TÜRKİYE CUMHURİYET MERKEZ BANKASI

CBT RESEARCH NOTES IN ECONOMICS

Network Structure of the Turkish Economy[1]

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Özet: Bu notta, sektörel şokların ekonomi geneli dalgalanmalar üzerindeki etkisi incelenmektedir. Sektörler ara malı kullanımı nedeniyle birbirlerine bağlıdır. Bu nedenle, bir tedarikçinin maruz kaldığı verimlilik şoku, tedarikçinin ürettiği ara malını kullanan sektörleri doğrudan ve diğer sektörleri de dolaylı olarak etkileyebilir. Türkiye ekonomisine ait Girdi-Çıktı Tablosu kullanarak elde edilen bulgular, sektörel şokların ekonomi geneli dalgalanmalarda göz ardı edilemez bir rol oynayabileceğini göstermektedir.

Abstract: In this note, we analyze the role of idiosyncratic sectoral shocks on aggregate fluctuations. Sectors are connected with each other through intermediate input use. Productivity shock to a supplier may be transmitted directly to immediate users' of the intermediate goods and indirectly to other sectors through network structure. Working with Input-Output Table of Turkish economy, we show that sectoral shocks may play non-negligible role in aggregate fluctuations.

1. Introduction

Aggregate variables such as output, consumption, investment and employment fluctuate, rather than following a steady growth rate. These fluctuations may be triggered by macro shocks (such as monetary policy or fiscal policy shocks) that affect all sectors simultaneously. In addition to economy-wide shocks, micro shocks (firm-specific or sectoral shocks) may lead to aggregate fluctuations because of interactions among sectors and possible cascade effects.

Business cycle literature mostly concentrates on different types of aggregate shocks in explaining fluctuations in the economy because of the "diversification argument" of Lucas.

[1] We are grateful to the referees for helpful suggestions..

Lucas (1977) argues that due to the law of large numbers (LLN), independent sectoral shocks will average out and only macro shocks will be important for the aggregate fluctuations as the number of sectors approaches to infinity. Yet as stated in Cochrane (1994); aggregate shocks cannot fully explain all the fluctuations. In his distinctive work, Horvath (1998) considers the role of sector specific shocks. He shows that idiosyncratic shocks can generate the aggregate fluctuations observed in data in a multi-sector model. Dupor (1999) objects to the findings of Horvath (1998) and posits that a single sector model can also produce the findings of a multi sector model if the number of sectors is large enough.

The critical assumptions behind the results of Lucas and Dupor are the homogeneity in size of sectors and the balance in the network structure between sectors. Two recent papers question these assumptions. Gabaix (2011) shows that firm-specific shocks may not cancel out and lead to aggregate fluctuation when the distribution of firm size is fat tailed. He labels this idea as *“granular origins of aggregate fluctuations”* and discusses the vitality of Samsung and Hyundai for the Korean economy. These two firms account for 35 per cent of Korean exports and sales of these two firms is 22 per cent of Korean GDP. So, shocks to these firms may not cancel out. He tests his proposition for the US economy for 1952-2008 and concludes that around one third of the fluctuations of the US GDP can be linked to idiosyncratic shocks to top 100 US firms.

Acemoğlu, Carvalho, Özdağlar and Tahbaz-Salehi (2012, ACOT here after) take a different perspective on the issue and study the role of network structure on the aggregate fluctuations. After defining a network structure based on the intermediate input usage within the sectors in the economy, they conclude that idiosyncratic shocks to sectors can yield aggregate fluctuations under certain network structures and label their idea as *“network origins of aggregate fluctuations”.* They show that sectoral shocks can generate sizable volatility, approximately 2% volatility, in the U.S. GDP.

In this study, we analyze the impact of sectoral network structure on aggregate fluctuations in Turkish economy following the recent work of ACOT. We construct sectoral network structure of the Turkish economy by using the 1998 Input-Output (I/O) table. Our analysis reveals that sectoral shocks can explain a non-negligible part of the aggregate fluctuations in Turkish economy. Besides, second order interconnections are more important for aggregate volatility compared to first order interconnections.

