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Key Sector Analysis by IO Networks: Evidence from Turkey

Summary: In this study, the key sectors of Turkey are determined using Input-Output (IO) network analysis. Different centrality measures are analyzed and compared. Accordingly, eigenvector, page rank, hub, and authority centralities are calculated. The effects of an economic shock are also analyzed using random walk centrality and counting betweenness. Findings indicate that the key sectors are "Wholesale and Retail Trade; Repair of Motor Vehicles", "Transport, Storage and Communications", "Agriculture, Hunting and Forestry", "Construction", "Real Estate Activities", and "Textiles, Textile Products, Leather and Footwear". Furthermore, the same sectors are determined to be vulnerable to economic shocks.

Keywords: Input-output networks, Key sector, Centralities.

JEL: C67, D85, L14.

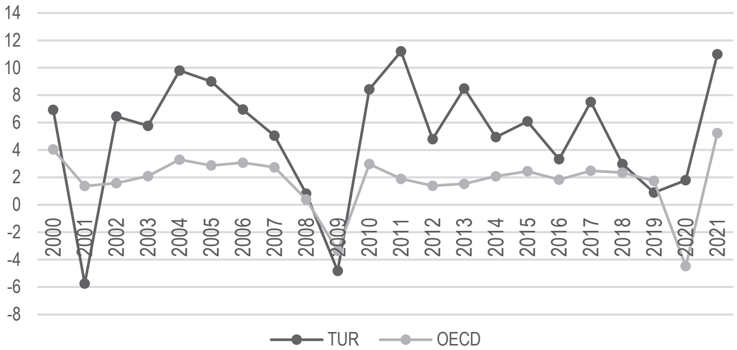
World conjuncture is experiencing unpredictable changes due to epidemics, natural disasters, invasions, and more. These changes place nations under pressure in many ways, so knowledge of the dynamics of a national economy and its weaknesses is critical. Consequently, an old but effective analysis, determining the core sectors in an economy, has gained importance. These analyses allow policy makers to predict the effects of an internal or external shock on the economy. Visualizing the interaction between sectors provides insight into which sectors truly feed others, as well as the effectiveness of such a tradeoff. Moreover, one can determine which sectors will be affected immediately and which will bear the costs of the shock for an extended period of time.

For Turkey, traditional methods are widely used to determine the key sectors. The main contribution of this study is to use new and significantly more suitable methods to analyze the complex nature of the present economic structure. Different methods are used and analyzed to attain a comprehensive approach. Furthermore, some sectors that are important in several ways for Turkey are discussed in detail.

In Section 1, a brief explanation of the Turkish economic structure is given. In Section 2, the theoretical background is provided, and in Section 3 the basics of the IO networks are outlined together with the related literature. Following this are the empirical results and discussions, and the final part summarizes this study and presents concluding remarks.

1. Recent Developments in the Turkish Economy

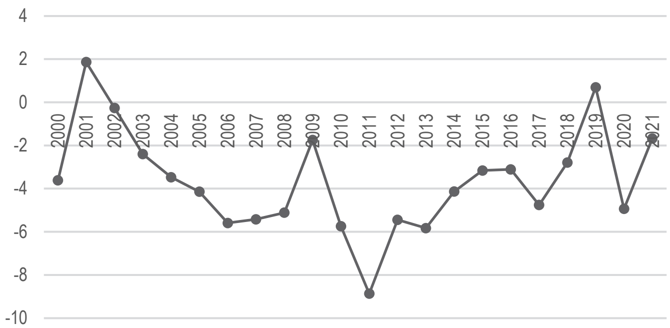
In the 2000s, Turkey generally grew more than the OECD average (Figure 1). Its significant decline in economic growth in 2001 was due to the economic crisis. Although in 2019, Turkey's performance fell below the OECD average, over the next two years Turkey outperformed other OECD countries. Recently, IMF updated their growth predictions for the world and Turkey. Global growth forecasts have been downgraded from 3.6% to 3.2% and 2.9% for 2022 and 2023, whereas for Turkey, the forecasts in April 2022 of 2.5% for 2022 and 3% for 2023 have been upgraded to 4% and 3.5%, respectively.



Source: Author's calculations based on data from the World Bank.

Figure 1 Annual Growth of Turkey and OECD Countries (%)

This growth performance comes with the expense of a large current account deficit (CAD). One can see from Figure 2 that the current account balance was only positive in 2001 and 2019. Determinants of the CAD are analyzed in many studies, which reflect the basic structural problems of the Turkish economy.



Source: Author's calculations based on data from the World Bank.

Figure 2 Current Account Balance of Turkey (% of GDP)

The main component of Turkish imports is energy payments. Turkey is foreign-dependent on energy, and this has a strong negative effect on trade balance. Gökhan Karabulut and Ayşe Çelikel Danışoğlu (2006), Muzaffer Demirbaş, Hakan Türkay, and Musa Türkoğlu (2009), Furkan Beşel (2017), A. Yasemin Yalta and A. Talha Yalta (2017), and Hamiyet Yiğit and Süleyman Açıkalın (2019) are some examples of empirical works which indicate that energy import is one of the main determinants of the CAD. İsmet Göçer (2017) analyzed the years between 1996 and 2012 and concluded that 37% of the current account deficit is due to energy import. This factor is followed by the foreign trade deficit except energy (26%), interest payments of external debt (24%), income transfers by foreign direct investment (7%), and portfolio investments (6%).

Turkey is applying an export-oriented growth policy, which results in an increase in export values. However, imports are simultaneously increasing, thus offsetting the increase in exports. When considering the components of Turkish imports, the largest share consists of intermediate goods. The share of intermediates in imports increased from 69% in 2015 to about 82% in 2022 (Table 1). Therefore, some empirical studies emphasize the importance of Turkey producing its own intermediates in order to lower the CAD (Ali Konak 2018; Yiğit and Açıkalın 2019; Ebru Gül Yılmaz 2022). Republic of Türkiye Ministry of Treasury and Finance (HMB) mentions in the report of "The New Economy Program: 2021-2023" that, for the critical sectors which are highly dependent on foreign inputs, research and development plans will be encouraged to enhance domestic products and technologies.

Table 1 Imports Content for Turkey, 2013-2022 (% of Total Imports)

	2015	2016	2017	2018	2019	2020	2021	2022
Capital goods	17	18	14	13	12	14	13	10
Intermediate goods	69	67	73	76	77	74	77	82
Consumption goods	14	15	13	11	10	11	9	8

Source: Author's calculations based on data from TURKSTAT.

The dependence of imported intermediates contributes to the import dependence of exports. This dynamic, together with energy dependence, makes the economy vulnerable to changes in exchange rates. Recently, the interest rate policies of both the USA and European countries have placed great pressure on the prices of the US dollar and Euro with respect to the Turkish Lira (TL). Attempts have been made to balance increases in exchange rates through specific policies, such as "currency protected deposits". It seems that the exchange rates have somehow been balanced.

Unlike many countries, Turkey is applying a low-interest-rate policy despite the significant increase in inflation. In August 2022, the consumer price index was 80.21% with respect to the previous year, while the domestic producer price index was 143.75%, and the non-domestic producer price index was 111.34%. To compensate for the harmful effects of the rise in price levels, the government prefers to use some tools apart from interest rates. In fact, on August 18, 2022, the Turkish Central Bank decreased the policy rate from 14%-13%. Instead of increasing interest rates, the government uses alternative macroeconomic policies.

The strategies of the Turkish government are summarized under the “Turkish Economy Model”. The Central Bank of the Republic of Türkiye (CBRT) announced the aim of the model as achieving sustainable economic growth, which is to be realized through price stability provided by investment, employment, production, and exports. “Liraization (or dedollarization)” is strongly supported. This is a reverse dollarization strategy which encourages all domestic economic agents to hold their assets in TL. On the other hand, different forms of subsidies are applied so that the domestic actors are supported against price increases while nourishing consumption and employment.

2. Theoretical Framework

A typical IO table is provided in Table 2. Here, only two sectors are represented: the agricultural sector and the non-agricultural sector. Z_{ij} represents the flow from sector i to sector j, and each row represents the contribution of the corresponding sector to the other sectors. From Table 1, the agricultural sector uses Z_{11} as an input of its own, then sells Z_{12} amount of intermediates to the non-agricultural sector. These, together with the consumption of agricultural products, constitute the final goods. The final goods and exports of the agricultural products, F_1, add up to the total demand for agricultural products, X_1. Columns represent the inputs used for producing the products of the related sector. In other words, the columns represent the expenses of the sectors. Expenses on intermediates, other expenses, such as taxes and wages, and expenses on imported goods sum up to the total supply of the sector. The system described by the IO tables is balanced, namely row sums are equal to column sums.

Table 2 General Form of an IO Table

Sectors		1	2	Final consumption	Exports	Total final use	Total demand
1	Agriculture	Z_{11}	Z_{12}			F_1	X_1
2	Non-agriculture	Z_{21}	Z_{22}			F_2	X_2
	Value added						
	import						
	Total supply						

Source: By author.

For *n* sectors, the row sums for each sector i can be expressed as:

$$X_i = \sum_{j=1}^{n} Z_{ij} + F_i. \quad (1)$$

The same summation can be rewritten as:

$$X_i = \sum_{j=1}^{n} a_{ij} X_j + F_i, \quad (2)$$

where:

$$a_{ij} = \frac{z_{ij}}{X_j}, \quad (3)$$

is referred to as the technical coefficient.

If the matrix is denoted with entries a_{ij} as A, the above summation can be written in matrix notation as:

$$X\,(I-A) \;=\; F \;\text{ or } X \;=\; (I-A)^{-1}F. \tag{4}$$

The matrix A is referred to as the technical coefficient matrix, and the matrix $(I-A)^{-1}$ is referred to as the Leontief inverse.

Key sector analysis using IO tables has a long history. The classical way to analyze IO tables is through the forward and backward linkages. The former, FL_i, is calculated as the sums of the ratio of elements in the rows of the matrix $Z=\{Z_{ij}\}$ divided by the corresponding row sum. The latter, BL_i, is the summation of the column elements of Z divided by the corresponding column sum:

$$FL_i \;=\; \textstyle\sum_{j=1}^{n}\frac{z_{ij}}{x_j}\,, \tag{5}$$

$$BL_i \;=\; \textstyle\sum_{i=1}^{n}\frac{z_{ij}}{x_j}\,. \tag{6}$$

Hollis B. Chenery and Tsunehiko Watanabe (1958) introduced the weighted backward linkage measure. Their index can be found through Equation (7):

$$m \;=\; ne^{T}A\,/\,e^{T}A\,e, \tag{7}$$

where n is the number of sectors in the model, e is the column vector of ones (i.e. $e_i=1, \forall i=1,..,n$), and A is the technical coefficient matrix (Henrique Morrone 2017). Accordingly, e^TA gives the column sums of matrix A. The expression on the right-hand side of the equation, $e^TA\,e$, gives the sum of all the coefficients in A. Together with n, the sum of sector j's backward linkages is divided by the simple average of all the backward linkages in the economy (Khan Haider and Adam Szymanski-Burgos 2021).

