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Network Simulation on the Evaluation of Urbanization in Turkey against the COVID-19 Pandemic

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The COVID-19 pandemic, which began as an international health crisis, has quickly become an economic crisis on both national and global scale. As economies are linked through global value chains, this crisis has significantly affected the global economy. The strict measures to prevent the rapid spread of the virus negatively affected the supply and demand relations. In this study, the authors examine the inter-provincial supply–demand relations in Turkey via a complex network analysis. The analysis has the following two stages: examination of topological properties and simulation estimates. The topological analysis reveals the complexity and core–periphery structure of the inter-provincial trade network. Istanbul comes to the forefront as the strongest node in the network in terms of both supply and demand. Simulation results reveal that such economic dependence on Istanbul alone makes the inter-provincial trade system more vulnerable against supply or demand shock.

Keywords: COVID-19; inter-provincial trade; supply shock; demand shock; complex network analysis.

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1. Introduction

Daily economic statistics continue to reveal the destructive effects of COVID-19 pandemic, which has caused a significant contraction in global and national economic activities since

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the end of 2019. It is not yet possible to make an assessment of the full impact of the pandemic on macro variables since its global economic impact has not been fully reflected in the current statistics. Nevertheless, a statistical prediction can be made based on the available data about the possible economic consequences of the restrictions and measures taken by the authorities to limit the spread of the pandemic. Currently, there are studies that examine the national economic effects of the pandemic, so are an increasing number of studies that examine the global effects of the health crisis through understanding the importance of the global value chain has. The common starting point for both global and national studies is economic "shocks".

The pandemic and the response to it revealed the economic vulnerability of countries to economic disruption caused by this type of health crisis. This vulnerability underlines the importance of examining the economic effects of the pandemic on a national scale. The effects of supply/demand shocks caused by COVID-19 and the determination of proper policy implementations have recently become a major field of study in Turkey. One of these studies is by Voyvoda and Yeldan (2020), in which the effects of the pandemic on some economic indicators are analyzed via a macroeconomic general equilibrium model and proper policies are then determined. Another important study is Akçiğit and Akgündüz (2020), in which the spread of the economic shock caused by COVID-19 is analyzed with respect to credit card spending, provincial GDP, and inter-provincial trade data.

In this study, the effects of economic shocks in the inter-provincial trade structure, which also represents the supply–demand dynamic, are examined by using inter-provincial trade data via a complex network methodology. In contrast to the research of Akçiğit and Akgündüz (2020), this study discusses the economic vulnerability during the COVID-19 crisis in terms of urbanization. The process behind the evaluation of economic vulnerability with regard to urbanization can be summarized as follows: Unbalanced urbanization leads to excessive demand for housing, which in turn increases the rent in the short run. The increase in rent deepens an already lopsided distribution of income by disrupting the relative price structure. Another issue caused by unbalanced urbanization is that the capital turns towards the housing sector with high returns in the short term, and the capital moves away from productive areas that will increase both competitiveness and foreign currency input in the long term. This causes the current account deficit of the country to increase. When the capital turns to areas where the rent is high in the short term, it moves away from the sectors that increase production and employment in the long term, thus creating a more fragile economic structure. This is a critical part of the economic realities that relate to the urbanization process in Turkey. Within this fragile structure, what will be the possible consequences of a supply/demand shock stemming from COVID-19 pandemic specifically in terms of inter-provincial trade?

In working toward an answer to this question, first a theoretical framework on supply/demand shocks within the scope of COVID-19 pandemic is detailed. Then, the studies in the current literature and their findings are summarized. After economic indicators related to the Turkish economy are presented on the provincial level, the data and methodology used in the study are explained. Finally, the findings are evaluated within the scope of the relationship between economic fragility and urbanization.

2. Literature Review on the Economic Effects of COVID-19

The literature on the economic effects of the COVID-19 pandemic is fairly recent and is developing quite rapidly. Bernstein *et al.* (2020) classified these studies into two distinct categories. According to the assessment, the studies in the first category use the Susceptible–Infected–Recovered (SIR) epidemiology method and examine the spread of the disease. The studies in the second category use New Keynesian and/or multi-sectoral models to examine the economic effects of the pandemic and the impact of different policies to be implemented. As a relevant part of this study, the findings of the studies in the second category are mentioned and assessed in this section.

Of the findings, Fornaro and Wolf (2020) used the New Keynesian model to outline a sobering and perhaps pessimistic scenario where the contraction in supply, namely the negative supply shock, would be rigid and permanent. In light of this scenario, they concluded that an intense fiscal policy would be needed to get the global economy out of stagnation. Das (2020) did not use an explicit model in his evaluation of the Indian economy and he emphasized the trade-off between economy and health. He observed how the policies of economic closure prevent the spread of the pandemic, while at the same time, it causes supply and demand shocks. Thus, while these policies reduce the welfare of the people economically, on the other hand, they increase their welfare by preventing a more serious health crisis. The net change in welfare depends on the magnitude of the economic difficulties faced by households and businesses. In the end, Das pointed out that in countries like India, where the vast majority of the workforce works informally and consists of day laborers, the economic challenge will be considerably higher than those in the OECD countries. By using the nonlinear aggregate supply/aggregate demand model, Baqaee and Farhi (2020) revealed that Keynesian output was hump-shaped whereas Keynesian unemployment increased in response to economic shocks. In other words, the difficulties related to unemployment were higher than those related to output. The authors found that a negative supply shock is inevitably stagflationary, whereas negative aggregate demand shocks are deflationary and have more economic effects than a negative supply shock. Guerrieri *et al.* (2020), as a result of their studies which examined supply shocks within the framework of the Keynesian model, found that demand overreacted to these kinds of supply shocks and caused a demand-deficient recession. After surveying the implementation of various policies and their effectiveness, the authors found that various fiscal policies are ineffective, whereas an optimal policy to combat the pandemic is a combination of expansionary monetary policy and broad social security measures.

Economic studies on Turkey are also continuously increasing. For instance, in a study examining the effects of demand shock on a provincial scale, Akçiğit and Akgündüz (2020) analyzed credit card spending data and revealed that there was a 30% decrease in aggregate demand in a month during the pandemic. They showed the effects of demand shocks and how they spread among the provinces. They also described how a three-month drop in demand resulted in a 7% drop in sales of regional businesses. The authors, who also discussed the impact of the overseas demand shock, analyzed the geographical impact of the contraction in exports, and estimated that a three-month contraction would decrease firm sales by 4.2% (Akçiğit and Akgündüz, 2020). Likewise, Voyvoda and Yeldan (2020) examined the probable costs of the COVID-19 pandemic for the Turkish economy within the scope of a general equilibrium model. The findings of their study revealed that the pandemic would cause 26.7% loss in GDP and 22.8% loss in employment. Furthermore, this sort of decline in employment is predicted to cause a 46% decrease in household disposable income. As a result of the study, the authors propose a policy that priority should be given to increasing household income, which is implemented in the form of direct income support from the public sector. The main elements of this policy proposal support the regular income transfer which corresponds to approximately half of the formal average wages of wage earners. They also propose support for small- and medium-sized companies, self-employed people, and increasing public consumption expenditures by 20%.

