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Towards a better understanding of the impact of economic disruptions on the Moroccan economy: An input-output network analysis

Hafsaa Ouifak
ENSIAS, University Mohammed V in Rabat
e-mail: hafsaa.ouifak97@gmail.com

Abstract

Input-Output tables are often used to understand the interactions between different industries. In this paper we want to extract a clear view of the Moroccan economy, with the objective to identify some of its structural features and to understand the impact of some disruptions such as those due to natural hazard, that can affect these interactions between the different sectors and regions and so the global economy.

Keywords: *Network analysis, input-output tables, economic disruptions.*

1. Introduction

Morocco is one of the developing countries trying to reach economic diversification and growth even though it is still classified by the World Bank as a lower middle-income country, but the Moroccans are still taking the challenge to build a new developed Morocco. The understanding of the economy and how disruptions, such as those due to nature, can affect it is related to its regional sectors and the interactions between them, so the need to analyze input-output tables to extract a view of the global economy. Input-Output tables illustrate the flows between industries and help us to understand the country's economy, by understanding sectoral interdependence and modes of functioning. The modelling of the I-O tables as graphs can help visualizing, analyzing and understanding the interconnections between industries, and so understanding the impact of disruptions on the country. It can also help on identifying opportunities that the country should take to strengthen linkages within the economy to help building a new strong economy.

This paper is organized as follows. In the coming section, we introduce some related works to input-output networks analysis. The third section is about the data source and methods that we want to implement in our analysis. The fourth one is about results and discussion and finally a conclusion.

2. Related works

Our inspiring work was [14] that aims to quantify economic disruptions in regional input-output networks of New-Zealand. They calculate both traditional matrix based IO measures (e.g. multipliers) and new network theory-based measures, and they find that path-based measures, such as betweenness centrality, give a good indications of economic disruptions, while eigenvector-type centrality measures give results comparable to traditional IO multipliers. [1] studied the relationship between sectoral shocks and aggregate volatility, by investigating the role of the Australian input-output tables, but they focused only on the input-output network but not in the interactions between sectors that happens on many levels. [9] used network input-output analysis to study embodied energy flows between producer and consumer regions in china. This approach track multi-layer energy flows by integrating the Energy embodied in bilateral trade (EEBT) approach and social network analysis (SNA). And to understand how shocks and disruptions impacts the economy, there are many works like : [5] choose three different models to study how economic shocks propagate and amplify through the input-output network connecting industrial sectors in developed economies in several European countries.. In morocco too, there are many works about analysing input-output tables but without the consideration of social network analysis or graphs theory. [19] identify the Moroccan key sectors to help policy makers in setting an adequate industrial strategy. The unweighted Rasmussen approach is implemented to classify the productive sectors. [8] use dynamic variant input-output model to simulate the economic impact of renewable energy development in Morocco. Some other works are about understanding the impact of pandemics on economy and the models used for that task: [11] describes in details the methodology developed for assessing the daily economic costs of control strategies for mitigating the effects of COVID-19, that is being currently applied to inform regional and national governments in Brazil and Colombia on the potential regional and sectoral economic costs of different strategies of lockdown measures. [18] study the impact of pandemics on the economy and how much it can lose during crisis, using dynamic inoperability input-output model.

3. Data and method

Data:

[12] present a construction of an inter-regional input-output matrix for Morocco (IIOM-MOR), which was a part of a project that aims to develop an economic model for the country. Even though this dataset was created for Moroccan data until 2013, we still using it to understand the interactions between different sectors and regions and derive new interpretations. In all the following work, the data is processed and analyzed using R studio.