Poul Nørregaard Rasmussen (1956) further modified the index by replacing A in the previous index with the Leontief matrix. In doing so, he obtained the backward linkage indicator as:

$$z \;=\; ne^{T}\,(I-A)^{-1}\,/\,[e^{T}(I-A)^{-1}\,e]\,. \tag{8}$$

If the demand in one sector increases, z gives the amount of total output increase which is needed to match this increased demand (Morrone 2017). Forward linkage, on the other hand, calculates how much a sector will produce whenever there is a one-unit increase in the demand for all sectors. It is calculated as the column sums of the Leontief matrix, $(I-A)^{-1}$.

Eric Dietzenbacher (1992) modified the weighted direct backward linkage index of Chenery and Watanabe to form an iterative process, given as:

$$m_{i+1} \;= n\,m_i{}^{T}\,A\,/\,m_i{}^{T}\,A\,e, \tag{9}$$

starting with m_0, which is the vector of the backward linkage indicator. Here, larger weights are used for the sectors with higher backward linkages. Dietzenbacher (1992) showed that, as i tends to infinity, this recursive formula converges to an eigenvector problem, which can be given as:

$$m_{i+1} = n\, q^T / (q^T e) \qquad \text{where} \qquad q^T A = \lambda_D\, q^T. \tag{10}$$

Here, λ_D is the dominant eigenvalue of the technical coefficient matrix A, and q is the corresponding left-hand eigenvector. Obtaining an eigenvector problem is a practical way for solving the problem. Morrone (2017) summarizes the advantages of this method compared to Rasmussen and Hirschman's calculations. The eigenvector method assigns larger weights to the sectors which have higher backward linkages. This method is sensitive to structural transformations, and it enables us to observe the clusters of activities (Morrone 2017).

After these studies, other methods are used to identify the key sectors. One is the hypothetical extraction method, which was developed by Jean H. P. Paelinck, Jean de Caevel, and Joseph Degueldre (1965). Here, the idea is to analyze what will occur if one of the sectors is removed from the system. This is applied by substituting zeros for the rows and columns in the Leontief matrix corresponding to the closing sector (see Dietzenbacher 1997; Ronald Eugene Miller and Michael Lahr 2001; Esfandiar Jahangard and Vida Keshtvarz 2012; Dietzenbacher and Ronald Eugene Lahr 2013).

Guido Cella (1984) proposed the total linkage calculation, which can further decompose into backward and forward linkages. Geoffrey J. D. Hewings, Michael Sonis, and Rodney Charles Jensen (1988) introduced the concept of fields of influence in order to examine the effects of a technological change. In some studies, the clustering approach is also used to determine the cluster of industries and identify key sectors accordingly (see Stan Czamanski and Luiz Augusto de Q. Ablas 1979; Sergio Rey and Daniel Mattheis 2000; Bárbara Díaz, Laura Moniche, and Antonio Morillas 2006).

Unfortunately, the measures related to the Leontief matrix and multiplier calculations within the IO tables have some shortcomings. These analyses do not account for the relative importance of the nodes in terms of their place in the interconnectivity of the sectors or the stability of the economic system (Theodore Tsekeris 2015). Only the direct effects are measured, and the indirect effects cannot be detected. The system is also linear, and inputs are consumed in fixed proportions by the sectors (Darla K. Munroe and James J. Biles 2005). Firms are assumed to operate with constant return to scale, while the technology remains the same, input supply curves are perfectly elastic, and final demands are price-inelastic (Munroe and Biles 2005; Claudio Ferrari et al. 2019). These assumptions may lead to overestimated multiplier effects (Munroe and Biles 2005).

The network approach provides an opportunity to overcome these issues (Tsekeris 2015). Considering the interaction of the sectors using network analysis allows for an examination of the complex structure of the system. Network analysis is especially effective in analyzing systems with interacting actors (Semanur Soyyiğit and Yasemin Asu Çırpıcı 2018). It adopts its basics from the graph theory, which can be traced back to Euler's solution to the Königsberg Bridge problem in 1736 (Leonhard Euler 1736). Here, the idea is to identify the agents, called nodes, and the linkage between those agents. Agents can include individuals, firms, sectors, or countries. The interactions among those agents may be social relations, trade relations, financial relations, and more. The very nature of the networks provides a wide range of applicability in many disciplines, such as biology, sociology, finance, and economics (for detailed information on network properties see Çırpıcı and Soyyiğit 2017).

IO tables represent interactions among the sectors, and this structure is suitable for network applications. In this case, nodes are defined as the sectors, and the flow of goods represent the linkages among these nodes. This construction leads to a "weighted", "directed", and "self-looped" network. Weighted networks are those with some sort of weight attributed to the links. In IO analysis, they correspond to the amount of the flow of goods between two sectors in monetary terms. "Self-looped" refers to a flow within the sectors, where the links in a network may be one-way or two-way. If all the links in a network are two-sided, indicating that the direction of the link does not matter, then the network is referred to as an undirected network. In this case, all the relationships are reciprocal. For example, if A is friends with B, B will be a friend of A, or if A is married to B, then B is automatically married to A. On the other hand, if the direction of the link matters, then the network will be a directed network. Consider a parent child relationship, where if A is the parent of B, B cannot be the parent of A. In international trade relations, it matters which country is the seller and which is the buyer, and in IO analysis, the direction of the flow of goods matters. Therefore, IO networks are directed networks.

There are different notations to represent networks. One is to name the nodes in the network as $N = \{i_1, i_2, .., i_n\}$ and represent the relations between the nodes as a matrix. This matrix is referred to as the augmented matrix, g. As such, each entry, g_{ij} refers to the link between the nodes i_j and i_k. For an unweighted network, the augmented matrix is usually composed of ones and zeros, which represents whether there is a link between the nodes. For weighted networks, the entries of the matrix will be the weights of the correspondent link. The whole network can be represented as $G(N, g)$. Furthermore, an individual link can be written as (i_k, i_j) for a directed network, $\{i_k, i_j\}$ for an undirected network, or simply as $i_k i_j$ for both.

Any sequence of nodes $\{i_1, i_2, .., i_k\}$ for which all the links $i_{t-1} i_t$ belong to g for $t = 1, 2, .., k$ is called a walk. When all nodes are visited only once, $\{i_1, i_2, .., i_k\}$ is called a path. There may be more than one path between the two nodes i_k and i_j, but the shortest path is referred to as the geodesic and is represented as $l(i_k, i_j)$. A graph, $G(N, g)$, which is not directed is connected when every two nodes in the graph are connected by some path. A complete graph is one that contains every possible edge between all the vertices.

The number of links that a given node has is referred to as the degree of that node. If the network is a directed network, nodes have in-degrees and out-degrees. The former corresponds to the number of incoming links to a node, while the latter indicates the number of out-going links. The degree distribution in a network is an important indicator. Almost all real-world networks, including natural ones, such as food chain networks, protein networks, the basic neural network (a graph of the neural network for the worm C. Elegans), and metabolic networks, as well as manmade networks, such as electric grid lines, transportation networks, collaboration networks, and social networks, possess the so-called power law distribution. Power law can be represented as follows (Oliver Hein, Michael Schwind, and Wolfgang König 2006):

$$P(k) \approx k^{-\gamma}. \tag{11}$$

Here, $P(k)$ shows the probability of the occurrence of nodes with degree k in the network. Low values for the parameter γ indicate a higher probability of nodes with many links. This means that there is a greater probability of observing "super-nodes" that have many more links than other nodes. Consequently, the presence of super nodes corresponds to a high heterogeneity of connectedness (Carlos León and Ron Berndsen 2014). This heterogeneity shows itself as a "fat-tailed" distribution, which indicates the occurrence of a small number of nodes with high degrees together with a large number of nodes with low degrees. The nodes with high out-degree are referred to as hubs, and the nodes with many incoming links are referred to as authorities. When considering international trade relations, hubs will be the countries with the highest export scores, while authorities will be the countries with the highest import scores. As such, power law distribution is an indicator of the presence of hubs and/or authorities in the network.

Centrality measures are a crucial part of network analysis. They also serve as a useful tool for obtaining valuable information about network structure. There are many different centrality measures, and they all serve to identify the most important nodes in the network. The chosen measure will depend on what type of centrality is being sought. For example, degree centrality indicates the nodes which have the highest number of links. If it is important to find the nodes which have many links, this measure will be used. It is formulated as the total number of links, d_i of a node, divided by a normalization factor of $n-1$, where n stands for the number of nodes in the network:

$$C_d(i) = \frac{d_i}{n-1}. \quad (12)$$

Closeness centrality is a well-known measure that relates the importance of a node according to its closeness to other nodes in the network. It is inversely related to the total distance of the nodes to all other nodes:

$$C_{cl}(i) = \frac{n-1}{\sum_j l(i,j)}. \quad (13)$$

Here, $l(i,j)$ is the shortest distance between nodes i and j. A modified version of this measure provides us with the decay centrality, which is also related to the closeness of the nodes. Here, however, there is a decay parameter that rates the nodes according to their distance from the node under consideration. This is formulized as:

$$C_\delta(i) = \sum_{j\neq i} \delta^{l(i,j)}, \quad (14)$$

where δ is the decay parameter and $l(i,j)$ is the geodesic between nodes i and j. δ is between 0 and 1. As such, the influence of node j on the centrality of node i will decline as the distance between them increases. Values of δ closer to 1 indicate that the contribution of far distance nodes are declining more rapidly.

Another important measure is the betweenness centrality. This measure determines the nodes that have a bridging role, and it considers different paths between the nodes and searches for specific ones which these paths pass through. This means that bridging nodes are those which many nodes will need to go through in order to travel from one part of the network to the other:

$$C_b(i) = \sum_{i,j \neq k} \frac{P_k(i,j)/P(i,j)}{(n-1)(n-2)/2}. \tag{15}$$

Here, $P(i,j)$ is the number of geodesics between i and j, while $P_k(i,j)$ stands for the number of geodesics between i and j which go through k.