2. Sectoral Structure

In this section, we discuss sectoral network structure of Turkish economy using the 1998 I/O Table. We start with network structures provided in ACOT in order to give some intuition for how network structure can affect the propagation mechanism of micro shocks. In the next two figures, if an arrow from sector i points sector j, then sector i supplies intermediate goods to sector j. A shock to any sector in the network structure in Figure 1 will not cause aggregate effects as n (sectoral detail level) goes to infinity. This is due to the fact that effect of sectoral shock to other sectors is negligible since each sector is equally important for any sector. However, for the network structure in Figure 2, a shock to Sector 1 will affect all other sectors, which in turn generates aggregate fluctuation even n goes to infinity.[2]

Figure 1. Each Sector Relies Equally on all Other Sectors

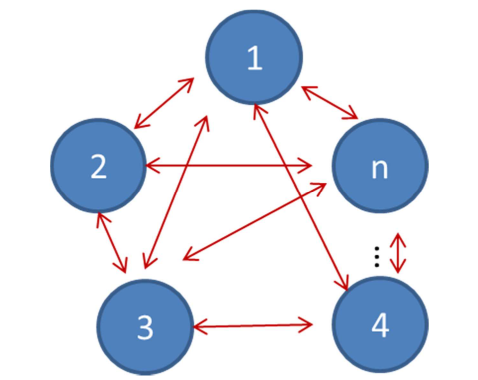
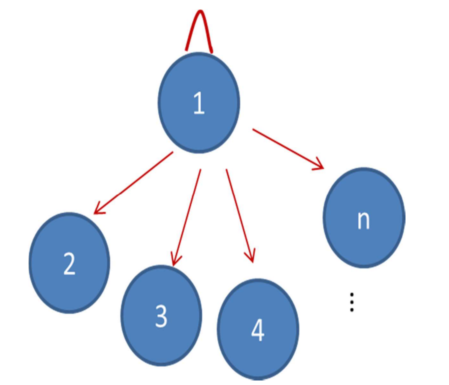


Figure 2. A sector is the Only Supplier of Other Sectors



Source: Acemoğlu et al. (2012).

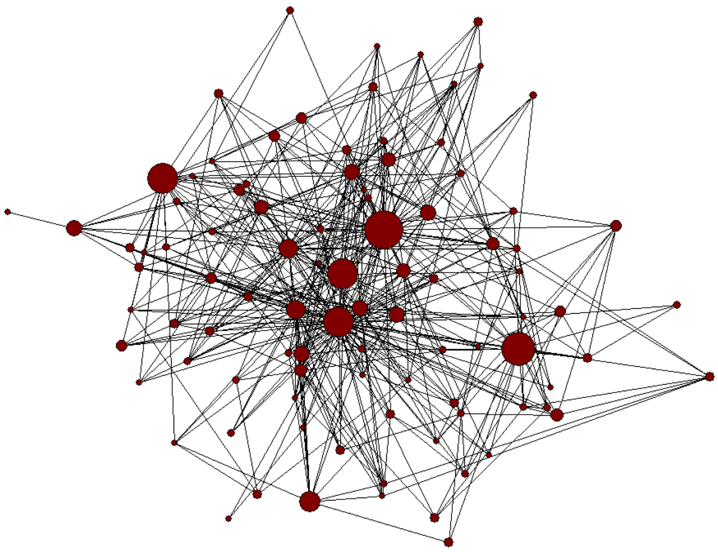
Examples provided above are two extreme cases. Figure 3 illustrates the network structure of Turkish economy obtained from 1998 I/O Table.[3] In the figure, circles denote the sectors and lines show the link between two sectors in terms of intermediate input usage. Sizes of the circles are proportional to the nominal input supply in 1998. The bigger the circle is, the bigger the weight of the sector, as a supplier in the economy, is. Also, the graph is designed so as to locate highly connected sectors with other sectors close to center and less connected sectors away from center. Network structure in Figure 3 is clearly not very close to Figure 1 and Figure 2. Indeed, it stands between two figures. Although some sectors are

[2] This structure is named as star network.
[3] The links with weight smaller than 0.4% are not displayed.

connected with small number of sectors, there are some sectors that highly interact with other sectors. So, there is still room for the sectoral shocks to contribute sizably to aggregate fluctuations.

In the rest of the note, our aim is characterizing the aggregate volatility in terms of depicted network structure and calculating the effect of sectoral shocks on the Turkish economy using this characterization.