Topology:

The input-output tables can be considered as weighted directed networks where nodes represents the different sectors and the weights represents the size of flows going from sectors of the rows to the sectors of columns. The following matrix form can describe the IO network:

$$T \equiv \begin{bmatrix} f_{11} & f_{12} & \dots & f_{1n} & y_1 \\ f_{21} & f_{22} & & f_{2n} & y_2 \\ \vdots & & \ddots & & \vdots \\ f_{n1} & f_{n2} & \dots & f_{nn} & y_n \\ z_1 & z_{11} & & z_n & 0 \end{bmatrix} \equiv \begin{bmatrix} F & \bar{y} \\ z^t & 0 \end{bmatrix}$$

Where f_i represent the internal flows, z_i and y_i represent the boundary flows.

Centrality measures :

The concept of centrality is not new for networks. Centrality measures explain the importance of single or cluster of nodes. There are indeed many definitions of importance of node correspondingly many centrality measures for different types of networks. Centrality measures mainly include degree centrality, eigenvector centrality, hubs and authorities, closeness centrality and betweenness centrality [13]. [14] show that there is a strong correlation between traditional IO multipliers and the eigenvector based centrality, whereas path-based centrality measures correlate well negatively with Disruption multipliers.

Sector strength:

The sector strength is how much a node (a sector) investigates on other sectors and it is called "Output sector strength", or how much it takes from other sectors and it is called "Input sector strength". It is the sums of the flows (the weights) that goes out or comes in a given sector.

$$s_i^{in} \equiv \sum_j f_{ij} = F_i$$

$$s_i^{out} \equiv \sum_j f_{ij} = F_i$$

Therefore, we can consider the normalized sector strength as follows:

$$s_i^{norm} \equiv \frac{s_i}{\sum_j s_j} = \frac{s_i}{w}$$

Where s_i is either an in-strength or an out-strength and the s_i^{norm} is the normalized strength.

Betweenness Centrality:

Betweenness Centrality is another different centrality concept; it measures the extent to which a node lies on path between other nodes. It quantifies the number of times a node act as a bridge along the geodesic path between two other nodes. So nodes lying on that path have higher betweenness centrality and influence on the whole network. Mathematically, we can express the betweenness for a general network by $g_{jk}(i)$ to be the number of geodesic paths from j to k that pass through i. And we define g_{jk} to be the total number of geodesic paths from j to k. Then the betweenness centrality of node i is

$$C_B(i) = \sum_{j<k} g_{jk}(i)/g_{jk}$$

Closeness centrality:

This centrality measures the mean distance from one node to other nodes. It is the concept of geodesic path, the shortest path between two nodes. Closeness centrality has small values for nodes that are separated from others by only a short geodesic distance on average. Such nodes might have better access to information at other nodes or more direct influence on other nodes. In a financial network, for example, a financial institution with lower mean distance to others might have better access to liquidity and important financial information. Closeness is based on the length of the average shortest path between a vertex and all vertices in the graph [13].

$$C_c(i) = \left[\sum_{j=1}^{N} d(i,j)\right]^{-1}$$

Where, d is the distance between node i and j, while N refers to the number of nodes within the network.

Eigenvector centrality:

A nodes importance in a network would increase if it has connections with other themselves important nodes. This is the concept behind eigenvector centrality. Instead of awarding nodes just one point for each neighbor, eigenvector centrality gives each node a score proportional to the sum of the scores of its neighbors [13]. [4] Defines the centrality $c(v_i)$ of a node v_i as positive multiple of the sum of adjacent centralities, i.e.

$$\lambda c(v_i) = \sum_{j=1}^{n} a_{ij} c(v_j) \ \forall i$$

In matrix notation with $c = c(v_1), \dots, c(v_n)$ this yields

$$Ac = \lambda c$$

This type of equation is well known and solved by the eigenvalues and eigenvectors of A. $A = a(i,j)$ is an adjacency matrix in this network.