In the eigenvector centrality measure, the centrality of the neighbors is important. Eigenvector centrality solves a nested equation system, where each node's centrality value is dependent on its neighbors' centralities. As such, any node becomes more central as its neighbors become more central. It is given by the eigenvector of the adjacency matrix g, which corresponds to the largest eigenvalue. This measure is designed for both directed and undirected networks, but it is most effective for the latter. It is also significant that the effects of nodes on other nodes are calculated independent of the distance between the nodes, so the measure is not decaying with the distance. Additionally, if a central node is connected to many other nodes, then those nodes will become central because of the recursive structure of the eigenvector centrality. However, they may not be central in reality (Federica Cerina et al. 2015).

The shortcomings of the eigenvector centrality can be eliminated by using page rank centrality, which distinguishes between the connections according to their distance. A node will be central if it is connected to other central nodes, but, simultaneously, the nodes that it is connected to must not have any other significant connections (Cerina et al. 2015). Page rank centrality is an algorithm developed by the founders of Google, Lawrence Edward Page and Sergey Brin. It is used by Google to rank web pages and evaluates the importance of web pages following hyperlinks in web networks. Accordingly, it enables, for example, Google to return high-significance pages in response to a user query (Rodolfo Baggio and Magda Antonioli Corigliano 2009). A user browsing a certain web page may move to another web page that is hyperlinked within the current page. Consequently, a link provided in the current page leads them to another page. The user will use a hyperlink with a probability p, and they will go to a randomly selected new page with the probability $1 - p$.

Page rank centrality is a modified version of eigenvector centrality, which gives us the following iteration:

$$P_{i+1} = A^T P_i. \tag{16}$$

Here, P_i is the vector of page rank values at stage i, and A is the stochastic adjacency matrix. The page rank of a single node i is given by the formula:

$$P(i) = \sum_j \frac{P(j)}{O(j)}. \tag{17}$$

Accordingly, $P(i)$ is equal to the page ranks of the nodes js which are pointing to node i, divided by the out-degrees of those nodes. This measure is further modified with a damping factor, d, by Sergey Brin and Lawrence Edward Page (1998):

$$P(i) = (1-d) + d\left(\frac{P(j_1)}{O(j_1)} + \frac{P(j_2)}{O(j_2)} + \dots + \frac{P(j_k)}{O(j_k)}\right). \tag{18}$$

Another version of this formula is given as (Nan Ma, Jiancheng Guan, and Yi Zhao 2008):

$$P(i) = \frac{(1-d)}{n} + d\left(\frac{P(j_1)}{O(j_1)} + \frac{P(j_2)}{O(j_2)} + \dots + \frac{P(j_k)}{O(j_k)}\right). \quad (19)$$

The damping factor, d, gives the probability of a web-surfer who continues clicking on links (Ma, Guan, and Zhao 2008). As it corresponds to a probability, it can take values between 0 and 1, which guarantees that the algorithm never gets caught in a "sinking node" or "dangling nodes" (Francisco Pedroche, Miguel Romance, and Regino Criado 2016; Panpan Zhang, Tiandong Wang, and Jun Yan 2021). These nodes are ones which have zero out-degree. With the help of the damping factor, when the user arrives at a sinking node, the process will not terminate (Zhang, Wang, and Yan 2021). The value suggested for d by Brin and Page (1998) is 0.85.

Other important measures are authority and hub centralities, which are known as the Kleinberg centrality measure. Authorities refer to nodes which have high in-degree, and hubs are those with high out-degree scores. Considering web pages, for example, authorities refer to how much information is held by a node on a certain topic, whereas hubs are those which know where to find information on a given topic. In terms of international trade, authorities and hubs are referred to as big importers and big exporters, respectively. In some cases, these measures serve as useful alternatives to previous measures when those measures do not provide enough information. For example, Çırpıcı and Hale Kırer (2015) analyzed the international trade of EU countries with their partners using a network analysis based on export relations. They observe that the degree, betweenness, and eigenvector centralities did not provide any information. The structure of the network points out four countries which have the strongest export relations, but this result could not be explained by standard economic indicators, such as GDP and GDP *per capita*. Only network relations could reflect the true structure, and this could be observed only through hub centralities. Authority and hub centralities are calculated by applying eigenvector centrality to the $A = \Omega^T\Omega$ and $B = \Omega\,\Omega^T$ matrices, respectively, where Ω is the adjacency matrix.

Centrality analysis is an especially useful method for determining key sectors. However, the structure of the IO networks makes some of these measures ineffective. These networks are nearly complete, and degrees of the nodes are close to each other, which makes the degree centrality and betweenness centrality ineffective. In fact, in this paper, the R package was used, which allowed almost all centralities that can be calculated using R to be determined. This indicates that centralities such as Cluster Rank, Diffusing Degree, Density of Maximum Neighborhood Component, Eccentricity Centrality, K-core Decomposition, Clustering Coefficient, Entropy Centrality, Markov Centrality and others provide precisely the same values for all nodes. Additionally, the closeness centrality and some related centralities, such as Radiality Centrality and Barycenter Centrality, which consider the distances between the nodes, are also ineffective. In fact, in these measures, only two or three different centrality scores can be observed. Many nodes may share the same centrality values, so they do not produce effective results.

Another challenge with the IO networks is self-loops. The existence of self-loops sometimes makes the computations difficult. Therefore, in many network analyses, self-loops are ignored or dismissed from the system, and some algorithms automatically do this. Values for degree centrality, eigenvector centrality, and clustering coefficient are affected by the presence of self-loops (Wei Wei et al. 2011). Furthermore, ignoring self-loops will result in important information loss, so it is crucial to seek measures that can handle self-loops efficiently. Florian Blöchl et al. (2010) suggest two measures in this manner: Random Walk Centrality and Counting Betweenness. These measures allow the sectors that will be affected by an economic shock more quickly and the sectors that will bear the cost of the shock the longest to be determined.

Random walk centrality is calculated as the inverse of the average of a distance measure, which is referred to as the mean first-passage time (MFPT). Starting from node s, the MFPT indicates the expected number of steps required for a random walker to reach node t for the first time. It is given by:

$$C_{rw} = \frac{n}{\sum_{j \in V} H(j,i)}, \tag{20}$$

where, $H(j,i)$ stands for the MFPT from node j to node i. This is given in matrix notation as:

$$H(.,t) = (I - M_{-t})^{-1} e . \tag{21}$$

Here, M is the transition matrix, which is the normalized adjacency matrix obtained by dividing each row of the adjacency matrix by its corresponding row sum. M_{-t} shows that the t-th row and the column of matrix M is deleted, so it is of dimension $(n-1)x(n-1)$. I is the $(n-1)$ dimensional identity matrix, and e is the vector of 1's of dimension $(n-1)$ (Blöchl et al. 2011). Sectors with high random walk centrality measures are particularly sensitive to supply conditions, so they are the nodes most immediately affected by a supply shock.

Counting betweenness is a measure which gives the persistence of shocks in each sector. Large values indicate that the effects of the shocks will last longer (Pirapat Pareeratanasomporn 2017). It is given by the following formula:

$$C_{cb}(i) = \frac{\sum_{s \in V} \sum_{t \in (V - \{s\})} N^{st}(i)}{n(n-1)}, \tag{22}$$

where

$$N^{st}(i) = \sum_{j \neq t} \frac{N_{ij}^{st} + N_{ji}^{st}}{2}, \tag{23}$$

and

$$N_{ij}^{st} = m_{ij}((I - M_{-t})^{-1})_{si}. \tag{24}$$

$N^{st}(i)$ shows how many times one will visit node i while going from node s to node t, and m_{ij} is the probability of a random walker going from i to j (Blöchl et al. 2011).

3. Literature Review

There are many studies identifying key sectors using network analysis, which mostly use the PageRank, eigenvalue centrality, and hub and authority centralities (Martha G. Alatriste-Contreras 2015). Additionally, some community detection methods are used.

Communities are the group of nodes which have denser relationships between themselves and sparse relationships with nodes outside the community. There are some methods that indicate the core nodes of these communities, and they may be considered as key sectors. This approach is used for performing multi-country analyses (Julian Maluck and Reik V. Donner 2015; Tsekeris 2017).

Alatriste-Contreras (2015) analyzed the effect of a sectoral shock and its diffusion throughout the economy using the Herfindahl concentration index. Analyzing the intra-EU trade network using IO tables of 2005 for 22 EU countries, they determined the key sectors by using authority and hub scores. Their results revealed that the most central sectors at the same time were those that highly diffused the effects of an economic shock and had high aggregate impacts on the economy.

Studies concerning Turkey mainly focus on traditional IO analysis. In fact, there are many studies calculating backward and forward linkages, or some modifications of these, mainly based on the calculations of multipliers drawn from the IO tables. Veli Yılancı (2008) analyzed the 1998 IO table for Turkey and determined the key sectors. Mehmet Kula (2008), Sibel Atan (2011), Necla Ayaş (2011), Ergül Han, Tuğberk Tosunoğlu, and Ceyda Özsoy (2011), and Murat Ozan Başkol (2012) analyzed the 2002 IO table for Turkey with different sectoral aggregations. Both Kula (2008) and Han, Tosunoğlu, and Özsoy (2011) used the Chenery-Watanabe (CW) and Rasmussen Methods for the whole economy of 56 sectors and 23 sectors, respectively. However, Atan (2011) split her analysis into domestic and foreign intermediates in order to analyze the effects of intermediate goods on the structure of intersectoral linkages and the sectoral structure of the economy. Ayaş (2011) analyzed the strategic sectors of the Turkish manufacturing industry. Başkol (2012), in addition to backward and forward indices, calculated variability indices, which demonstrates how evenly other sectors are linked with the sector concerned (Abbas Valadkhani 2003). For 22 sectors, Ziya Gökalp Göktolga and Yusuf Akgül (2011) compared the years 2002 and 1998, whereas Esra Alp, Recep Kök, and Başkol (2017) compared 2002 with 2012. Both studies found that most of the key sectors could not maintain their positions in the next period.

More recent works include Hale Akbulut (2019), Abdullah Topcuoğlu and Fatih Volkan Ayyıldız (2019), Ferhat Pehlivanoğlu and Muhammet Rıdvan İnce (2020), and Hande Kul-Gelal (2021). While Akbulut (2019), Topcuoğlu and Ayyıldız (2019), and Kul-Gelal (2021) analyzed the whole economy to determine the key sectors (for 2015, 2014 and 2012 IO Tables, respectively), Pehlivanoğlu and İnce (2020) analyzed the economic impacts of the manufacturing sector on the Turkish economy by looking at subsectors for all IO tables published from 1970-2012.

