications Filed (NonResidents) (2012)
Australia	4.280	20.603	2.39	12.7	2.627	23.731
Austria	4.565	5.103	2.84	12.8	2.528	294
Belgium	3.983	7.484	2.24	11.4	755	127
Canada	4.563	29.017	1.73	12.4	4.709	30.533
Chile	317	1.979	4.6	4.6	336	2.683
Czech Rep	3.111	4.127	1.88	16.1	867	150
Denmark	6.730	6.071	2.98	14.2	1.406	229
Estonia	3.541	514	2.18	10.7	20	5
Finland	7.482	4.878	3.55	8.5	1.698	129
France	3.918	31.686	2.26	25.4	14.540	2.092
Germany	4.139	46.259	2.92	15.8	46.620	14.720
Greece	2.168	4.534	0.69	9.2	628	28
Hungary	2.389	2.289	1.30	18.1	692	66
Iceland	7.012	258	2.60	14.3	37	7
Ireland	3.513	3.186	1.72	22.6	492	63
Israel	6.602	6.096	3.93	15.8	1.319	5.473
Italy	1.820	26.503	1.27	7.1	8.439	871
Japan	5.158	47.106	3.39	17.4	287.013	55.783
Korea Rep	5.928	25.593	4.04	26.2	148.136	40.779
Luxembourg	6.194	204	1.44	8.1	109	52
Mexico	386	4.128	0.43	16.3	1.294	14.020
Netherlands	3.506	15.508	2.16	20.1	2.375	338
NewZealand	3.693	3.472	1.27	9.7	1.425	5.674
Norway	5.588	4.777	1.65	18.9	1.009	555
Poland	1.753	7.564	0.90	7.0	4.410	247
Portugal	4.781	4.621	1.50	4.1	621	26
Slovak Rep	2.804	1.099	0.82	9.3	168	35
Slovenia	4.398	1.239	2.80	6.2	442	11
Spain	2.719	22.910	1.30	7.0	3.266	209
Sweden	5.181	9.473	3.41	13.4	2.288	148
Switzerland	3.285	10.019	2.87	25.8	1.480	1.508
Turkey	987	8.328	0.86	1.8	4.434	232
UK	4.024	46.035	1.72	21.7	15.370	7.865
USA	3.979	208.601	2.79	17.8	268.782	274.033

Source : Worldbank (http://wdi.worldbank.org/table/5.13)

3. Methodology

3.1.Research Goal

In this paper, with MDS we aim to analyze the similarities or distances between the examined variables for technology. Besides, HCA has been made for the given variables in order to compare the similarities or disparities between variables related to technology development of Turkey. Hierarchical clustering method (HCM) uses the similarities or distances between objects when forming the clusters. Similarities are a set of rules that serve as criteria for grouping or separating items. These similarities can be based on a single dimension or multiple dimensions, with each dimension representing a rule or condition for grouping variables. Since the factors which affect the technologic development determine the statistical methods used in present study, the Euclidean distance approach for MDS analysis and the squared Euclidean distance for HCA are known as the most common distance measures.

3.2. Sample and Data Collection

In this paper, we use the long data set, which has been widely used to investigate various issues related to technological development. The study covers the monthly time period between 1996 and 2011. MDS is a means of visualizing the level of similarity of individual cases of a dataset. MDS can be considered to be an alternative to factor analysis. In general, the goal of the analysis is to detect meaningful underlying dimensions that allow the researcher to explain observed similarities or dissimilarities between the investigated objects. In factor analysis, the similarities between objects or variables are expressed in the correlation matrix. With MDS, you can analyze any kind of similarity or dissimilarity matrix, in addition to correlation matrices (Borg and Groenen, 2005).

3.3. Analyses and Results

In this paper, MDS has been implemented as two dimensional in order to be well understood. As regards Table 5, the coordinates have been determined according to technological development indicators for Turkey from 1996 to 2011. It can be obviously seen which variables are close to or separated from each other in the two dimensional plane. Variables which show similarities with each other in the first dimensional are high-technology exports (HTE) and patent applications, nonresidents (PAF) that have negative values and that are approximated to each other. Based on Table 6, which is constituted depending on Euclidean distances, it can be seen that variables are in accord with each other cluster in the same geometric locus or that variables are dissimilar to each other distinctively.

Figure 2 provides a more detailed analysis of the variables. This figure depending on Euclidean distance shows variables that are similar to each other and are agglomerated in the same place or that are dissimilar to each other and are clustered in different locations. In reference to Figure 2, High-technology exports (HTE), patent applications, nonresidents (PAF), stocks traded (ST) take part in different positions by comparison with other many variables. Long-term unemployment (LTU) positions as notably distinct from other variables. In the same way, it has been observed that health expenditure (HE), share of women employed in the non-agricultural sector (SWE), research and development expenditure (RDE), internet users (IU), GNI per capita (PPP), patent applications, residents (PA), scientific and technical journal articles (STJ) variables are situated more differently.