3. Theoretical Framework: Supply and Demand Shocks within the Scope of the COVID-19 Pandemic

Since the emergence of macroeconomics after the Great Depression of 1929, both theoretical and empirical studies on the impact of shocks in the economy and the policies to be implemented have taken an important place in the economic literature. The current pandemic has also forced economists to think intensively about economic shocks and their effects. This type of research is even more crucial in the current global system, since the shock experienced in one country is not merely limited to that country, but it rapidly spreads its effects to other countries. However, in the literature, researchers have different opinions regarding the nature of the shock experienced during the COVID-19 crisis. After re-interpreting Say's law from "supply creates its own demand", to "supply creates its own excess demand", Guerrieri *et al.* (2020) stated that negative supply shock will trigger a contraction in demand and this contraction will cause a shrinkage in production and employment more than the shock itself. They handled and analyzed the pandemic process in light of this type of shock, which they call the Keynesian supply shock. In his study on pandemics and macroeconomic uncertainty in India, Das (2020) stated that the crisis caused by the pandemic was different from the crisis in 1929. He described that during the Great Depression, there was a problem from the demand-side and the Keynesian multiplier was effective during that period; however the current crisis is different from the Great Depression since it involves both supply-side and demand-side shocks. Baqaee and Farhi (2020) defined the macroeconomic shock caused by the pandemic as extraordinary. Accordingly, the shock experienced cannot be categorized as merely a supply or demand shock and does not affect every part of the economy equally. According to the authors, the shock experienced with COVID-19 is a combination of negative supply shocks and negative demand shocks. This type of pandemic causes a drop in existing labor endowment due to government-driven economic closure, deaths, or reduced desire to work.

Furthermore, productivity may decrease due to the change of work patterns and management styles. A pandemic can also change the composition of what is ultimately demanded in the market. While household spending shifts from travel and entertainment items to necessity and health spending, there may also be changes in the marginal propensity to consume. Fornaro and Wolf (2020) building on the idea that the virus creates a global negative supply shock, have studied whether the aggregate demand will be affected and what would be the extent of the potential effects. When these descriptions about economic shocks are compared, it would seem quite unlikely to reach a common consensus for defining COVID-19 economic shocks. While some authors describe this type of shock as a supply shock, others seem to define it as a combination of supply and demand shocks. The main reasons for the contraction caused by these shocks are as follows (Caraccialo *et al.*, 2020): (i) direct losses in labor supply due to death or infection, (ii) loss of workforce due to government interventions such as quarantine and social distance, (iii) decreases in propensity to consume of households and in propensity to invest of firms, due to quarantine and uncertainty, (iv) distortions in global interactions in the context of the global value chain and trade, and (v) possible hysteresis effect preventing a return to the pre-crisis situation.

The relation of the issue with urbanization is important because the urbanization structure makes the economy more vulnerable against possible shocks than might be otherwise. The European Committee of the Regions has discussed how increased urbanization causes goods and services to concentrate on critical infrastructures and therefore they emphasize the need for national and regional leaders to be prepared for economic losses against natural or human disasters (European Committee of the Regions, 2020). Harris (1990) states that the largest cities in the world have become a feature of developing countries rather than developed countries. He stated that this concentration in big cities within these low-income countries causes a phenomenon of "primacy" in the geography and leads to the growth of a single city. This view is involved in the economic approaches that address the growth of cities on a macro scale. Among these approaches, according to what is called "Single Big City Theory" the hierarchical structure among cities is formed under the domination of one or two cities. The reason behind this formation is that the flow of the resources during the urbanization process converges to just a few cities. Since it has validity in many developing countries, this phenomenon is also called "Single Big City Law" (Ertürk and Sam, 2011).

As a result of the factors mentioned above, the abnormal and unbalanced development of the city network in developing countries affects urban systems and causes a phenomenon called "urban primacy". Urban primacy has some economic, social, political, and administrative consequences. The concept of urban primacy has two conflicting economic perspectives. The first one sees urban primacy as the engine/driving force of economic growth and accepts these cities as important economic centers and a focal point for social advancement. The other view sees urban primacy as a bottleneck of economic growth, and believes that overpopulation will have negative effects such as the ineffective use of space and inefficiencies related to overpopulation. Faraji *et al.* (2016) who are sympathetic to the latter view, give statistical examples of various countries explaining this phenomenon.

For example, Lima, the capital city of Peru, carries out half of the country's economic activities on its own. This city constitutes 61% of the industrial GDP, 56% of the construction sector's economic activity, and 9% of the agricultural sector. In Columbia, 29% of the country's GDP is produced in Bogota, and the per capita income in this city is 50% higher than the per capita income across the country. However, the economic indicators of these countries show that the increasing economic concentration in the cities does not parallel the economic development of the country as a whole (Faraji *et al.*, 2016). A further interpretation of the concept of primacy would even characterize massive cities as "parasitical" rather than truly "productive". In other words, they are seen as parasitical with respect to the continuous flow of external resources from the rural areas. This delays the development of other cities since these less populated or rural areas have insufficient investments to develop at a similar pace. This also causes regional deterioration in the economy and weak political integration. The growth of mega cities particularly within developing countries is the embodiment of the "urban primacy" phenomenon (Hussain and Imitiyaz, 2018).

It is noteworthy that many of the economic patterns that continue in Turkey today are carried over from the traditions of the Ottoman administration. From the perspective of the capital city Istanbul in the Ottoman Empire, the surrounding area was almost entirely viewed as a mere source of food. The efforts to construct the capital increased its attractiveness, triggered immigration and increased the rent. The increased rent deepened the efforts of the public administration to reconstruct and the process was a continuous self-reinforcing cycle. After the formation of the Turkish Republic, the thrust toward industrialization was considered from the perspective of agglomeration economies and was carried out mainly in Istanbul and Hinterland. Thus, the economic heritage of the Ottoman Empire, that is, the attraction-migration-rent mechanism, continued. Therefore, Istanbul still continues to be the city which contains the most concentrated economic activity in Turkey. Although Istanbul's share in Turkey's surface area is 0.7%,[1] the share of the city's economic activities is significantly high in comparison to other cities in Turkey. The situation is therefore worth examining.