All the key sectors determined by these studies are provided in Table A1 in the Appendix. The results vary in each study depending on the aggregation level and method implemented. Different subsectors of the manufacturing industry can be found in the results. The most common key sectors are the Manufacture of Food Products and Beverages, and the Manufacture of Chemicals and Chemical Products. The Textile and Metal Industries are also often included as key sectors.

There are some studies which focus on determining key sectors in Turkey using IO networks. Gülsün Gürkan Yay and Serkan Keçeli (2009) analyzed the 2002 IO table of Turkey to guide policy makers in deciding which sectors to prioritize for investment decisions. They applied several methods and concluded that the following are leading sectors: Research and Development; Manufacture of Pulp, Paper, and Paper Products; Electricity, Gas, Steam and Hot Water Supply; and Collection, Purification and Distribution of Water.

Jahangard and Keshtvarz (2012) applied a network approach to key sectors in Iran, South Korea, and Turkey. They analyzed the total, immediate and meditative effects, but those measures rely on multiplication calculations from IO tables. For Turkey (from the 2002 IO table), the sectors with high total effects were: Health and Social Work; Other Manufacturing; Wood and Products of Wood and Cork; Textiles, Textile Products, Leather, and Footwear; Paper and Paper Products; Printing and Publishing; Food Products, Beverages and Tobacco; and Construction. Immediate effects for Turkey indicated the following sectors: Other Manufacturing; Health and Social Work; Construction; Wholesale and Retail Trade; Repairs; Hotels and Restaurants; and Wood and Products of Wood and Cork. Meditative effects indicated the following sectors: Other Manufacturing; Construction; Hotels and Restaurants; Other Services; Textiles and Textile Products; Leather and Footwear; Food Products, Beverages, and Tobacco; Distribution of Water, Gas, and Electricity; Wood and Products of Wood and Cork; and Machinery and Equipment Products. Also, the revised total effect determined the following sectors: Other Manufacturing; Food Products, Beverages and Tobacco; Wood and Cork Products; Health; Construction; Communication; Pulp and Paper Products; Textiles and Textile Products; Non-Metallic Mineral Products; Education; and Electricity, Water and Gas.

Cerina et al. (2015) analyzed multi-regional input-output tables to identify the key sectors using final-demand weighted backward linkage, PageRank Centrality, and the Community Coreness Measure for the years 1995-2011. In different years, different sectors were considered key sectors. By the final-demand-weighted backward linkage measure, Construction, Food, Beverages and Tobacco, and Textile sectors were listed as key sectors, while the Page Rank measure listed the Textile Sector and Food Sector as key sectors. The community coreness measure considered Construction, Food, Beverages, and Tobacco, and Agriculture, Hunting, Forestry, and Fishing sectors as key sectors. Finally, the community detection by Newman and Girvan for 1995, 2003, and 2011 was applied. Results showed that for all three years, Agriculture, Hunting, Forestry, and Fishing and Food, Beverages and Tobacco were determined to be key sectors. The third key sector was Construction for 1995 and Inland Transport for the following two years.

Mauro Gallegati, Raffaele Giammetti, and Alberto Russo (2019) analyzed the effects of Brexit on EU countries and some others using the 2014 World Input-Output Table (WIOT). They used the hypothetical extraction method and although the main aim was to determine the countries and sectors most affected, the analysis allowed the sectors most affected within each country to be traced. Accordingly, Motor Vehicles, Wholesale Trade, and Financial Services sectors were the most affected in Turkey.

Each of these studies analyzed groups of many countries, including Turkey. As far as in known, no detailed network analysis has determined the key sectors of Turkey independently. Moreover, in this study, the effects of an economic shock are further considered by determining the sectors that will be affected immediately and those that will experience the effects of the shock the longest. Only one study (Blöchl et al. 2010) focuses on the measures used here, but Turkey is once again analyzed together with other countries, and the data used is for 2000.

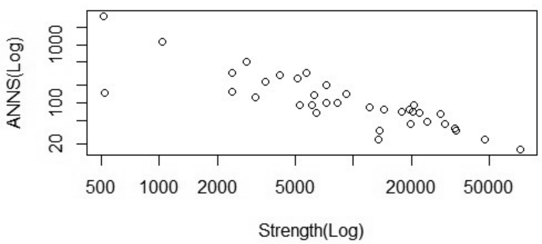
Alper Duman and Gül Ertan-Özgüzer (2015) employed one of the measures used here, but they continue with a panel data analysis. They evaluated the counting betweenness centrality for 40 countries, including Turkey, for each year between 1995-2011. However, they used these measures to calculate the Gini index of centrality measures, which they employ as a proxy for heterogeneity in the networks. Subsequently, they formed a fixed-effect panel data model to determine whether there is a correlation between this heterogeneity and the countries' growth performances. They illustrate a negative relationship between the heterogeneity of IO networks and economic growth.

Blöchl et al. (2010) determined the central nodes for 37 countries and 47 sectors. The first measure indicated that, for Turkey in 2000, the top key sector was Food Products, and the second measure suggested Textiles. Applying hierarchical clustering, they formed a dendrogram, which indicates that Turkey is closest to India. Random walk centrality node ranking for these two countries indicated similar sectors with different rankings. For Turkey, the sectors were ranked as follows: Food Products; Wholesale and Retail Trade; Construction; Hotels and Restaurants; Agriculture; Finance and Insurance; Textiles; Land Transport; Travel Agencies; and Machinery and Equipment.

4. Empirical Findings

In the literature, different measures are preferred for finding key sectors. The traditional method uses backward and forward linkages, which are very particularly effective in measuring the effects of a change in supply and demand on the economy. Additionally, they can provide insight into determining key sectors. However, those calculations are based on linearity. In order to capture the complex nature of the economic system, this study seeks useful alternatives, such as IO networks, which introduce many tools for analyzing complex systems, as mentioned above.

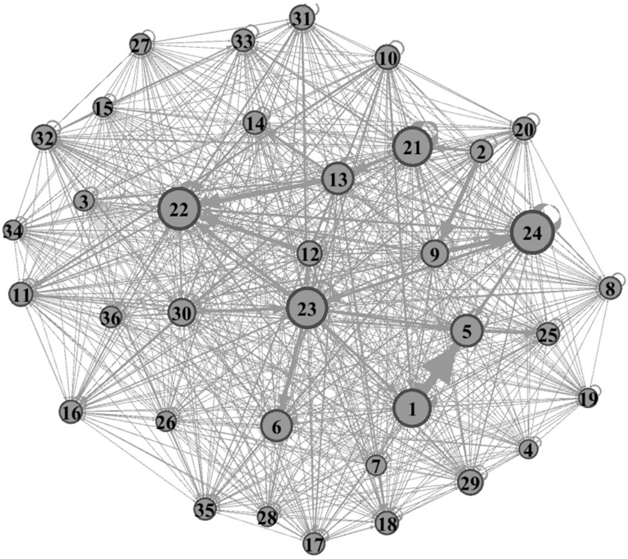
In this study, the OECD 2018 IO table for Turkey is used. In the original table, there are 44 sectors, and the table is aggregated into 36 sectors. A list of the sectors and abbreviations is found in Appendix Table A2.



Source: Computed by author using R.

Figure 3 Out-Strength Plot

Skewness of the data is calculated as 1.953957, indicating that the data is right skewed, and kurtosis is 7.586583, indicating a fat tail distribution. Additionally, K-S value is calculated as 0.1214782, with an α value of 3.158419 and a probability of 0.2087. These indicators confirm that the data has power law distribution, which is evidence of a core-periphery structure; namely, hubs are expected in the system. This structure can be seen from the sketch of the out-strength in Figure 3.



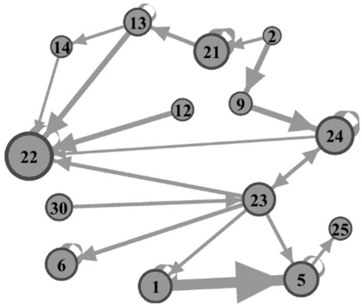
Source: Author's construction using Gephi.

Figure 4 Weighted Degrees

A picture of the network is provided in Figure 4. Here, the node and edge sizes are drawn according to the weighted degrees of the nodes. There is a very dense structure, and almost all nodes are linked to each other.

To attain a clearer vision, filters are used, and weak links are deleted to give weighted in-degrees in Figure 5 and weighted out-degrees in Figure 6. In order to make the comparison easier, the same filtering is used in both figures. Filtering is carried out with respect to the weights of the links. Therefore, the general structure, nodes, and links are the same in both figures. The ranking of the sectors in terms of weighted in-degree and weighted out-degree can be followed by the sizes of the nodes.

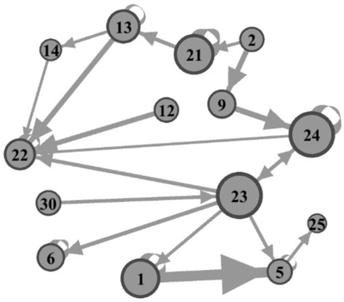
In Figure 5, the nodes are scaled according to their weighted in-degrees. The largest weighted in-degree value is observed for sector 22, which is the "Construction" (Const) sector. The construction sector is the greatest demander, which has strong connections with the other sectors. The strongest connections in terms of their weights are found in "Basic metals" (13), "Other non-metallic mineral products" (12), "Wholesale and retail trade; repair of motor vehicles" (23), "Fabricated metal products" (14), and "Transport, storage and communications" (24). The next largest weighted in-degree value is for the "Transport, storage and communications" sector (24), which receives the largest inputs from "Coke and refined petroleum products" (9) and "Wholesale and retail trade; repair of motor vehicles" (23). Sector 24 is followed by the "Electricity, gas and water supply" sector (21), with the strongest links to "Mining and quarrying, energy producing products" (2) and "Wholesale and retail trade; repair of motor vehicles" (23). The strongest relationship is between 1 and 5 which are "Agriculture, Hunting and Forestry" (Agr) and "Food Products, Beverages and Tobacco", each of which are (Food) sectors, which is not surprising.



Source: Author's construction using Gephi.

Figure 5 Weighted In-Degrees Filtered

Figure 6 indicates the filtered weighted-out degrees. This time, sector 23, which is "Wholesale and Retail Trade; Repair of Motor Vehicles" (Wholesale), has the largest score. Sector 24, which is "Transport, Storage and Communications" (TSC), closely follows 23. Both sectors are strong suppliers for the other sectors. The wholesale sector has the strongest links with "Textiles, textile products, leather and footwear" (6), Constr (22), TSC (24), Food (5), and Agr (1). The TSC sector is closely related with the Wholesale (23) and Constr (22) sectors.