Figure 3. Inter-Sectoral Network of Turkish Economy



Circles denote sectors and lines show the link between two sectors. Size of the sectors are proportional to the actual input supply of the sector. We use UCINET for drawing the picture.

3. Data

TURKSTAT published I/O Tables for various years between 1973 and 2002. I/O table shows the input composition of each sector. Most of the I/O Tables have around 60 sectors and the 1998 I/O Table is an exception and covers 97 sectors.[4] Furthermore, we normalize the input usage of each sector to one. This assumption helps us to disregard the size of the sectors and focus only on the network connections.

We denote the set of sectors by N such that $|N|=n$ and the input-output matrix by square matrix W where w_{ij} represents the share of sector j in intermediate good usage of sector i. We have $\sum_{j=1}^{n} w_{ij} = 1 \; \forall i \in N$ since we work with shares instead of nominal values of input supply. This means that W is stochastic matrix.

[4] We dropped two sectors from 1998 I/O Table in our analysis as their out-degree is zero.

Sectors may play different roles as input suppliers. We capture this asymmetry using the concept named as "out-degrees". Out-degree d_i of sector i can be defined as:

$$d_i = \sum_{j=1}^{n} w_{ji} \quad (1)$$

We explain the out-degree concept by the following example. Table 1 illustrates a simple economy composed of three sectors: agriculture, manufacturing and services. In the upper part of the table, intermediate input use and supply of sectors are provided. Rows show the use of intermediate input of a sector from the three sectors in the economy. A sector can supply input to itself. For instance, seed (supplied by agriculture) is used in the production of tomato (produced by agriculture). In this economy, agriculture uses 20 unit intermediate input in the production process: 5 units of 20 units are supplied by the agriculture itself, 10 units by manufacturing and the remaining part is supplied by services. Columns show the input supply of a given sector to other sectors. For instance, table shows that manufacturing supplies 40 unit intermediate good which is distributed as 10 units to agriculture, 25 units to manufacturing and 5 units to services. Note that we only take the input use and supply relation from the I/O table as it is the relevant part for this study. However, I/O table includes consumption and export data for each sector.

Second part of Table 1 shows the calculation of out-degree for the simple economy. First of all, for each sector we calculate the share of intermediate input use from each of the three sectors. Then we take the column sum to obtain out-degree of the sector. The largest degree is 1.46 and belongs to manufacturing.

Table 1. Example of Out-Degree Calculation

Intermediate Goods Use (rows) and Supply (columns)				
	Agriculture	Manufacturing	Services	Intermediate Input Use
Agriculture	5	10	5	20
Manufacturing	5	25	10	40
Services	0	5	10	15
Total Output	10	40	25	75
Intermediate Goods Share				
	Agriculture	Manufacturing	Services	
Agriculture	0.25 (=5/20)	0.50	0.25	
Manufacturing	0.13	0.63	0.25	
Services	0.00	0.33	0.67	
Out-degree	0.38	1.46	1.17	

4. Model

We borrow the multi-sector model from ACOT. The utility function for representative households consuming n distinct goods:

$$u(c_1, \dots, c_n) = A \prod_{i=1}^{n} c_i^{1/n} \tag{2}$$

where c_i is the consumption of good i and A is the normalization constant. The representative household is endowed with one unit of labor.

In production side, we have n sectors and $N = \{1, \dots, n\}$ denotes the set of sectors. Sector $i \in N$ produces good x_i through Cobb-Douglas technology:

$$x_i = z_i^{\alpha} l_i^{\alpha} \prod_{j=1}^{n} x_{ij}^{(1-\alpha)w_{ij}} \tag{3}$$

where z_i is productivity shock, l_i is the amount of labor and x_{ij} is the amount of sector j good, $\alpha \in (0,1)$ is the share of labor and $1-\alpha$ is the share of intermediate input use in production of good i, and w_{ij} represents the share of sector j good in intermediate input use of sector i. Technology shocks to sectors, $\{z_1, \dots, z_n\}$, are independent and $\epsilon_i \equiv \log(z_i)$ are from the distribution F_i. So, we can represent economy by three tuple $E = (N, W, \{F_i\}_{i \in N})$.