4. The Turkish Economy and the Impacts of the COVID-19 Pandemic on It

4.1. *The Turkish economy on a provincial scale*

The urbanization process of Turkey is parallel to the development within the society. Compared to developed countries, Turkey experienced the process of capitalization quite late, particularly in terms of integration with capitalist production and trade relations. This process is often expressed as the overgrowth of a small number of urban settlements with respect to other cities, and attracting population and economic resources unevenly (Türkonfed, 2017). In this context, Çalışkan and Tezer (2018) state that when looking at the urbanization process of Turkey beyond the growth of the urban population, there are

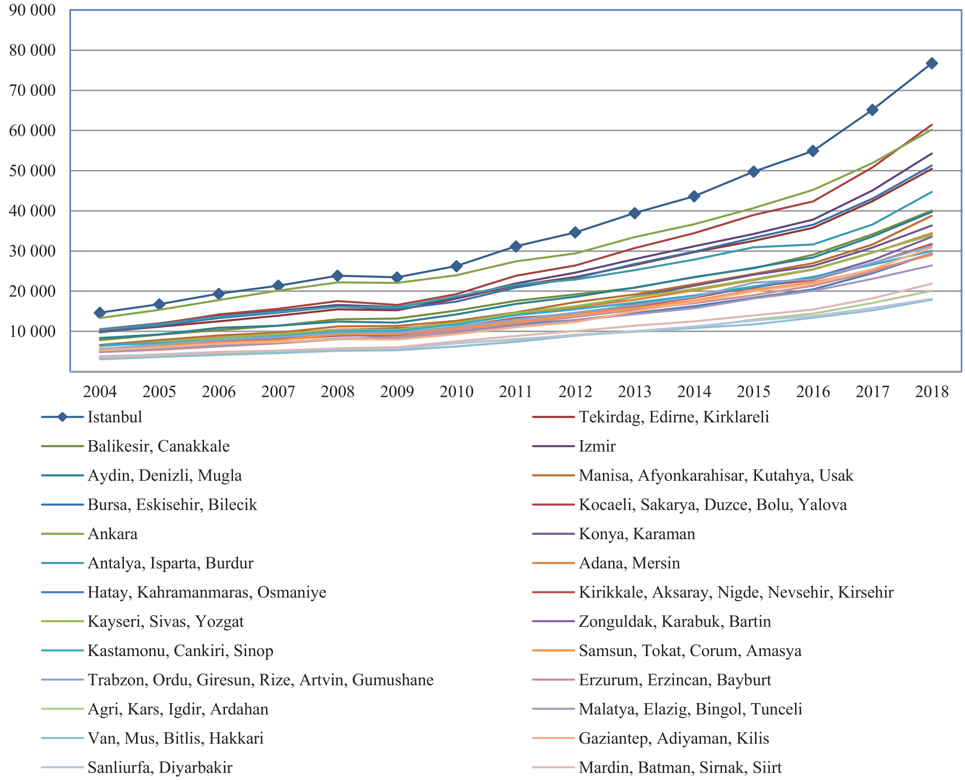
[1] https://www.harita.gov.tr/images/urun/il_ilce_alanlari.pdf (accessed May 2, 2020).

many dimensions on how to approach an active solution to urbanization. These dimensions are political–economic issues, societal–environment relations, ecological effects, rural structures, and rural–urban relations. Looking at the political–economic approach as a part of the study, urbanization in Turkey manifests itself in the way the space/environment of the metropolis is being redeveloped, in the decline of waste land in urban areas and in the spatial transformation process under neoliberal policies (Çalışkan and Tezer, 2018). In this context, the increase of capital flowing to the cities, a new stage reached in the level of urban rent, the struggle regarding the reconstruction of space and the sharing of rent created by this redevelopment are the subjects discussed specifically with respect to Istanbul (Çalışkan *et al.*, 2013).

Istanbul is a city where economic development continues to accelerate particularly in terms of its importance in global and national economic activities. For this reason, the flow of both global capital and national capital to the city continues.

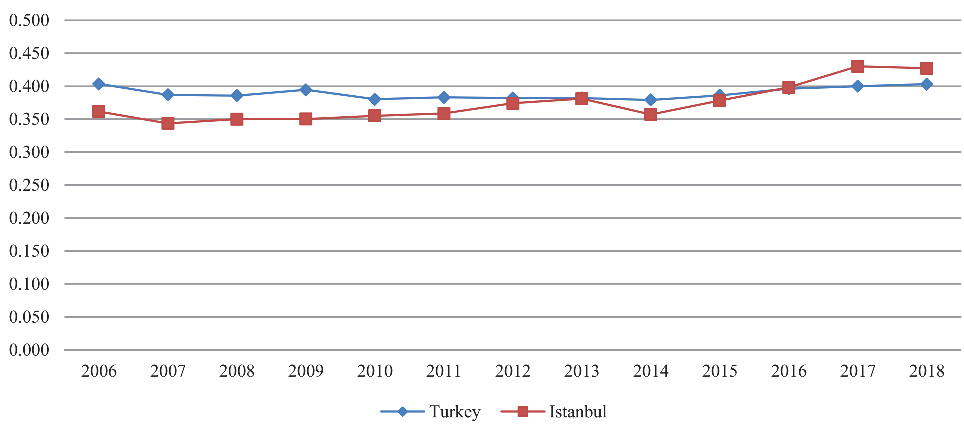
The share of Istanbul in GDP was around 31% as of 2018, meaning that approximately one third of the GDP was created in Istanbul alone. When looking at the shares by types of economic activity, it is seen that the share of agriculture, which already had a very low share, has decreased further. While Istanbul's share of industrial production in Turkey was 32.5% in 2004, this ratio dropped to 27.9% as of 2018. In contrast, it is seen that the share of Istanbul in Turkey's service sector increased steadily and reached 36% by the year 2018. The parallel between Istanbul's share in the service sector and its share in the total GDP reveals the structure of city's service sector-oriented growth (TUIK, 2020). When employment statistics are examined, the overwhelming superiority of the service sector in the city of Istanbul is also noticeable in how it performed in employment creation. The share of service sector in total employment in Istanbul is so high in comparison to the share of the other sectors. Moreover, this share of the service sector continues to gradually increase. It increased from 62.8% in 2014 to 67% in 2019 (TUIK, 2020). This table can also be evaluated as a reflection of the different dynamics encountered in developed and developing countries. Urbanization in developed countries has emerged in a way that accompanies the technological innovations that ensure continuous growth in production, trade, and services; however in developing countries, urbanization takes place at a faster pace than industrialization. In addition, the service sector develops following the development of agriculture and industry in developed countries; whereas in developing countries, production develops based on the service sector rather than the industry. The urbanization process in these developing countries does not have the structural features found in developed countries, but only follows the definition of urbanization in terms of population (Çan, 2020).