PageRank:

PageRank is formally defined by [17], who developed a method for assigning a universal rank to web pages based on a weight-propagation algorithm. A page has high rank if the sum of the ranks of its in links is high. The PageRank rank formula is:

$$PR(u) = 1 - d \sum_{v \in B(u)} \frac{PR(v)}{N_v}$$

And it has been modified by [20] for weighted networks as:

$$PR(u) = (1-d) + d \sum_{v \in B(u)} PR(v) W_{(u,v)}^{in} W_{(u,v)}^{out}$$

where u represents a sector. $B(u)$ is the set of sectors that point to u. $PR(u)$ and $PR(v)$ are rank scores of sector u and v, respectively. N_v denotes the number of outgoing links of sector v. The $W_{(u,v)}^{in}$ and $W_{(u,v)}^{out}$ represents the weight links in and out of a sector. The damping factor d in the original study was set as 0.85. If d=0.85, this means that there is an 85% chance that a random investment will follow the links provided by the sector of investment, and a 15% chance that a random investment starts in a completely new sector which has no link to previously sector.

4. Results and discussion

The sectors of all regions are all connected, which makes the network more complicated in terms of interconnections between all nodes. That may lead to an easy propagation of a shock and impact between all the sectors as [16] said and this is the case for most countries. To simply visualize the graph we will chose 6 regions instead of all the 12 ones and that shows clearly how are strong the connections between regions and industries before talking about weights.

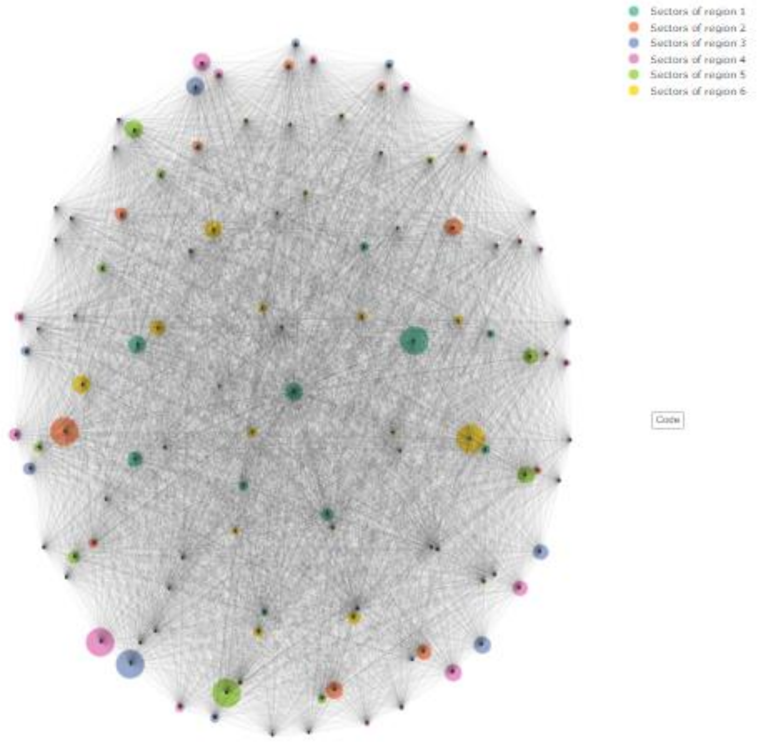

Figure 1: A graph representation of the IO table of 6 regions of Morocco.

Network measures:

The input output network is a dense network (nearly-complete) with most industries having connections with most other industries and have a low average path length, because that would say that uniformly more ties are being made and more release relationships and therefore more collaborations between the industries of the region. In order to measure the importance of nodes (sectors) in the network the following centrality measures were calculated:

Table 1: List of calculated centrality measures.

Centrality measure	Package
In/Out Strength centrality	igraph [7]
Closeness	igraph [7]
Betweeness	igraph [7]
Eigen vector	igraph [7]
Page Rank	igraph [7]

Strength centrality :

In our case the in/out strength centrality measure highlights the industries of the region of Casablanca-Settat(R_6), especially the sectors shown in the table :

Table 2:Top 5 sectors in the In/Out Strength centrality.