The market clearing equations for the model are:

$$x_i = c_i + \sum_{j=1}^{n} x_{ji} \quad \forall i \in N \tag{4.a}$$

$$\sum_{i=1}^{n} l_i = 1 \tag{4.b}$$

Now, we can solve the model for utility maximizing household and profit maximizing firm where $(p_1, \dots, p_n)$ is the price vector for goods and h is the wage. Then the logarithm of value added in the economy is:[5]

$$y = \log(h) = v'\varepsilon \tag{5}$$

where $v = \frac{\alpha}{n}(\mathrm{I} - (1-\alpha)\mathrm{W}')^{-1}\mathbf{1}$ is the influence vector[6] representing the importance of each sector in economy and $\varepsilon = (\varepsilon_1, \dots, \varepsilon_n)'$ is the shock vector.[7] We can characterize the aggregate volatility, var(y), of the economy and see the effect of each sector by using the influence vector.[8] Note that each entry in influence vector v includes the impact of first, second and higher order effects of a shock to a sector due to network structure. However, in this study we focus on the first and second order effects of shocks in aggregate fluctuations.

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[5] The normalization constant is chosen, following ACOT, as $A = n\exp\left[\left(-\frac{B}{\alpha} - \frac{1-\alpha}{\alpha}\sum_{i=1}^{n}\sum_{j=1}^{n} v_i w_{ij} \log(w_{ij})\right)\right]$

[6] **1** represents n-dimensional vector consisting of ones.

[7] Detailed derivation of the influence vector is available in ACOT.

[8] ACOT makes a detailed characterization by using influence vector.

We first give some definitions before introducing theorems that relate aggregate fluctuations and “first and second order” connections.

We define the first order degree of sector i as:

$$d_i^1 = \sum_{j=1}^{n} w_{ji} \tag{6}$$

This is the same as the definition of out-degree in previous section. Clearly, one unit shock to sector i affect sector j proportional with w_{ji} at first round. Then, we define the second order degree of sector i as:

$$d_i^2 = \sum_{j=1}^{n} d_j w_{ji} \tag{7}$$

Observe that if a sector i is highly connected to sectors with high first order degree, then its second order degree is high. We can represent the first and second order degree sequence of the economy by $\{d_1^1, \dots, d_n^1\}$ and $\{d_1^2, \dots, d_n^2\}$, respectively.

We say that a degree sequence has a power law distribution if probability density function is in the form $f(k) = c_0 k^{-\alpha}$ where c_0 is positive constant and $\alpha > 1$. Power law implies that we have few sectors with high degree and many sectors with low degree. Then, the counter cumulative distribution, $P(k) \equiv \frac{1}{n}|\{i \in N: d_i > k\}|$, can be written by $P(k) = ck^{-\beta}$ where c is constant and $\beta > 0$ is the shape parameter.[9]

ACOT provide two key theorems that characterize the relation between the network structure of the economy and the role of sectoral shocks in aggregate fluctuations. Furthermore, they show that if the empirical distribution of degree sequences of the inter-sectoral network can be approximated by a power law then the attenuation of aggregate volatility depends on the shape parameter of power law. Simplified versions of Corollary 1 and 2 of ACOT presented below.

Corollary 1: If the first order degree sequence of the economy with n sectors has a power law distribution with shape parameter $\beta \in (1,2)$, then aggregate volatility of the economy $\sqrt{var(y)}$ is proportional to $n^{-\frac{\beta-1}{\beta}}$.

Corollary 2: If the second order degree sequence of the economy with n sectors has a power law distribution with shape parameter $\zeta \in (1,2)$, then aggregate volatility of the economy $\sqrt{var(y)}$ is proportional to $n^{-\frac{\zeta-1}{\zeta}}$.

Observe that if β=2, the aggregate volatility decays with 1/√n which means that LLN holds. If β is close to 1, we have fat tails i.e. we have many sectors with high degree and Theorem 1 implies that sectoral shocks do not attenuate immediately and cause higher aggregate