As can be seen in Fig. 1, Istanbul alone has a higher per capita income than all other regions. However, it cannot be said that this type of success was achieved with a balanced distribution of income. In Fig. 2, the distribution of the Gini coefficient for both Turkey and Istanbul is shown. Accordingly, it is observed that there is not much change in the Gini coefficient for Turkey over the period. However, the Gini coefficient for Istanbul has an upward trend over the period. Together with Fig. 1, we can infer that the increasing GDP per capita in Istanbul is accompanied by an imbalanced distribution of income.



Source: TUIK.

Fig. 1. GDP per capita (Classification of Statistical Region Units, Level 2, 2004–2018).



Source: TUIK.

Fig. 2. The Gini coefficient according to disposable household income (2006–2018).

Istanbul is also very important in terms of providing goods and services to other provinces within the country. At the same time, it creates an important demand for goods and services produced in other provinces due to its productive structure and population. In this sense, the COVID-19 pandemic reminded us how essential inter-provincial trade is in Turkey, because inter-provincial trade covers the dynamics of supply and demand for goods and services produced within the country. Exports from one province to another represent the demand for goods and services produced in that province. The pandemic transferred quickly from a global health crisis into an economic crisis that caused economic closures and the limiting or complete ceasing of economic and social activities. As the health crisis spread, it became necessary to implement strict measures in order to prevent the spread of the pandemic. In order to limit the contact between provinces in Turkey, travel was prohibited into and out of 30 major cities as well as the city of Zonguldak. Although there was an attempt to implement these regulations in a way that would not prevent the trade of goods and services between provinces, the fact that other provinces are so attached to a single province (Istanbul) illustrates the economic fragility caused by the urbanization process in Turkey. There are discussions that the concentration of resources in mega cities contains serious economic risks because increasing urbanization causes goods and services to concentrate on and be limited to critical infrastructures. For this reason, it is emphasized that national and regional leaders should be prepared for economic losses that arise from natural or human disasters (European Committee of the Regions, 2020).

In Table 1, the provinces that rank in the top 10 in terms of inter-provincial export and their shares in total inter-provincial exports in Turkey are listed. As is seen, Istanbul ranks first with a 35% share, meaning that Istanbul has the highest share in terms of providing goods and services to the other cities. Based on this table, it can be inferred that other provinces within the country are significantly dependent on Istanbul.

Table 2 illustrates the top 10 provinces and their share of trade relations with Istanbul. Accordingly, Ankara, which is also a capital city of Turkey, ranks first with the highest

Table 1. Inter-provincial trade (2017).

Provinces	Export share (%)
Istanbul	34.44
Ankara	11.54
Kocaeli	8.83
Izmir	7.26
Bursa	4.36
Gaziantep	2.08
Hatay	1.99
Adana	1.89
Konya	1.87
Antalya	1.56

Source: Ministry of Trade and Industry Entrepreneur Information System.

Table 2. Top 10 provinces' trade relations with Istanbul (%, 2017).

Export of Istanbul		Import of Istanbul	
Provinces	%	Provinces	%
Ankara	19.70	Kocaeli	21.67
Izmir	9.85	Ankara	19.35
Bursa	7.45	Izmir	11.70
Kocaeli	7.43	Bursa	7.11
Antalya	3.87	Tekirdag	2.73
Konya	3.20	Gaziantep	2.70
Gaziantep	3.12	Antalya	2.69
Adana	2.84	Adana	2.24
Mersin	2.56	Konya	2.09
Tekirdag	2.44	Denizli	1.73

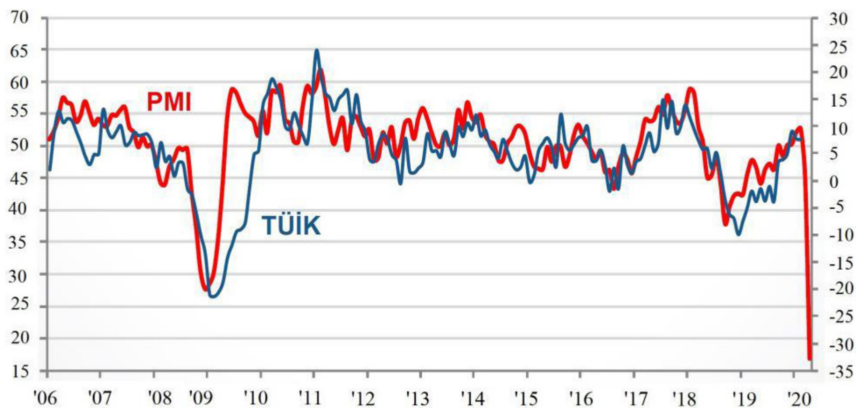
Source: Ministry of Trade and Industry Entrepreneur Information System.

share among other provinces to which Istanbul exports. When it comes to import of Istanbul from other provinces, Kocaeli ranks first with a share of 21.67%. Besides, as is seen in the table, Istanbul has trade relations not only with the provinces in the inner circle, but also with the Turkish provinces that are located geographically quite far from Istanbul. In Istanbul's commercial structure with other provinces, imports are the back link and input, while exports are the forward link and output. When evaluated in the context of input–output, it is noteworthy that the existence of a structure that is fed from other provinces and also feeds those provinces is quite deep in Istanbul. As of 2019, Istanbul contains 20.6% of total employment in Turkey (TUIK, 2020). In this context, it would not be an exaggeration to say that if there is a supply or demand shock originating from Istanbul, this shock will have a devastating effect throughout the country.

Macroeconomic indicators presented in this part of the study indicate the fragility of economic dependence on only one province, as well as how important Istanbul is for the GDP, employment, and inter-provincial trade. This vulnerability may be expressed in both the inter-provincial supply–demand balance and in inter-provincial logistics. In this study, the supply–demand relationship between provinces are taken as "fundamental". Before examining this relationship, it is necessary to analyze the effects of the pandemic on the indicators that reflect supply and demand dynamics.

4.2. *Impacts of the COVID-19 pandemic on the Turkish economy*

All countries without exception were adversely affected economically by the COVID-19 pandemic. Apart from the indirect effects experienced as a result of being linked to the global value chain, countries have also suffered significant economic contraction on the national level. In this section of the study, some indicators are presented in order to show how the Turkish economy is affected by the pandemic.