Table 2 : Variables Used in the Analysis

RDE	Research and development expenditure (% of GDP)
HTE	High-technology exports (% of manufactured exports)
LTU	Long-term unemployment (% of total unemployment)
PA	Patent applications, residents
PAF	Patent applications, nonresidents
HE	Health expenditure, total (% of GDP)
PPP	GNI per capita, PPP
SWE	Share of women employed in the non-agricultural sector (% of total non-agricultural employment)
ST	Stocks traded, total value (% of GDP)
IU	Internet users (per 100 people)
STJ	Scientific and technical journal articles

Table 3 : Raw (Unscaled) Data for Subject 1

	1	2	3	4	5	6	7	8	9	10	11
1	,000										
2	6,384	,000									
3	6,309	6,767	,000								
4	1,131	6,439	6,175	,000							
5	6,923	1,923	6,247	6,910	,000						

6	1,788	6,161	6,650	2,429	6,886	,000					
7	1,609	6,334	6,264	1,279	6,885	2,048	,000				
8	1,606	6,357	6,428	1,704	6,886	1,675	1,155	,000			
9	4,287	4,991	6,185	4,291	5,721	3,953	4,168	4,463	,000		
10	1,190	6,553	6,275	1,311	7,092	1,554	,932	,977	4,316	,000	
11	2,860	6,660	6,084	3,063	7,222	1,884	2,312	1,943	4,618	2,044	,000

Table 4 : Iteration History for the 2 Dimensional Solution (In Squared Distances)

Iteration	S-stress	Improvement
1	,13091	
2	10264	,02827
3	,10064	,00200
4	,10051	,00013

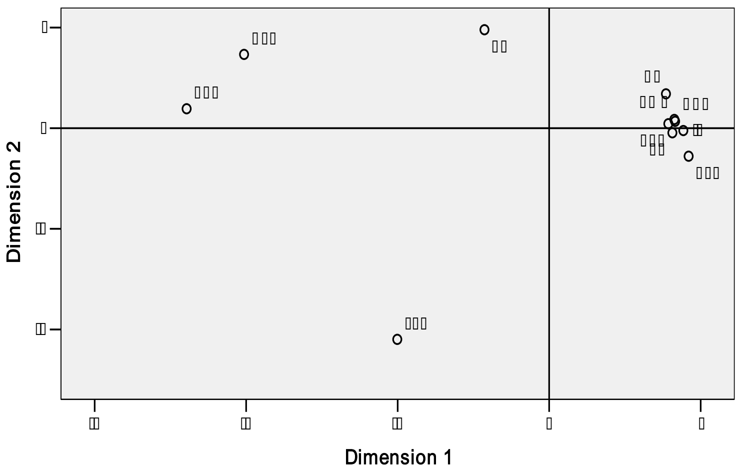
Iterations stopped because S-stress improvement is less than 0,001000
Stress values are Kruskal's stress formula 1.
For matrix
Stress = ,11133 RSQ = ,97478

Stress value for two dimension is to account for 97% of data and 4 iterations have been done until S-stress improvement is less than 0,001000. Kruskal Stress Value, as it is seen in the Table 4, is notably a high value. This value demonstrates that stress value has an explanatoriness level of 99%, that is, the result of analysis has a high level of explanatory power.

Table 5 : Stimulus Coordinates Dimension

Stimulus number	Stimulus name	1	2
1	RDE	,8316	,0680
2	HTE	-2,0139	,7335
3	LTU	-1,0022	-2,0988
4	PA	,8136	-,0454
5	PAF	-2,3929	,1932
6	HE	,7712	,3415
7	PPP	,7865	,0443
8	SWE	,8263	,0869
9	ST	-,4269	,9786
10	IU	,8858	-,0232
11	STJ	,9208	-,2786

Fig. 2. Euclidean Distance Model



3.3.1. Results of Hierarchical Cluster Analysis (HCA)

Conglomeration has been researched visually to indicate what results are obtained from MDS. It has been consulted firstly to hierarchical cluster analysis in order to determine how many clusters will be constituted from the data set. As can be understood, Table 6 shows agglomeration schedule that is the one of hierarchical cluster methods, where Ward's method has been used as a submodule. Then two step cluster has been used in order to make the final decision concerning how many clusters aggregate approximately in the SPSS package.

In this modeling approach, taking into account of Table 6 and Table 7, there seems to be evidence that the result of analysis in which cluster occurs with two or three agglomerations. This raises the question whether there is systematic auto-clustering between hierarchical cluster method and auto-clustering resulting from Schwarz's Bayesian Criterion (BIC) taking place on Two-Cluster solution. Thus, the chosen number of cluster may be three that the BIC is the smallest value. In other words, the number of cluster seems to be three. Furthermore, the study gives results that should be three cluster both dendrogram using Ward Method and two cluster analysis.