Source: Author's construction using Gephi.

Figure 6 Weighted Out-Degrees Filtered

Centralities are calculated using two different algorithms in R. The first gives all centralities at once, so all the centralities that can be calculated by R are seen. The code for this is presented in Box 1.

Box 1 Codes for All Centralities in R

```
install.packages("CINNA")
library(CINNA)
X <- calculate_centralities (g_DATA, except = NULL, include = NULL, weights =
NULL)
pca_centralities(X, scale.unit = TRUE)
```

As a second choice, the igraph package is used to find the centralities one by one, as presented in Box 2. the centrality scores are not the same for these choices, but the rankings of the scores are the same.

Box 2 Centrality Codes in R Separately

```
library ('igraph')
#BETWEENNESS
betw <- betweenness(g_DATA, directed=T, weights=NA)
#WEIGHTED BETWEENNESS
weighted_betw <- betweenness (g_DATA, directed=T)
#page_rank
prank <- page_rank (g_DATA, directed=TRUE, weights = NULL)
#HUBS
hub_DATA <- hub.score (g_DATA, scale = FALSE, weights=NULL, options =
igraph.arpack.default)
#AUTHORITIES
aut_DATA <- authority.score (g_DATA, scale = FALSE, weights=NULL, options =
igraph.arpack.default)
```

As emphasized by the other studies, the results differ according to which measure is selected. As all centrality measures are defined as being 'central' differently, this is not a surprise. The most effective approach is to use the correct measure for the correct data. IO tables are of a specific structure. First, these tables are highly dense and nearly complete. This causes some measures, such as degree centrality and betweenness centrality, to be ineffective. Additionally, IO tables are weighted and directed. These features are occasionally not considered by some algorithms. Finally, and most importantly, these tables contain self-loops, which make computations difficult in network analysis. Recently, the algorithms have found ways to address self-loops so that it is possible to calculate the centralities affected by the existence of self-loops, such as the eigenvector centrality.

Although all centralities were checked for, the results of those most appropriate to the data of this study are presented here, and these choices are also supported by the literature. The results are given in Table 3. The columns of the table refer to eigenvector centrality, page rank, hub centrality, and authority centrality, respectively. For each measure, the top ten sectors are indicated. Although the rankings differ, most of the sectors are the same. Special attention must be given to the hub and authority centralities, as they specify in what manner the sectors are important. For example, both eigenvector and PageRank list the Wholesale sector as first, and hub centrality further indicates that it is the second largest hub. As such, this sector is an important supplier for the other sectors as well as the sixth largest demander. The TSC sector is also of particular importance, as it ranks in the top 5 and is also the third largest hub and authority. Previous studies have different aggregations related to this sector. Yılancı (2008) takes Transport and Communication together and identifies it as a key sector. Kula (2008) takes Land Transport and Transport via Pipelines separately and showed that they are key sectors according to both the Chenery-Watanabe and Rasmussen method. Atan (2011) concludes that Transportation, Storage, and Communication Services is one of the key sectors. Notably, the top sector results found in the analysis of this study differ from those of most studies that used traditional methods.

Table 3 Centrality Measure Ranking of the Sectors

Rank	EIGEN	PageRank	HUB	AUTH
1	Wholesale	Wholesale	Agr	Food
2	TSC	Const	Wholesale	Const
3	Agr	Food	TSC	TSC
4	Food	RealEstate	Metal	Textile
5	Const	TSC	Coke	Agr
6	Coke	Accom	OtherNonMet	Wholesale
7	RealEstate	Agr	Chem	RealEstate
8	Metal	PubAdm	PST	Accom
9	Electric	Textile	Rubber	Metal
10	Textile	Admin	Admin	Motor

Source: Author's research.

Some sectors are in the top 10 as both hub and authority. TSC has already been mentioned, and others are Agr, "Basic Metals" (Metal), and Wholesale. These sectors are both significant suppliers and demanders and are therefore key sectors. On the other hand, the sectors listed in the first two columns can be compared to the sectors in the last two columns. The Food sector is shown in the first two columns, and the fourth column indicates that this sector is important because it is a large demander. "Real Estate Activities" (RealEstate) is also listed in the first two columns, because this sector is also a large authority.

The studies using the 2002 IO table of Turkey, Kula (2008), Ayaş (2011), Han, Tosunoğlu, and Özsoy (2011), Jahangard and Keshtvarz (2012), and Topcuoğlu and Ayyıldız (2019) identify "Textiles, Textile Products, Leather and Footwear" (Textile) as a key sector. In this study, however, it is ranked as tenth and ninth in the first and the second columns, respectively. Among the studies using IO multipliers, the Wholesale sector is only mentioned by Kula (2008), while Blöchl et al. (2010) and Gallegati, Giammetti, and Russo (2019) identify Wholesale as a key sector through network analysis

The spillover effects are further analyzed to predict which sectors would be affected by an economic shock and those which will be affected by such a shock for an extended period of time. Accordingly, random walk centrality (RW) and counting betweenness (CB), as suggested by Blöchl et al. (2011), are used. For computation, the MATLAB codes provided by the authors are used.

The results are provided in Table 4. The findings of this study for the random walk centrality are like those in Blöchl et al. (2011), except their order. Wholesale is the sector that would be affected first by an economic shock, followed by Const and RealEstate. Consequently, these are the most vulnerable sectors. The Const sector, in addition to being one of the immediately effected sectors, is the main sector where the crisis will persist. Furthermore, an economic shock would have long-term effects on the Textile, "Electricity, Gas and Water supply" (Electric), and Agr sectors. Two columns have common entries: Wholesale, Const, TSC, Food, Agr, and Textile. These sectors are particularly sensitive to economic shocks and cannot recover from them quickly. As such, policy makers should examine these sectors carefully.

Table 4 Random Walk Centrality and Counting betweenness Scores

Rank	RW	CB
1	Wholesale	Const
2	Const	Textile
3	RealEstate	Electric
4	TSC	Agr
5	Food	TSC
6	Accom	Food
7	PubAdm	Health
8	Agr	Wholesale
9	Textile	Metal
10	Admin	Motor

Source: Author's research.

"Metal Production" is determined to be a key sector in almost all studies using traditional methods. However, the Metal sector is not listed as a key sector in studies applying network analysis for Turkey. The results of this study identify the "Basic Metals" sector as the fourth largest hub and the ninth largest authority. Additionally, this sector is one of the first ten sectors listed by the counting betweenness measure. The Health and Social Work sector is mentioned as a key sector only by Jahangard and Keshtvarz (2012). The findings of this study indicate that the "Human Health and Social Work Activities" and "Electricity, Gas and Water Supply" sectors are among those which would be affected by a shock for an extended period of time. The latter sector is suggested as key sector by Blöchl et al. (2011), Jahangard and Keshtvarz (2012), and Topcuoğlu and Ayyıldız (2019). When the key sectors and those sensitive to shocks are compared, they generally coincide, as suggested by Alatriste-Contreras (2015). This makes key sector analysis more valuable.

5. Discussion

Applying a single method to identify key sectors may lead to limited information. Additionally, key sector analysis must be analyzed together with the general economic structure in order to acquire a clear vision of the strategic sectors which should be given special attention by authorities. Based on the results of this study and present eco-political conjuncture, special emphasis should be placed on three sectors: TSC, Wholesale, and Construction.

TSC

Increase in global trade volume has boosted the importance of the transportation sector. Improving the logistics gain importance in terms of stimulating economic development (International Transport Forum 2015). To enhance national competitiveness, it is necessary to have a strong logistic system (Jean-François Arvis et al. 2018). On the other hand, transportation is one of the most affected sectors in the case of an economic crisis (Presidency of the Republic of Turkey - Presidency of Strategy and Budget (SBB)

2021). The outbreak of the COVID-19 pandemic directly affected the supply chain and logistics. Before fully recovering from the pandemic, the world also witnessed the Russian invasion of Ukraine, which further enhanced concerns about the supply chain and transport security. Consequently, diversification in suppliers of internationally traded goods and transportation roots have gained importance.

Alternative transportation roots have been discussed by several countries prior to the recent crises. European Union's Silk Wind Initiative, United States' New Silk Road Initiative, China's One Belt One Road, Japan's C5 Plus 1, Korea's Opening Policies for Central Asia and the Eurasia Initiative, and Turkey's Silk Road Project and the Middle Corridor are projects aiming to connect the Central Asia to the Europe (Selçuk Çolakoğlu 2021). Turkey has an advantageous position in geopolitical terms. Since the Transportation, Storage, and Communication Services is both an important hub and authority in the Turkish economy, Turkey must utilize this advantage in its growth strategies.

TURKSTAT data shows that TSC has an approximately 11% share in GDP between 2010-2020. The most used indicator of the logistic trade performance is the Logistic Performance Index (LPI), which was announced by the World Bank two years in row. Data is available from 2007-2018, and Turkey's LPI scores, rankings, and changes in the LPI score are given in Table 5.

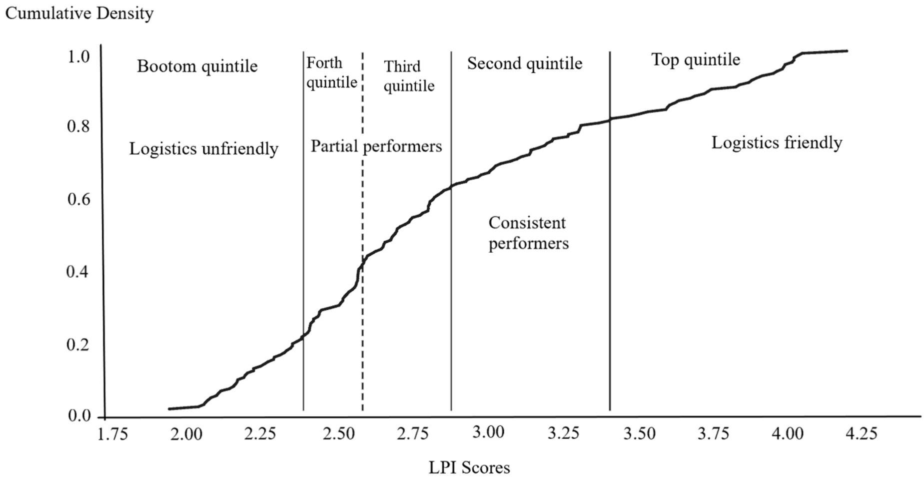
Table 5 LPI Scores of Turkey

	2007	2010	2012	2014	2016	2018
Rank	34	39	27	30	34	47
Score	3.15	3.22	3.51	3.50	3.42	3.15
Change in score		0.07	0.29	-0.01	-0.08	-0.28

Source: Author's calculations based on data from the World Bank.