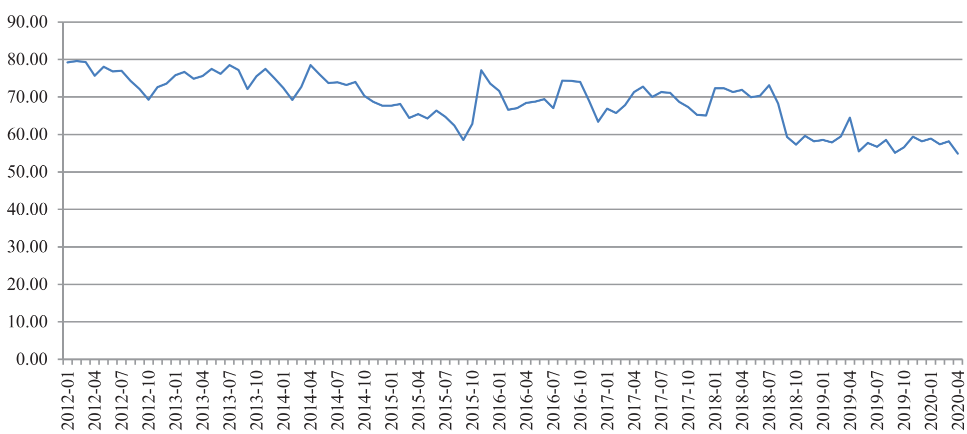


Source: Istanbul Chamber of Industry, Turkey PMI Manufacturing Industry Report.

Fig. 3. PMI production index (2006–2020).

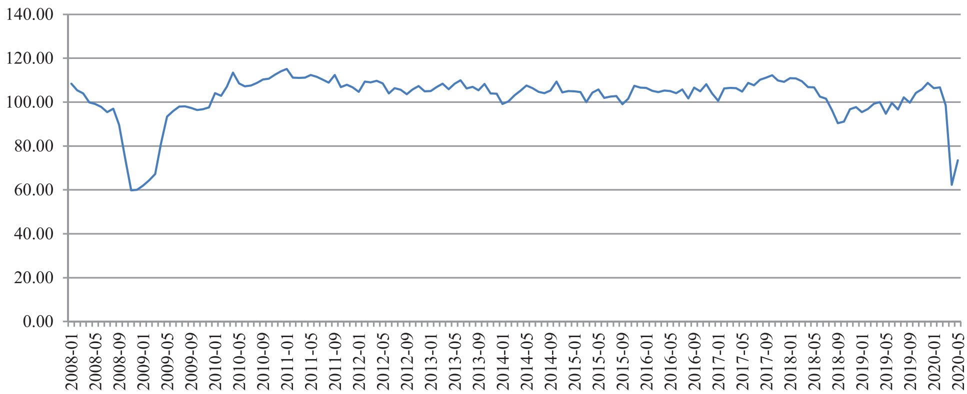
Figure 3 shows the trend of the Purchase Management Index (PMI) since 2006. PMI is a financial indicator that determines the tendency of businesses to purchase goods and services. In a questionnaire given to the purchasing managers of various businesses, questions are asked about the position they will take in terms of demand for goods and services on a monthly basis. The aim is to determine and predict the purchasing trajectory for the future. This index is considered as one of the leading indicators of a country's growth forecast (Akdağ *et al.*, 2018). When Fig. 4 is analyzed, an unprecedented decrease in the index value over the period is seen in April 2020. This decrease can be taken as a sign of a serious decrease in supply in the real sector.

Figure 4 shows the Consumer Confidence Index (CCI), which can be used to track the consumer behavior. The CCI is calculated by applying the Monthly Consumer Tendency Survey. This index measures consumers' personal financial status, current state assessments



Source: TCMB EVDS Database, https://evds2.tcmb.gov.tr/ (June 9, 2020).

Fig. 4. The CCI in Turkey (January 2012–April 2020).



Source: TCMB (2020), https://evds2.tcmb.gov.tr/index.php?/evds/serieMarket (May 27, 2020).

Fig. 5. Real sector confidence index.

regarding the general economy and their expectations for the future and future spending and savings trends (Beşel and Yardımcıoğlu, 2016). The CCI is within the range of 0–200. If the index value is over 100, it means optimism in consumer confidence, and below 100 means pessimism in consumer confidence (Arısoy, 2012). According to Fig. 4, the index has decreased to its lowest level in the last 100 months with 54.9 as of April 2020. Consumer confidence in the economy has decreased considerably and this will be reflected as a decrease in consumption for the coming periods. These figures indicate a sharp demand shock in the economy.

When the real sector confidence index in Fig. 5 is analyzed, the hardest decrease during the global crisis occurred in April, followed by some improvement in May. Although indicators such as the unemployment rate and the industrial production index are also important in reflecting the damage caused by the pandemic in the economy, post-pandemic statistics of these indicators cannot be included since they have not been published yet in the period of this study. However, it can be said that the indicators above reveal the uncertainty in the economy and the negative effects of the pandemic on supply–demand behavior of economic actors.

When all these explanations about the impacts of the pandemic on Turkish economy in terms of supply and demand, channels are integrated with the uneven distribution of inter-provincial trade (see Tables 1 and 2), it can be inferred that any probable supply/demand shock may cause huge harms on the economy due to this unbalanced urbanization. As explained in the theoretical framework section, this unbalanced urbanization causes urban primacy, and economic consequences of urban primacy makes economic relations among provinces more fragile.

5. Methodology and the Data

The first and most important step in understanding a complex system is to disaggregate the system (Reichardt, 2009). A complex network analysis is a new tool that is used to analyze a system by disaggregating it. The fact that most economic formations can be handled within the framework of the network has also increased the use of a network analysis in economics. International trade relations and financial relations between economic agents and production relations within the global value chain are the major fields in which network structures exist in economics. The representation of these formations within a network structure provides the opportunity to see the parts of the system and the relationships between those parts. Therefore, the complex network approach to economic phenomena has begun to even attract the attention of policy makers (OECD Global Science Forum, 2009).

A network can be basically defined as a set of nodes and relationships between these nodes. Network is denoted as $G = (V, E, f)$ mathematically, in which V represents the set of a finite number of nodes; E represents the set of the links between these nodes and f corresponds to a map that matches elements of E with elements of V (Estrada, 2015). A network can be classified as a binary/weighted and directional/undirectional network, depending on the characteristics of the connections in it (Chow, 2013). In the case of the weighted network in which each connection has a different weight, the definition of the network changes to $G = (V, W, f)$ in which $W = \{w_1, w_2, \ldots, w_m\}$ indicates the set of weights.