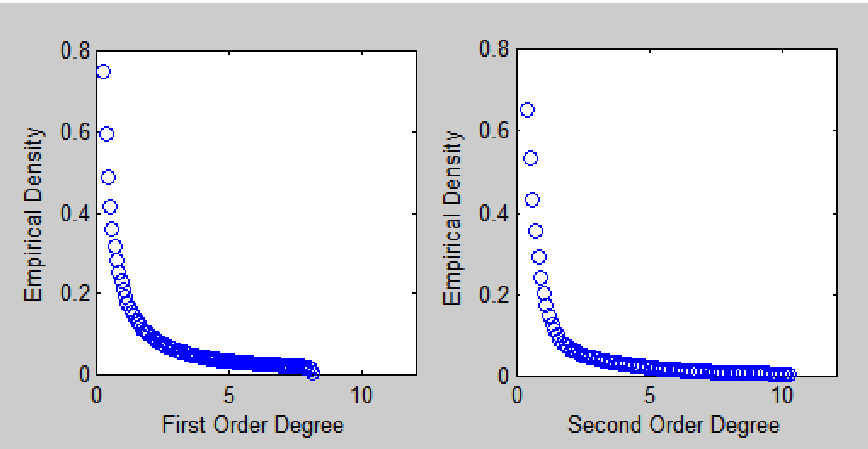
[9] If we denote cumulative distribution function (CDF) with F(k), then CCDF is 1-F(k).

volatility compared with the previous case. The same interpretation applies for second order degree sequence. Furthermore, we can say that second order effects are more important for aggregate volatility if $\zeta < \beta$.

5. Estimation

We can summarize the methodology to estimate the shape parameters introduced in the *Corollary 1 and 2* as follows. First of all we calculate out-degrees, and then we get the counter cumulative distribution function (CCDF) of the first and second order out-degrees. We estimate shape parameters which are the slopes of the tails of CCDFs.

Figure 4. Probability Density Functions



First of all, we present the probability density functions (PDF) of out-degrees in Figure 4. Shape of the curve is similar to shape of a Pareto Distribution. In particular, sectors that have very high out-degrees are scarce and there are relatively more sectors which have low out-degrees. Figure 5 shows the CCDF for first order out-degrees and Figure 6 shows the CCDF for the second order out-degrees. We estimate the shape parameter of CCDF for the tail of the distribution after some cut-off point, not for the whole sample. We determine cut-off point using methodology of Clauset et al. (2009) which gives a cut-off value around 0.5.[10] For robustness, we estimate shape parameters for two different cut-off values, namely 40 per

[10] Clauset et al. (2009) method endogenously chooses the first 57 and 51 observations out of 95, for first and second order out-degrees respectively. They use Kolmogorov-Smirnov statistics in likelihood calculation.

cent and 50 per cent of the tails. This estimation can be done using ordinary least squares (OLS) but in small samples OLS may be biased. Therefore, as in ACOT, we use an adjusted version of OLS introduced by Gabaix and Ibragimov (2011).

Estimations for both cut-off values (Table 2) indicate that shape parameter for both first and second order are closer to 1 than 2. This suggests that sectoral shocks may not die out even sectoral detail level goes to infinity, contrary to the implication of LLN. Moreover, since the estimate of shape parameter for second order effects is lower than the estimate for the first order effect, second order interactions are relatively more important for the characterization of the aggregate volatility of the Turkish economy.