Considering the overall LPI ranking of Turkey, Turkey's position continues to worsen, except in 2012. Data for the last three years indicates a significant drop in ranking. Here, it is necessary to carefully consider the notes of the World Bank concerning interpretations of the LPI data, which emphasize that the rank may be misleading and scores need to be traced. For Turkey, a decline is observed in the overall scores as well. Pursuing the analysis further, one may examine the cumulative distribution of the scores and consider the global position of Turkey.

Arvis et al. (2018) provide the necessary analysis, which can be seen in the Figure 7. Accordingly, the scores of Turkey fall into the second quintile. Countries in this category are labeled as "Consistent performers", referring to the countries which outperform others in the same income group. In fact, Table 6 illustrates that, for all years, Turkey's LPI score is higher than average for upper middle-income countries. Turkey ranks in the first four among its income group, although in 2018 Turkey held the sixth position. Prior to 2018, Turkey's score was higher than the Europe and Central Asia Region. In that year, however, Turkey experienced its largest decline in overall LPI, which placed it below the regional average.



Source: Arvis et al. (2018).

Figure 7 Cumulative Distribution of LPI, 2018

Table 6 Comparison of LPI Scores of Turkey and Country Groups

	2007	2010	2012	2014	2016	2018
Turkey	3.15	3.22	3.51	3.5	3.42	3.15
Income: Upper middle income	2.68	2.82	2.84	2.82	2.73	2.76
Region: Europe and Central Asia	2.46	2.71	2.71	2.76	3.23	3.24

Source: Author's calculations based on data from the World Bank.

The downward trend in LPI scores after 2012 should be examined through the components of LPI. There are six components of LPI defined by the World Bank: (1) the efficiency of customs and border management clearance; (2) the quality of trade- and transport-related infrastructure; (3) the ease of arranging competitively priced international shipments; (4) the competence and quality of logistics services; (5) the ability to track and trace consignments; and (6) the frequency with which shipments reach consignees within the scheduled or expected delivery time.

Scores (s) and ranks (r) for Turkey in terms of the components of LPI are given in Table 7. In terms of customs, infrastructure and quality of logistics are the main problems in the logistic sector of Turkey. These issues include excessive customs and bureaucratic procedures, lack of well-qualified personnel in logistics, and deficiency in technological infrastructure (Tevfik Yapraklı and Musa Ünalan 2017; Mert Aksungur and Mustafa Bekmezci 2020). Different document and data requests made by various agencies as well as complicated and strict customs controls result in time delays in customs (International Transport Forum 2015). To overcome these problems, Turkey increased automation in customs procedures, eased documentation requirements, and improved customs administration. Consequently, the time required and cost of preparation of goods for transportation decreased by half for the Europe and Central Asia (ECA) region. Nonetheless, the cost of imports are higher than the cost of exports.

Table 7 LPI Scores of Turkey by Components of LPI

	Customs		Infrastructure		International shipments		Logistics quality and competence		Tracking and tracing		Timeliness	
	s	r	s	r	s	r	s	r	s	r	s	r
2007	3.00	33	2.94	39	3.07	41	3.29	30	3.27	34	3.38	52
2010	2.82	46	3.08	39	3.15	44	3.23	37	3.09	56	3.94	31
2012	3.16	32	3.62	25	3.38	30	3.52	26	3.54	29	3.87	27
2014	3.23	34	3.53	27	3.18	48	3.64	22	3.77	19	3.68	41
2016	3.18	36	3.49	31	3.41	35	3.31	36	3.39	43	3.75	40
2018	2.71	58	3.21	33	3.06	53	3.05	51	3.23	42	3.63	44

Source: Author's calculations based on data from the World Bank.

Time delays also result from inadequate peak-season capacity for infrastructure and telecommunications in border crossings as well as insufficient container port capacity. Moreover, port hinterland transport is not adequate. Connections with other ports, high-quality roads, and railways are limited, which causes delays in the movement of goods (International Transport Forum 2015).

In domestic freight, the share of road transport is approximately 90%, which leads to high costs and large CO_2 emissions. In foreign trade, mode of transportation data from TURKSTAT for 2013-2022 shows that the largest share is in sea transport and ranges between 52%-60% for both imports and exports. For imports before the pandemic, in 2018, the share of sea transport was 59.15%, road transport was 16.93%, air transport was 12.44%, and rail transport was 0.56%. For exports, shares of sea, road, air, and rail transports were 61.41%, 29.48%, 7.97%, and 0.43%, respectively. The rest of the shares were considered "others", which is approximately 11% for imports because of the transport of energy via pipelines. The significant difference in the shares of various alternatives is a disadvantage for Turkey. The Republic of Turkey Ministry of Transport and Infrastructure (UAB) published its 2053 vision for transportation and logistics (T.C. Ulaştırma ve Altyapı Bakanlığı (UAB) 2022). In this plan, adjustments between the different transportation alternatives are mentioned, and creating a combination of various alternatives is emphasized. Increasing the LPI ranking of Turkey to first 10 is targeted, and The Middle Corridor is also mentioned. Turkey is intended to be the logistic base in the Middle Corridor.

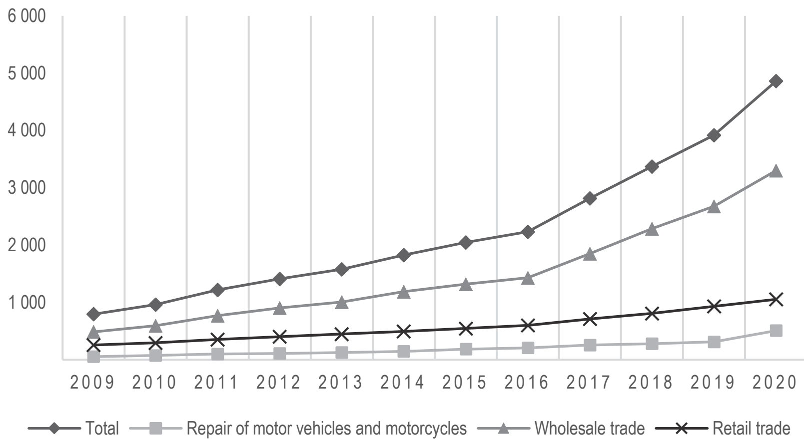
The Middle Corridor begins in Turkey, passes through Georgia and Azerbaijan, crosses the Caspian Sea, and reaches China. Consequently, the Middle Corridor serves as an intermodal transportation root. H Cork ow Cork ever, the Russian invasion of Ukraine and sanctions of the EU and US are negatively affecting the Northern Corridor, which makes the Middle Corridor a strong alternative to the Northern Corridor. As mentioned by the Republic of Turkey Ministry of Foreign Affairs (MFA), the Middle Corridor is faster and more economical than the Northern Corridor. The Middle Corridor is 2.000 km and 15 days shorter than the sea route. Furthermore, climate conditions are more favorable (Republic of Turkey - Ministry of Foreign Affairs 2022).

Turkey has already implemented large projects connecting the coasts of the Bosporus and Dardanelles. On the Bosporus, in addition to its two bridges, the Yavuz Sultan Selim Bridge has been built, and an undersea railway system and road, the "Marmaray" and the Eurasia Tunnel, have been inaugurated. On the Dardanelles, Çanakkale Bridge (Dardanelles Bridge), the bridge with the longest main span in the world, was built in, the 1915. There are also other ongoing projects including railways, motorways, and ports that will serve the Middle Corridor.

The importance of Turkey's logistic location was also highlighted by the Grain Corridor Agreement between Russia and Ukraine, which was signed in Istanbul. This agreement gave hope to the countries in Africa and the Middle East which are heavily or completely dependent on Ukraine and Russia for wheat imports.

WHOLESALE

The Wholesale sector in Turkey stands out with several indicators. The share of the Wholesale sector in GDP is approximately 12%, which is the largest share after the Manufacturing sector. While the GDP growth was 1.8% in 2020, Wholesale and Retail Trade grew by 4.4% (SBB 2021). Considering the Industry and Service sectors, the largest number of enterprises are active in the Wholesale sector. In fact, in 2020, 36.6% of the enterprises operating in Industry and Service sectors were in Wholesale. This was followed by the Transportation and Storage sector, with a share of 14.2%, and the Manufacture sector, with a share of 12.4%.



Source: TURKSTAT (2022a)[1].

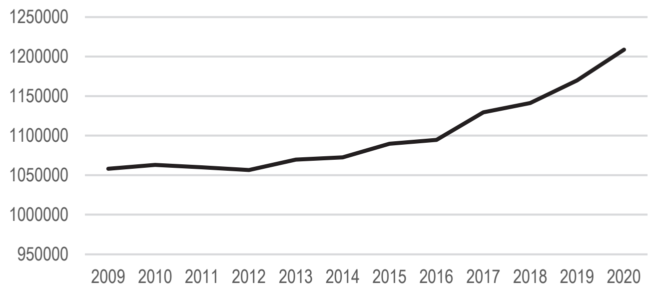
Figure 8 Turnover in Wholesale Sector, 2009-2020 (Billion TL)

Figure 8 demonstrates that turnover in the Wholesale sector has increased between 2009-2020 with a marked rise 2016. The main contribution to this increase came from the Wholesale trade. Additionally, the number of enterprises increased throughout the same period (Figure 9).