Studies using a complex network analysis are carried out with two separate methods (Bougheas and Kirman, 2014). The first is the statistical analysis showing the topological properties of the network, and the second is simulations performed over different scenarios on the network using these statistics. In the statistical analysis method, there are certain features of that network that are examined. The first of these features is connectedness. Connectedness, which is a statistically measurable property both at the node level and at the network level, is measured by the density coefficient at the network level. The formula of the density coefficient for a directed network that does not involve a self-loop and multi-link is presented in the following equation (Newman, 2010):

$$\rho = \frac{m}{n(n-1)}, \tag{5.1}$$

where m refers to number of links and n refers to the number of nodes. The density coefficient lies in the range of $0 \leq \rho \leq 1$, and indicates the ratio of the actual number of links to the possible maximum number of links. In other words, this statistic gives an idea about the ratio of links in the network. The closer to 1 the coefficient, the higher the connectedness. In the node level, connectedness is measured by degree in binary networks and by strength in weighted networks. The degree of a node corresponds to the number of links of this node. The strength of a node is the total value of the weights of links that belong to a node.

One of the other features examined in a topological analysis is the degree/strength distribution of the network. Many empirical analyses of real-world network structures reveal that a lot of nodes have a small number of links, while a small number of nodes have a great number of links. The shape of the degree/strength distribution of such a network on a logarithmic scale is a straight line. It means that the degree/strength distribution of this network follows power-law distribution. In power-law distribution which is represented as

$P(k) \propto k^{-\alpha}$, the formation of links in a network is not random. Power-law distribution is important since it indicates that network systems are directed by cores with high degree/strength. These cores determine the behavior of the whole system even if their number is quite low (Newman, 2008). In network theory, networks that follow power-law distribution are called scale-free networks because in the case of re-scaling of the distribution, the same functional form is valid in all scales. The importance of power-law in statistical physics stems from the relation with phase transition and fractals (Boccaletti *et al.*, 2006).

Power-law distribution has a higher peak point and a heavy-tail. One of the methods to understand whether a degree/strength distribution has a heavy-tail is to analyze skewness and kurtosis values. If the kurtosis value is positive, then the distribution has a heavy-tail (Decarlo, 1997). The skewness value is a measure to determine on which side of the distribution the heavy-tail is. If the skewness is positive, the heavy tail is on the right. It means that the distribution is right-skewed. In case of a negative skewness value, the distribution is left-skewed (Lovric, 2010). However, it is also necessary to test the fitness of the power-law distribution statistically. The Kolmogorov–Smirnov (KS) test is one of the test used for this. If the p-value is lower than 0.05, null hypothesis represents that the fitness of power-law is rejected (Igraph, 2020). Clauset (2011) states that the fitness of the power-law distribution is an indicator of the complexity of the formation examined. Therefore, it is an important step in a complex network analysis to analyze the fitness of the degree/strength distribution to power-law distribution.

Another important feature of a network is assortativity/disassortativity. Assortativity refers to the tendency of nodes with a high degree/strength to be related to nodes with high degree/strength. In contrast, disassortativity refers to the tendency of nodes with a high degree/strength to be related to nodes with low degree/strength and vice versa (Reichardt, 2009). A correlation coefficient is used in order to determine whether an assortative or disassortative structure exist in the network (Newman, n.d.). This coefficient lies in the range of $-1 < r < 1$. If the coefficient is positive, there is an assortative structure; if the coefficient is negative, there is a disassortative structure. There is perfect assortativity in the network if $r = 1$ and there is perfect disassortativity if $r = -1$. Determination of existence of assortativity/disassortativity in the network is one of the important stages in a network analysis. The reason is because a disassortative structure corresponds to the existence of a core–periphery structure in the network (Fuge *et al.*, n.d.; Csermely, 2013). In a core–periphery structure, nodes in the core are strongly connected with one another and also with the nodes in the periphery, while nodes in the periphery are not connected strongly with one another (Borgatti and Everett, 1999). Borgatti and Everett (1999) developed a correlation coefficient, core–periphery fit measure, which measures the similarity of a network that has ideally a core–periphery network structure and a network represented with real data. This coefficient lies between 0 and 1. The closer this correlation coefficient is to 1, the more the real data-based network structure exemplifies the core-periphery structure (Borgatti and Everett, 1999). The core–periphery structure reveals the need to identify the core and periphery nodes in question, that is, the hierarchical structure in the network. In this context, the measurement of centrality emerges as another important indicator.

In network theory, there are different centrality measurements developed to determine the importance of nodes in the network. In this study, hub and authority centrality measurements developed by Kleinberg (1999) were used. In a directed network, the nodes with many out-going links are called hubs while the nodes with many in-coming links are called authorities. However, Kleinberg (1999) states that it is not enough for a hub to only have many out-going links in order to be a "good" hub; it is also required for this hub to have out-going links to "good" authorities. Similarly, a "good" authority is an authority that has many in-coming links from "good" hubs. Hence, Kleinberg states that there is a 'mutually reinforcing relationship' between hubs and authorities (Kleinberg, 1999). Kleinberg developed an algorithm, which is called Hyper-linked Induced Topic Search Algorithm (HITs algorithm), that works with an iterative process in order to determine the hub and authority centralities of the nodes. At the end of this iterative process, all nodes in the network have a hub centrality score and an authority centrality score.

As mentioned above, simulations, apart from statistical analysis, can be performed in a network analysis for different scenarios. In this study, besides the statistical analysis, the effects of possible supply and demand shocks that may occur in the system are analyzed by simulation method. The simulation method used here is the "traditional default cascades" method. This is also called "threshold propagation". This simulation method calculates the levels of stress and loss caused by the shock that stems from the failure of a node in the network (Github). In other words, this simulation method examines the propagation process triggered by a shock in the system (Battiston *et al.*, 2016). Essentially, this simulation method simulates the propagation process of the shock caused by one of these organizations within the financial networks that represent the relationships between the institutions providing funding and using funds (Eisenberg and Noe, 2001). In this study, the simulation is applied by analogy to the goods-service trade network among provinces. Accordingly, each province in the adjacency matrix created is both a provider of goods and services, and has a demand for goods and services. In this context, the effects of supply and demand shocks caused by each province are examined in this created network. If it is examined in terms of a demand shock, a shock in one province will narrow the demand for goods-services imported from other provinces and will negatively affect the monetary flow to provinces that are goods-service providers. This may also affect the demands of these provinces from other provinces negatively, so that the contraction of demand in one province may affect the entire trade system negatively. In the supply shock, if one province cannot provide goods and services to other provinces, it means that the supply to the other provinces from the province which is exposed to shock, is disrupted and the system as a whole is generally affected. Another method of simulating shocks between financial actors is the DebtRank (DR) method. This method actually gives more effective results in seeing how the changes in the microscale affect the entire system in a network analysis. According to the DR method, balance-sheets of financial institutions are connected to each other as borrower (demand-side) and lender (supply-side) and, each institution has a buffer to absorb the losses it faces. The main determinant of the risk in the system is inter-connectedness, namely the structural feature of the network (Bardoscia *et al.*, 2015). In this study, the monetary dimension of goods and services trade between provinces is taken into consideration and shocks are analyzed with the DR algorithm based on the monetary nature of supply–demand dynamics between provinces. In this network, the counterpart of the buffer that financial institutions have in a financial network is taken as the values corresponding to the diagonal elements of the adjacency matrix. This expresses to what extent each province meets its own needs. To illustrate, in the case of a decrease in the export of goods and services from one province to another (supply shock), the province in the demand-side (importer) will be strong enough as long as it meets its own needs. The diagonal element in the adjacency matrix is used as a criterion for meeting its own needs.