Figure 5. Counter Cumulative Distribution of First Order Degrees

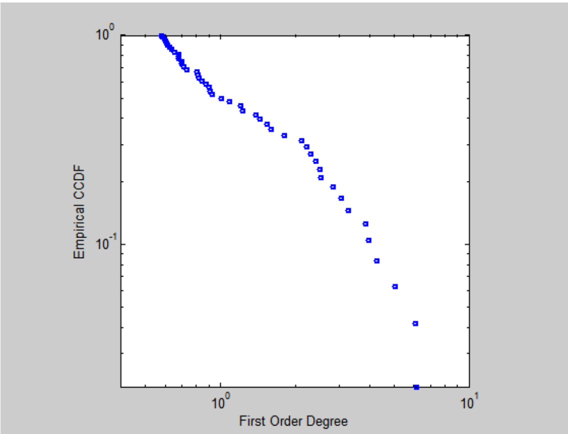


Figure 6. Counter Cumulative Distribution of Second Order Degrees

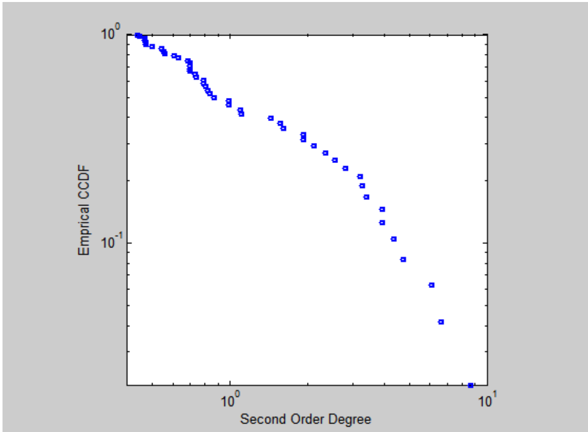


Table 2. Regression Results

	Cut-off: 50%	Cut-off: 40%
First Order Effect	1.28	1.33
	(0.26)	(0.3)
Second Order Effect	1.09	1.17
	(0.22)	(0.27)

Standard errors in parenthesis.

We do some back of the envelope calculations, similar to ACOT, to illustrate the effect of network structure based on our regression results. First, there are around 200 sectors in the

4 digit manufacturing industry. Manufacturing is around a quarter of GDP (in real terms). So, if the remaining sectors have a similar disaggregation structure, then the total number of sectors would be around 800 in Turkish economy. Second, the Turkish GDP is almost twice as volatile as the US.[11] In this respect, we conjecture that the standard deviation of sectoral TFP should be higher than that of reported as 0.058 by ACOT. Correspondingly, we conservatively take standard deviation of sectoral TFP as 0.075. With these assumptions, we report the results implied by the Theorem 1 and Theorem 2 in Table 3 for the different shape parameter values (Table 3).

Table 3. Effect on Aggregate Volatility

Number of Sectors	800	800	800	800	800
Shape Parameter	1.09	1.17	1.28	1.33	2
Size of the Shock	0.075	0.075	0.075	0.075	0.075
Effect on GDP Volatility	4.32	2.84	1.74	1.43	0.27

We get striking results in terms of how much sectoral shocks can affect aggregate volatility. Indeed, for a shape parameter of 1.09, as suggested by our estimations to be the relevant value to consider in the analysis, sectoral shocks play substantial role and corresponds to 4.32 per cent standard deviation of Turkish GDP. To give a better idea about reading this result, we present effect of sectoral shocks for alternative shape parameter values in Table 3. In the case of a balanced network structure in which LLN holds, shape parameter would be 2 and aggregate volatility with decay by $1/\sqrt{n}$. In this case, the contribution of sectoral shocks to aggregate volatility would be 0.27% which is almost negligible. Consequently, it can be inferred that sectoral shocks can play a major role in aggregate fluctuations.

Of course, it should be stressed that these are rough calculations. However, working with other estimated shape parameters presented in Table 2, we still get sizable effect from sectoral shocks. Moreover, the effect of sectoral disaggregation level on the results will be limited on the volatility (Table A1). Besides, we pick a modest value for the size of sectoral shocks. Clearly, larger sectoral shocks would imply larger aggregate volatility. All in all, we cannot ignore the network effects in the volatility of GDP. Therefore, results robustly indicate the importance of taking into account the idiosyncratic sectoral shocks on the analysis of

[11] See Barro and Ursua (2010) for historical data.

economic issues and designing economic policies. Furthermore, micro economic policies should take into account second order effects as well as first order effects while evaluating costs and benefits of a project.

We acknowledge that data availability is a constraint in our study. Using a recent I/O table with more detailed sectoral disaggregation would allow us to better understand recent dynamics of the economy.

6. Conclusion

In this note, following the recent paper of ACOT, we analyze the effect of the sectoral network structure obtained from input-output tables on the Turkish economy. We show that idiosyncratic sectoral shocks can generate non-negligible volatility in GDP through intermediate input usage channel. This implies that sectoral shocks can contribute considerably to the fluctuations in the GDP.

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APPENDIX

Table A1. Effect of Sectoral Disaggregation on the Results

Number of Sectors	400	800	1200	1600	2000
Shape Parameter	1.09	1.09	1.09	1.09	1.09
Size of the Shock	0.075	0.075	0.075	0.075	0.075
Effect on GDP Volatility	4.57	4.32	4.18	4.08	4.00

Editör, Ekonomi Notları, TCMB İdare Merkezi, İstiklal Cad, No: 10, Kat:15, 06100, Ulus/Ankara/Türkiye.
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