Figure 3, which shows the drawn dendrogram for the whole sample, indicates that technologic development data are fairly stable throughout specific area in two-dimensional notation except for the left hand side of the figure. However, there is a sharp discrepancy among purviews which is generated by clustering of variables. This method builds the hierarchy from the individual elements by progressively merging clusters (Ward's criterion). In this study, we have eleven elements as can be seen from Table 5. The first step is to determine which elements are to merge in a cluster. Usually, we want to take the two closest elements according to the chosen distance. From this point of view, variables influence technologic development that are agglomerated in three groups. First group is composed of PPP, IU, SWE, RDE, PA, HE, STJ data. ST, HTE, PAF data make up the second group. Finally, LTU data constitute the third group.

Table 6 : Hierarchical Cluster Method Agglomeration Schedule

Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	7	10	,435	0	0	2
2	7	8	1,053	1	0	4
3	1	4	1,692	0	0	4
4	1	7	3,456	3	2	7
5	6	11	5,232	0	0	7
6	2	5	7,081	0	0	9
7	1	6	11,878	4	5	8
8	1	9	26,833	7	0	10
9	2	3	54,489	6	0	10
10	1	2	117,431	8	9	0

Table 7 : Auto-Clustering

Number of Clusters	Schwarz's Bayesian Criterion (BIC)	BIC Change(a)	Ratio of BIC Changes(b)	Ratio of Distance Measures(c)
1	177,403			
2	186,062	8,659	1,000	1,180
3	229,749	43,687	5,045	1,392
4	267,398	37,648	4,348	1,251
5	324,373	56,975	6,580	1,873
6	380,021	55,648	6,427	1,175
7	436,536	56,514	6,527	1,298
8	495,390	58,854	6,797	1,145
9	554,956	59,566	6,879	1,034
10	614,137	59,181	6,835	1,409
11	674,142	60,004	6,930	1,068
12	733,870	59,728	6,898	1,575
13	794,252	60,383	6,974	1,260
14	854,760	60,507	6,988	1,096
15	915,313	60,553	6,993	1,250

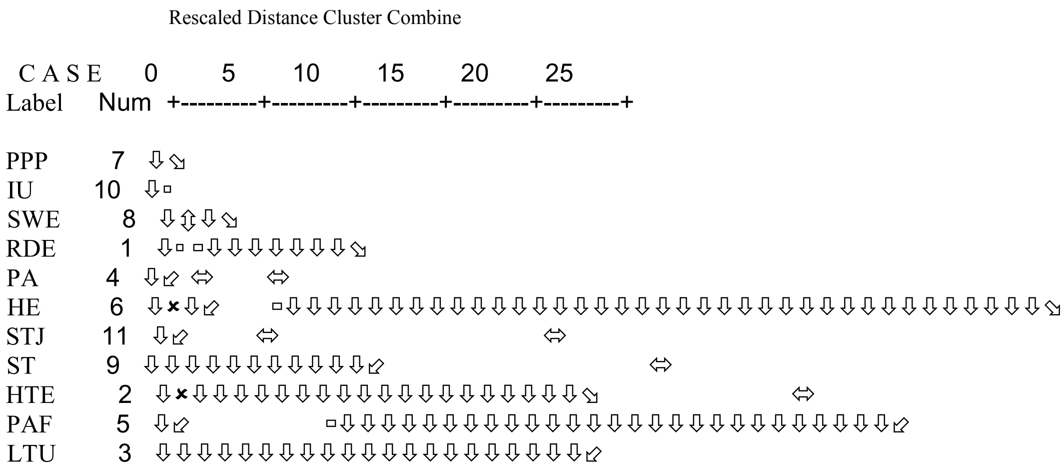


Fig. 3. Dendrogram Using Ward Method

4. Conclusion

Over the last decade, there has been an increased interest in technologic development among the researchers. By using technologic development indicator data, which is one of the longest data sets measuring technological developments in Turkey, we investigated which indicators are assumed to be more effective on technologic development in literature. In more detailed analysis, we observed the effects of the variables on technological development in different sub-groups. HTE (High-technology exports) and PAF (Patent applications, nonresidents) are found to be the most effective variables on technological development for Turkey. Interestingly, the results seem to suggest that technologic development is not related to long-term unemployment (LTU) status as compared to other variables. The empirical results which were obtained by using MDS (Multidimensional Scaling) and HCA (Hierarchical Cluster Analysis) methods suggest that the variables of research and development expenditure (RDE), patent applications, residents (PA), health expenditure (HE), GNI per capita (PPP), share of women employed in the non-agricultural sector (SWE), internet users (IU) and scientific and technical journal articles (STJ) have significant impacts on technological development and innovation and should be reviewed all together.

There is a long-term relationship between scientific innovation, technological development and economic growth. S&T input and output indicators such as R&D expenditures as of GDP, number of researchers, exports of high-tech products and patents and patent applications promotes the economic growth. In return, economic growth increases the demand for science and technology and boosts the innovational activities that will create a continuous interaction between scientific innovation and economic growth in the world. In this context, as a suggestion for further research, this analysis can be extended further by doing a similar research for different industries in a micro level. A sectoral level of analysis may also provide a more in-depth analysis by giving which factors and variables are more effective on the way to develop separate technological and innovation strategies for each industry.

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