In the analysis, inter-provincial trade data obtained from the Ministry of Trade and Industry Entrepreneur Information System was used. The elements of the matrix, which have a current value, were used in the analysis after deflating with the inflation rate from 2017. The R statistic package and Ucinet software were utilized in the analysis.

6. Empirical Results

6.1. *Results of the statistical analysis*

In this study, in which inter-provincial trade structure is examined via network tools, each province represents a node in the network. Exports from one province to another constitute the links on the network. In the inter-city trade matrix, although there are goods-service flows that the provinces realize for their own needs, these values, which constitute the diagonal elements of the matrix, were not taken into account in the statistical analysis in order to focus on the relations between the provinces. In this sense, there are 81 nodes and 6,293 links in the inter-provincial trade network.

According to Table 3, inter-provincial trade is reciprocal at the ratio of 0.98. The share of the actual number of links from the possible maximum number of links is 0.971. The negative assortativity correlation coefficient indicates that there is a disassortative structure in this network. As explained in the methodology section, disassortativity indicates the existence of a core–periphery structure in the network. In addition, the core–periphery fit correlation coefficient also indicates that the inter-provincial trade network corresponds to the core–periphery structure at the ratio of 0.986.

As mentioned in the methodology section, fitness to power-law distribution is an indicator of the complexity of the network. According to Table 4, positive skewness value indicates that the distribution is right-skewed and positive kurtosis value indicates that the

Table 3. Topological network statistics.

Reciprocity	0.980
Density	0.971
Clustering	0.997
Assortativity/Disassortativity	−0.070
Core–Periphery Fit Correlation Coefficient	0.986

Source: Authors' calculation.

Table 4. Fitness to power-law distribution.

Skewness	6.728
Kurtosis	52.386
α	1.733
KS test statistics	0.082
p-value	0.777

Source: Authors' calculation.

distribution has a heavy-tail. When it comes to the KS test results, we cannot reject the null hypothesis that refers to fitness to power-law distribution since the p-value is higher than 0.05. These results imply that the strength distribution in the network fits the power-law distribution, meaning that the inter-provincial trade network has a complex structure. Therefore, this result indicates the heterogeneity of the links of the nodes. The small number of nodes have high values of links, while many of the nodes have low values of links.

By evaluating the disassortativity and power-law distribution results together, we can see there is a core–periphery structure in the network and there is a small number of prevailing nodes in the network due to a high value of links. This result can be interpreted as the existence of complex behavior among the nodes. Therefore, it becomes important to determine the core nodes in the network. In this study, hub and authority centrality scores are measured.

Before explaining the results in Table 5, it is necessary to explain that hub centrality values correspond to the export impact of provinces over the network while authority centrality values correspond to the import impact of provinces over the network. According

Table 5. Hub and authority centrality.

Provinces	Hub centrality	Provinces	Authority centrality
Istanbul	0.988	Istanbul	0.990
Ankara	0.097	Ankara	0.108
Kocaeli	0.092	Izmir	0.051
Izmir	0.054	Kocaeli	0.038
Bursa	0.032	Bursa	0.038
Gaziantep	0.012	Antalya	0.019
Antalya	0.012	Konya	0.016
Tekirdag	0.012	Gaziantep	0.015
Adana	0.010	Adana	0.014
Konya	0.010	Mersin	0.012

Source: Authors' calculation.
Note: In the inter-provincial trade matrix, each province also supplies goods and services to itself. These supply values, represented by the diagonal elements of the matrix, were also taken into account in calculating the centrality measurements, in order not to ignore the potential of the provinces to meet their needs for the population and economic activity they host.

to the hub centrality score, Istanbul ranks first by far. The hub centrality of Ankara, which is the province that ranks second, is 0.097. Kocaeli, Izmir, and Bursa follow Ankara, respectively. These results reveal how important Istanbul is as a supplier of goods and services countrywide. Authority centrality, referring to the import impact, indicates the importance of each province from the demand-side of the network. Within this scope, it is possible to state that Istanbul constitutes a strong demand for the goods and services countrywide. Ankara ranks second with a 0.108 score and Izmir ranks third with a 0.051 score. An analysis of the import impact part of the table also reveals the central role of Istanbul in terms of demand for goods and services produced throughout the country.

6.2. *Simulation results*

The topological analysis done so far was based on the interpretation of the structural properties of the network with calculated statistics. By means of simulation, it can be predicted how certain shocks will have an impact on the network given various scenarios. Based on the findings above, the effects that may occur in the system are examined in the event of a supply or demand-induced shock in trade between provinces in this study. The algorithm used by this simulation method is based on the complete disappearance of links of a node in the system. Based on the data of this study, this situation corresponds to the worst scenario in which one province's trade with other provinces disappears completely. In this sense, it corresponds to a strict supply or demand shock originating from a province.

Table 6 summarizes the impacts of these shocks on the system in the event of a possible demand and supply (reset) caused by the provinces themselves. The results of the top 10 provinces that cause the highest additional stress are presented in the table.

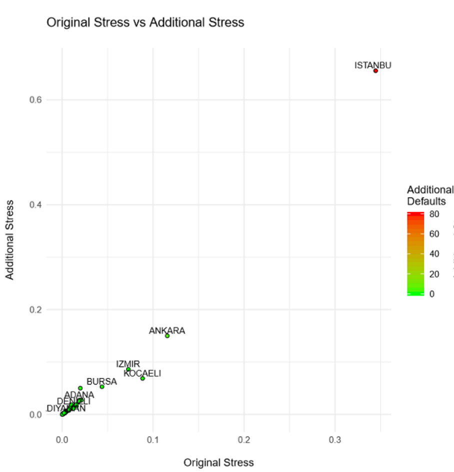
When the part showing the demand shock in Table 6 is examined, it is seen that Istanbul represents 34.4% of the simulated inter-provincial trade network. In case of a demand shock originating from Istanbul in this network, Istanbul creates 65.5% additional stress on the system. The demand shock originating from Istanbul causes an additional loss of 169 billion TL in total, causing the other 80 provinces to be affected. The additional stress to be created in the system by a demand shock in Ankara, whose representation rate is 11.5% in the system it is 15%. In case of a demand shock originating from Kocaeli which is the province with the third highest share of 8.8% in the inter-provincial trade network, approximately 7% additional stress occurs in the system. Although Izmir's share in the system is lower than that of Kocaeli, the additional stress caused by the demand shock in it is greater than that of Kocaeli. Considering that the additional stress score is expressed as the systemic importance of the province in the network (Github), it can be stated that Istanbul's risk factor in the system is quite high in terms of both supply and demand. The original stress and additional stress distributions of the provinces are seen in Fig. 6(a).