The Wholesale sector has contributed greatly to employment. In 2021, 14.1% of the workforce was employed in the Wholesale sector, making the sector the second

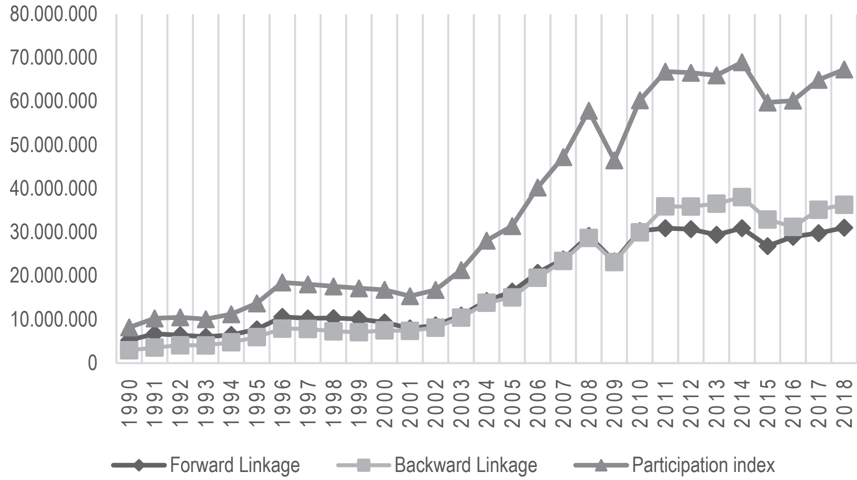
[1] **TURKSTAT.** 2022a. Annual Industry and Service Statistics. https://data.tuik.gov.tr/Bulten/Index?p=45836&dil=2 (eccessed January 12, 2022).

largest field after Manufacturing. One fourth of the employees in the Service sector are employed in the Wholesale sector.



Source: TURKSTAT (2022a).

Figure 9 Number of Enterprises in Wholesale Sector, 2009-2020



Source: OECD (2022)[2].

Figure 10 Turkey's Backward, Forward Linkages and GVC Scores (1990-2018)

World Bank issued a report, "Leveraging Global Value Chains for Growth in Turkey", in 2022, which analyses the participation of Turkey in the global value Chain (GVC) to enhance its growth. It indicates that GVC participation of Turkey is increasing but still below its potential. Related data can be found in the OECD Trade in Value-Added (TIVA) database. This database provides the value-added components for the gross exports of selected countries Cork together with the GVC index. Particularly, the backward and forward Linkages are important. Backward linkage measures how m

[2] **Organisation for Economic Co-operation and Development (OECD).** 2022. Trade in Value-Added (TIVA). https://www.oecd.org/sti/ind/measuring-trade-in-value-added.htm (accessed January 12, 2022).

Cork any goods and services from other countries are included in a country's exports. Forward linkage Cork measures the share of a country's exports used in another country's following exports. Turkey's backward and forward linkages as well as GVC scores are presented in Figure 10, and all scores are experiencing an increasing trend. After 2010, the backward linkage exceeds the forward linkage values. In the World Bank World Development Report 2020 (World Bank 2020), Turkey is said to move from limited manufacturing GVCs to advanced manufacturing. Countries in this stage are defined as those with a high share of manufacturing and business services as well as high backward integration. Compared with the limited manufacturing group, these countries are said to have improved political stability, much higher foreign direct investment flows, lower average tariffs, more efficient customs, and higher LPI scores.

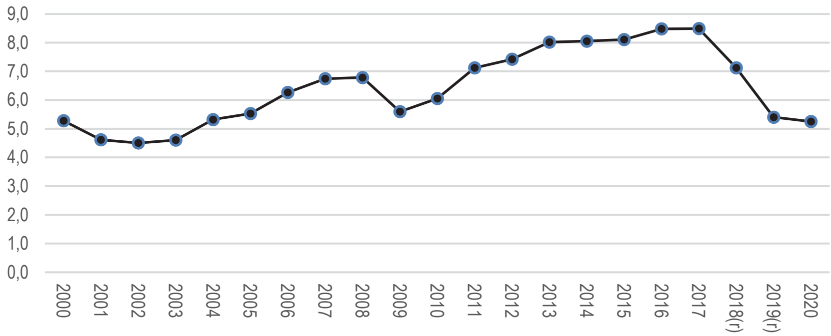
In 2022 report the World Bank for Turkey (World Bank 2022), the export potential of Turkey is emphasized. In fact, it is estimated that Turkey's exports are around 50% below their export potential. Therefore, it is suggested Turkey improve its global integration to foreign markets and especially increase trade with its major partners. Further policy recommendations are also given in the report, and these may be Cork referenced for further studies.

OECD TIVA data indicates that, in 2018, the Wholesale sector was the greatest source of domestic value-added content of exports. The percentage share in total exports of domestic inputs sent to third economies was 15.5% for the Wholesale sector, 11.7% for the Basic Metal sector, and 6.5% for the Land Transport sector. Wholesale and Land Transport sectors are the top two service sectors contributing to gross exports as well as the top service industries contributing to exports of manufactured goods.

CONSTRUCTION

In Turkey, the Construction sector is connected to about 200 other sectors as an importer from those sectors (İbrahim Can Bayrak and Osman Murat Telatar 2021). This was reflected in the findings of this study, which indicate that the Construction sector is the largest hub. Additionally, the sector has one of the top backward linkage scores. Changes in the activities of the sector have a significant impact on the rest of the domestic economy. Therefore, there is a tendency to take the Construction sector as a leading sector. In fact, at the beginning of the 2000s, an economic growth model based on the Construction sector was implemented and yielded promising results (Mehmet Ali Polat and Eda Fendoğlu 2021). However, in this analysis, the Construction sector is found to be the second most affected sector in terms of economic shock as well as the sector that will be affected the for the longest period. Thus, the vulnerability of this sector must be considered carefully. There is a general tendency of the Turkish government to follow closely developments in the Construction sector and intervene to provide it with support. One of these supports is the Housing Development Administration of the Republic of Turkey (TOKİ), which was established to meet housing requirements, specifically those of low and middle-income families. Furthermore, TOKİ carry out reconstructions, build facilities, and construct houses in the case of natural disasters. In addition to the activities of TOKİ, the government also provides financial support for the sector through favorable credit options.

The share of the Construction sector in GDP in current prices experienced an increasing trend up to 2018, except for 2009 (Figure 11). In 2018, the sector share decreased from 8.5 to 7.1 and further decreased to 5.4 and 5.3 in 2019 and 2020, respectively.



Source: TURKSTAT (2022b)[3].

Figure 11 Share of the Construction Sector in GDP (2000-2020)

The contribution of the Construction sector to the GDP growth becomes a negative value after the second quarter of 2018. There was a contraction in the Construction sector in the first two quarters of 2020, and in the third quarter some supportive policies implemented in the sector led to 4.7% growth. However, with the second wave of the pandemic, this was reversed in the fourth quarter, which saw a 12.5% decline in the growth rate of the sector (TurkRating 2021). Although in the first two quarters of 2021 the Construction sector grew by 3.1% and 3.3%, in the third quarter downsizing of 6.7% was observed (Turkey IMSAD - Association of Construction Material Producers 2021).

Table 8 Growth of GDP and Construction Sector

Years	Construction	GDP
2017	9.0	7.5
2018	-1.9	3.0
2019	-8.6	0.9
2020	-5.5	1.8
2021_Q1	3.1	7.4
2021_Q2	3.3	22.0
2021_Q3	-6.7	7.4
2021_Q4	-0.9	9.1
2022_Q1	-7.2	7.3

Source: Author's calculations based on data from TURKSTAT.

[3] **TURKSTAT.** 2022b. Annual Gross Domestic Product. https://data.tuik.gov.tr/Bulten/Index?p=Annual-Gross-Domestic-Product-2022-49742&dil=2 (eccessed January 12, 2022).

Compared to the GDP growth, the Construction sector's growth rate remained below the GDP growth rate after 2017 (Table 8). In the last three quantiles represented in the Table 7, contraction is evident in the sector despite significant growth rates in GDP.

Table 9 Employment in Construction Sector

Years		Thousand person		(%)
		Total	Construction	Construction
2009		82,136	5,198	6.3
2010		87,241	5,693	6.5
2011		92,663	6,687	7.2
2012		94,952	6,856	7.2
2013		97,943	7,154	7.3
2014		103,097	7,654	7.4
2015		106,005	7,662	7.2
2016		108,504	7,966	7.3
2017		112,299	8,431	7.5
2018		114,764	8,050	7.0
2019		112,169	6,265	5.6
2020		106,739	6,136	5.7
2021		115,306	7,080	6.1
2022	Quarter I	29,418	1,622	5.5
	Quarter II	30,765	1,833	6.0

Source: TURKSTAT (2022c)[4].

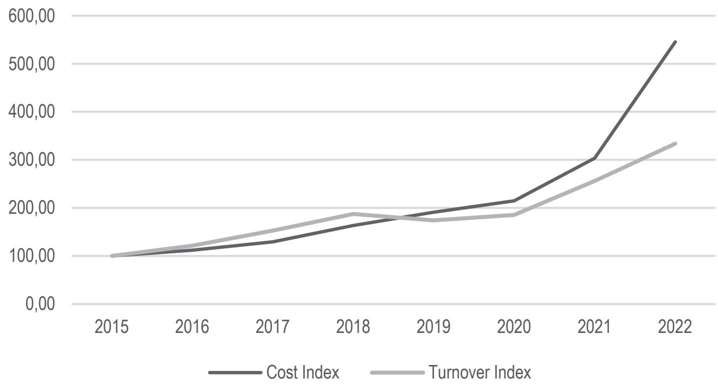
The contribution of the Construction sector to employment increased over time until 2018. In 2019, there was a sharp decline in the percentage of employment for the sector in total employment. Total employment in the first two quarters of 2022 increased by 7.4% and 8.1% compared to the first two quarters of 2021. However, in the Construction sector, a decrease of approximately 0.4% in the first quarter of 2022 and an increase of approximately 3.3% in the second quarter of 2022 were observed (Table 9).

Costs in the Construction sector also increased significantly. Figure 12 provides the cost index in the Construction sector based on 2015 prices as well as the turnover index. After 2018, turnovers fell below costs; although there was an increase in the turnovers, costs increased more rapidly. Increases in material and labor costs are presented in the Figure 12, together with increasing financial costs, surges in the demand, and increases in the exchange rates, which are significant challenges faced by the sector.

An important problem for the Turkish economy is the import dependency of exports. Turkey recently began implementing export-oriented policies. However, this has been seriously challenged by the economists, mostly due to the dependency of exports on the imported intermediates. Although these debates have been on the agenda recently, such arguments are not new for Turkey. In fact, import dependency

[4] **TURKSTAT.** 2022c. Labor Force Statistics. https://data.tuik.gov.tr/Bulten/Index?p=Labour-Force-Statistics-January-2022-45644&dil=2 (accessed January 12, 2022).

has been examined in many studies (Ş. Mustafa Ersungur and Alaattin Kızıltan 2007; Selim İnançlı and Konak 2011; Mehmet Şişman and Erdem Bağcı 2015; Yasemin Erduman, Okan Eren, and Selçuk Gül 2020; Emre Ünal 2020).



Source: TURKSTAT (2022d)[5].