When the results of a supply shock in Table 6 are analyzed, the additional stress that a supply shock originating from Istanbul will cause in the system is 50%. This shock affects 25 provinces, and an additional loss of about 75 billion TL will occur as a result. The additional stress that will occur as a result of a supply shock in Ankara, which is the second province closest to Istanbul in terms of its weight in the system, is 14%, while the

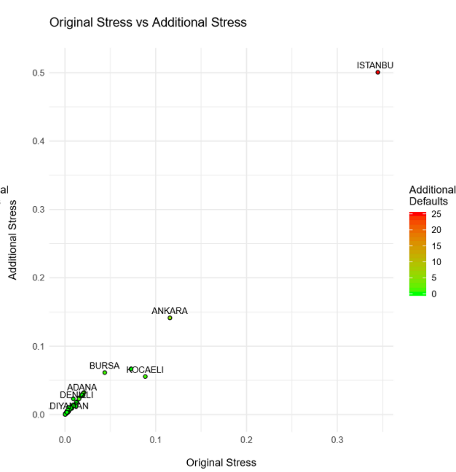
Table 6. Simulation results of the supply and demand shock.

Scenario	Original stress	Additional stress	Additional loss (Million TL)	Additional failure
		Demand shock		
Istanbul	0.344	0.656	169.671	80
Ankara	0.115	0.15	20.420	5
Izmir	0.073	0.086	12.318	0
Kocaeli	0.088	0.069	15.069	1
Bursa	0.044	0.053	8.261	1
Hatay	0.02	0.05	5.015	1
Adana	0.019	0.027	3.199	0
Gaziantep	0.021	0.027	3.675	1
Konya	0.019	0.025	3.166	0
Mersin	0.015	0.019	2.591	0
		Supply shock		
Istanbul	0.344	0.501	75.273	25
Ankara	0.115	0.141	21.458	5
Izmir	0.073	0.067	10.021	0
Bursa	0.044	0.061	9.124	1
Kocaeli	0.088	0.056	8.639	1
Gaziantep	0.021	0.032	4.337	1
Adana	0.019	0.03	3.711	0
Konya	0.019	0.029	4.015	0
Hatay	0.02	0.028	3.313	1
Antalya	0.016	0.025	4.139	0

Source: Authors' calculation.



(a) Demand shock



(b) Supply shock

Source: Made by the authors.

Fig. 6. Original stress and additional stress.

Table 7. Impact of the demand/supply shock that occurs in all provinces.

Degree of the shock (%)	Additional losses in case of demand shock (million TL)	Additional losses in case of supply shock (million TL)
0.10	137.864	143.991
0.20	147.887	153.131
0.30	153.731	158.509
0.40	159.575	163.670
0.50	165.418	168.831

Source: Authors' calculation.

additional stress caused by a supply shock originating from Izmir is approximately 7%. Figure 6(b) shows the original stress and additional stress distributions related to the supply shock of the provinces. In summary, the results show that a demand or supply shock originating from Istanbul in the national economy will seriously affect all other provinces.

The above findings were based on the examination via the traditional default cascades method of the effects that would occur in the system if the supply/demand in a province were completely cut off due to a shock. Finally, we will examine the impact of a demand/supply shock which occurs at the same rate in all provinces on inter-provincial trade network.

In Table 7, the amount of losses that will be caused by supply and demand shocks at different degrees in all provinces are presented. Accordingly, if there is a 10% decrease in demand in all provinces, a loss of approximately 138 billion TL will occur in the inter-provincial trade system. When these results regarding a demand shock are compared with those in Table 6, the loss that will occur if Istanbul's demand is completely reduced (Table 6) and is more than that will result from a 50% demand decrease in all provinces. When the supply shock results in Table 7 are analyzed, the losses that will occur in the trade system between the provinces because of a supply shock in all the provinces at the same time are higher than the losses stemming from the demand shock.

7. Conclusion and Discussion

Although it first emerged in 2019, the COVID-19 pandemic has spread and impacted every country since the beginning of 2020. It not only produced a global health crisis but also created an economic crisis on a national and international scale. In line with the precautions taken against the pandemic, the closure of businesses and the indefinite period of production interruption at many production points caused serious problems in terms of supply. The unemployment of workers and the uncertainty about the future caused a decrease in the propensity to consume. This study examines the economic losses that the mutually influencing processes will cause through the supply–demand dynamics between the provinces.

The findings obtained from the complex network analysis reveal that inter-provincial trade relations in Turkey have complex structural features. This structure also has a core–periphery property. The examination of this core–periphery structure reveals the existence of Istanbul as a super hub. The weight of this super hub in the system in terms of both demand and supply is incredibly high. Therefore, such dependence on only one hub inevitably increases the fragility of the economic system. The results of the simulation data underscore the vulnerability of the Turkish economy within this system.

In a healthy developmental process, it is observed in developed countries that the economic structure of its various provinces have a relatively balanced weight, even if not equal. However, the general characteristics of developing countries are disproportionate economic weights among its regions and provinces. Similar to many developing countries, Turkey also has this disproportionate characteristic. However, as the European Committee of Regions has highlighted, this situation increases a country's economic vulnerability to a possible natural or man-made crisis. The current pandemic is actually an example of this type of situation. The fact that the majority of the COVID-19 cases are seen in large cities, and the fact that Istanbul ranks first with a significant difference in the number of cases has caused stricter measures to be taken in large cities including Istanbul and consequently restricted all kinds of activities, especially economic ones. This situation not only prevents the efficient use of economic resources across the country, but also increases economic vulnerability and exposes other structural problems that are rooted in certain aspects of urbanization.

Subsequent research such as a sectoral analysis of the supply–demand relationship between the provinces will undoubtedly provide access to more refined results and interpretations. Since such data are not yet available, this constitutes the natural limitations of the study. Nevertheless, the true supply–demand dynamics that undergird general trade values among provinces reveal the economic challenges as an economy experiences these types of shocks.

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