Figure 12 Construction Cost and Turnover Indices, 2015-2022 (2015=100)

The measure used in studies using IO data for import dependency is generally the Import Requirement Ratio (IRR). IRR is obtained from the import inverse matrix. First, the technical coefficient matrix A will be disaggregated into two parts, domestic A_d and imported A_m matrices:

$$A = A_d + A_m. \tag{25}$$

Subsequently, the import inverse matrix will be obtained by:

$$R = A_m \, (I - A_d)^{-1}. \tag{26}$$

IRR for each sector i is the corresponding column sum of the matrix R. This sum gives the imported intermediate goods used to produce one unit of production in sector i. As such, the industrial dependency of the sector i on imported intermediate goods is obtained (Ünal 2020). The studies for Turkey generally indicate that the sectors with high IRR scores are those that are capital-intensive and high technology using sectors. Mostly, Coke and Refined Petroleum Products, Motor Vehicles, and Basic Metals sectors have the largest IRR scores. The row sums of the matrix R give the forward linkages, which indicate the amount of the goods of sector i required to be imported to meet an increase in the final demand.

Duman and Ertan-Özgüzer (2015) take the analysis further and suggest that it is not enough to examine only IRR figures. Instead, one should consider the sector shares in the value added (VA) and weight the IRRs accordingly. The authors simply multiply the IRR scores with the VA share of the corresponding sector. In their study, they attempt to locate an explanation for the surge in the imports by calculating the

[5] **TURKSTAT.** 2022d. Construction Cost Index, June 2022. https://data.tuik.gov.tr/Bulten/Index?p=45627&dil=2 (accessed January 2022d).

total direct and indirect import requirements of each sector using import requirement ratio (IRR). They concluded that the “Wholesale and Retail Trade; Repair of Motor Vehicles and Household Goods” sector had the highest weighted IRR score, so this sector’s contribution truly reflects the surging import values.

Table 10 Weighted Backward Import Linkages

No	Sector	Forward-VA
22	Const	0.02772
21	Electric	0.02050
24	TSC	0.01791
9	Coke	0.01773
5	Food	0.01406
6	Textile	0.01309
1	Agr	0.01233
13	Metal	0.01197
18	Motor	0.00959
16	Electr	0.00783
11	Rubber	0.00652
23	Wholesale	0.00617

Source: Author’s research.

This study applied the same idea and calculated the weighted IRR values (IRR-VA). The results indicate that the Construction sector has the highest IRR-VA value (Table 10). Consequently, together with its VA contribution, the Construction sector has a high dependency on imported intermediates. Considering the high RW and CB scores, it is possible to conclude that the sector requires the careful attention of policy makers.

The sectors with the highest 12 forward-import linkages are presented in Table 11. The top score is given to the Wholesale sector. As such, in order to meet the import requirement resulting from an increase in the final total demand, it is necessary to import mostly goods produced by the Wholesale sector, followed by the Metal sector and TSC sector.

Table 11 Weighted Forward Import Linkages

No	Sector	Forward-VA
23	Wholesale	0.04436
13	Metal	0.03224
24	TSC	0.03017
9	Coke	0.01861
1	Agr	0.00919
6	Textile	0.00849
18	Motor	0.00514
5	Food	0.00471
2	MinEn	0.00457
10	Chem	0.00418
16	Electr	0.00382
17	Machine	0.00358

Source: Author’s research.

The weighted IRR analysis further supports the importance of the sectors that this study has defined as key sectors.

6. Conclusion

Studies on determining key sectors have generally concentrated on traditional IO analysis, which is based on the multipliers calculated from these tables. Although these methods are still worth considering, such analyses should further attempt to capture the nonlinearities and complexities in economic systems. This step is possible through applying more recent analyzing techniques and combining different approaches for a more comprehensive analysis.

In this study, the key sectors for Turkey were determined by first applying six different centrality measures. The results revealed that the key sectors are "Wholesale and Retail Trade; Repair of Motor Vehicles", "Transport, Storage and Communications", "Construction", "Agriculture, Hunting and Forestry", "Real Estate Activities", "Food Products, Beverages and Tobacco", "Textiles, Textile Products, Leather and Footwear", and "Basic Metals". Further, the effects of economic shocks were considered, and it was concluded that the key sectors are those that will be affected most. Additionally, the effects of a shock will last longer for these sectors.

Combining these results with the economic structure of Turkey and its import dependency problem, this study focused on three main sectors: "Wholesale and Retail Trade; Repair of Motor Vehicles", "Transport, Storage and Communications", and "Construction". These sectors warrant careful consideration by policy makers.

It is crucial to determine which sectors have strong relationships with other sectors, as these sectors will not only trigger economic growth but are also those most sensitive to economic shocks.

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Appendix

Table A1 Key Sectors Determined by Previous Studies for Turkey

Author	Data	Results
Günlük-Şenesen (2005)	1998	Backward: Food Sector; Forestry and Logging
		Forward: sectors producing intermediates, notably petroleum products
Karaca (2007)	1998	Iron steel industry; Manufacture of chemicals and chemical products; Metal industry excluding the iron and steel industry; Cleaning, cosmetics, chemicals that are not included elsewhere; Manufacturing of fiber; Manufacturing of other metal products, services of metal work; wood and hardwood industry; Vegetable and animal oils and fats; Manufacture of special purpose machines; slaughterhouse and meat processing and storage; Manufacture of tanning of leather suitcase handbag etc.; manufacture of plastic products
Yılancı (2008)	1998	Bulmer-Thomas: Agriculture; Trade; Transport-Communication and personal services
Kula (2008)	2002	Agriculture, hunting and related service activities; Manufacture of food products and beverages; Textile; Manufacture of chemicals and chemical products; manufacture of other non-metallic mineral products; Metal Industry; Electricity, gas, steam and air conditioning supply; Wholesale trade, except of motor vehicles and motorcycles; Land transport and transport via pipelines; Supporting and auxiliary transport activities; Real estate activities
Han, Tosunoğlu, and Özsoy (2011)	2002	Chenery-Watanabe Method, Manufacture of food products and beverages; Manufacture of textiles; Metal industry; Revaluation industry
		Rasmussen Method: Manufacture of food products and beverages
Göktolga and Akgül (2011)	1998 and 2002	1998: Metal industry, Manufacture of clothing
		2002: Utilities, services and other activities sector; Manufacture wearing apparel
Ayaş (2011)	2002	Food-beverage; textile; garment; chemical products and machinery products
Atan (2011)	2002	Total backward and forward; manufacturing industry; electricity, gas, steam and air conditioning supply; mining and quarrying; activities of financial intermediary; other social, communal and personal service activities; and public administration and defense
		Domestic total: manufacturing industry; electricity, gas, steam and air conditioning supply; transportation, storage and communication services industry
		Import total: manufacturing industry; transportation, storage and communication services
Başkol (2012)	2002	Manufacture of paper and paper products; chemical, plastic and rubber, glass, stone and soil products sector; metal products sector
Alp, Kök, and Başkol (2017)	2002 and 2012	2002: manufacture of products of wood, cork, straw or plaiting materials, including basic shapes as well as assembled products; paper and paper products; software and other prerecorded compact disc, tape, and record reproducing; manufacturing of coke, refined petroleum products and nuclear fuel; manufacture of rubber and plastic products; manufacture of other non-metallic mineral products; manufacture of chemicals and chemical products; manufacture of basic metals and fabricated metal products, except machinery and equipment; revaluation industry; research and development services
		2012: manufacture of products of wood, cork, straw or plaiting materials, including basic shapes as well as assembled products; paper and paper products; software and other prerecorded compact disc, tape, and record reproducing; manufacturing of coke, refined petroleum products and nuclear fuel; manufacture of rubber and plastic products; manufacture of other non-metallic mineral products; basic metals; repair of fabricated metal products, machinery and equipment; financial service activities, except insurance and pension funding; advertising and market research; other professional, scientific and technical activities n.e.c; veterinary activities
Akbulut (2019)	2015	Demand-driven: electrical equipment; metal production; coal and petroleum products; other manufactured goods
		Induced effects: coal and petroleum products; electrical equipment; other manufactured goods
Pehlivanoğlu and İnce (2020)	1970-2012	Intermediate good industries
Topcuoğlu and Ayyıldız (2019)	2014	Product of basic metals; electric, gas, steam and climatization; textiles, textile products, leather and footwear

Kul-Gelal (2021)	2012	Supply-driven: wood and of products of wood and cork, except furniture; articles of straw and plaiting materials; paper and paper products; printing and recording services; rubber and plastic products; other nonmetallic mineral products; basic metals; water transport services; postal and courier services; publishing services; insurance, reinsurance and pension funding services, except compulsory social security; advertising and market research services; other professional, scientific and technical services and veterinary services
		Demand-driven: paper and paper products; printing and recording services; rubber and plastic products; other non – metallic mineral products; basic metals; advertising and market research services

Source: Arranged by author from the related studies.

Table A2 Sectors and Abbreviations

No	Sectors	Abbreviations
1	Agriculture, hunting and forestry	Agr
2	Mining and quarrying, energy producing products	MinEn
3	Mining and quarrying, non-energy producing products	MinNoE
4	Mining support service activities	MinSer
5	Food products, beverages and tobacco	Food
6	Textiles, textile products, leather and footwear	Textile
7	Wood and products of wood and cork	Wood
8	Paper products and printing	Paper
9	Coke and refined petroleum products	Coke
10	Chemical and chemical products	Chem
11	Rubber and plastics products	Rubber
12	Other non-metallic mineral products	OtherNonMet
13	Basic metals	Metal
14	Fabricated metal products	FabrMetal
15	Computer, electronic and optical equipment	Comp
16	Electrical equipment	Electr
17	Machinery and equipment, nec	Machine
18	Motor vehicles, trailers and semi-trailers	Motor
19	Other transport equipment	OtherTransp
20	Manufacturing nec; repair and installation of machinery and equipment	Repair
21	Electricity, gas and water supply	Electric
22	Construction	Const
23	Wholesale and retail trade; repair of motor vehicles	Wholesale
24	Transport, storage and communications	TSC
25	Accommodation and food service activities	Accom
26	Publishing, audiovisual and broadcasting activities	Publish
27	Telecommunications	Commun
28	IT and other information services	IT
29	Financial and insurance activities	Finance
30	Real estate activities	RealEstate
31	Professional, scientific and technical activities	PST
32	Administrative and support services	Admin
33	Public administration and defense; compulsory social security	PubAdm
34	Education	Educ
35	Human health and social work activities	Health
36	Other service activities	Other

Source: Author's choices.