Centrality measure	Region	Sector
In Strength	Casablanca-Settat	Food industry and tobacco
In Strength	Casablanca-Settat	Mechanical, metallurgical and electrical industry
In Strength	Casablanca-Settat	Other manufacturing, excluding petroleum refining
In Strength	Casablanca-Settat	Oil refining and other energy products
In Strength	Casablanca-Settat	Chemical and parachemical industry
Out Strength	Casablanca-Settat	Other manufacturing, excluding petroleum refining
Out Strength	Casablanca-Settat	Oil refining and other energy products
Out Strength	Casablanca-Settat	Mechanical, metallurgical and electrical industry
Out Strength	Casablanca-Settat	Food industry and tobacco
Out Strength	Casablanca-Settat	Trade

These sectors uses their outputs for further production of many other sectors (High Out Strength), and similarly uses the outputs of many other sectors for their own production (High In Strength). These sectors can be considered as very important and thus their region (Casablanca-Settat) adopting the most high strength measures. For most of other regions the Agriculture, forestry, hunting and related services have the highest out strength, and public's Construction, Food industry and tobacco and General public administration and social have the highest in strength. See figure 2.

Eigenvector centrality:

[12] presents an inter-regional input-output matrix for Morocco (IIOM-MOR) with a part of some output multipliers that we used to verify their correlations with the eigenvector centrality as mentioned in [14] to be high. The correlation test returns $\rho = 0.315$ using the Pearson test and $\rho = 0.51$ using Spearman test. The Spearman test is higher than the Pearson correlation when the trend is monotonous but not refined. The following figure shows the highest five eigenvectors measures details:

Table 3: Top 5 sectors in the eigenvector centrality.

Rank	Region	Sector
1	Casablanca Settat	Food industry and tobacco
2	Fes Meknes	Food industry and tobacco
3	Fes Meknes	Agriculture, forestry, hunting, related services
4	Souss Massa	Education
5	Rabat Sale Kenitra	Agriculture, forestry, hunting, related services

Closeness centrality:

The following figure shows the highest five In/Out closeness measures details:

Table 4: Top 5 sectors in the In/Out Closeness centrality.

Centrality measure	Region	Sector
In Closeness	Dakhla-Oued Eddahab	Chemical and parachemical industry
In Closeness	Dakhla-Oued Eddahab	Mechanical, metallurgical and electrical industry
In Closeness	Guelmim-Oued Noun	Chemical and parachemical industry
In Closeness	Souss-Massa	Mining industry
In Closeness	Beni Mellal-Khenifra	Textile and leather industry
Out Closeness	Guelmim-Oued Noun	Chemical and parachemical industry
Out Closeness	Dakhla-Oued Eddahab	Mechanical, metallurgical and electrical industry
Out Closeness	Dakhla-Oued Eddahab	Education, health and social action
Out Closeness	Dakhla-Oued Eddahab	Other non-Financial services
Out Closeness	Dakhla-Oued Eddahab	Chemical and parachemical industry

The most central nodes according to closeness centrality measure are shown in the last table and we can remark that the Chemical and para-chemical industry is mostly repeated and the closeness measure is especially higher on south regions. These sectors can quickly interact to all others around Morocco because they are close to all of them economically. We can also see them as more stable sectors.

Betweeness centrality:

The following figure shows the details of the sectors having the highest five Betweeness centrality measures:

Table 5: Top 5 sectors in the Betweeness centrality.

Rank	Region	Sector
1	Guelmim-Oued Noun	Chemical and parachemical industry
2	Dakhla-Oued Eddahab	Mechanical, metallurgical and electrical industry
3	Rabat Sale Kenitra	Fishing, aquacuture
4	Dakhla-Oued Eddahab	Education, health and social action
5	Casablanca Settat	Fishing, aquacuture

The nodes with high value of betweenness centrality will participate in a large number of shortest paths. In this context, the betweenness centrality is potentially a proper method to identify key intermediary sectors in the production network [15]. See figure 2. When considering both upstream as well as downstream propagation, a negative shock to a key intermediary sector can be propagated to different parts of the network. Counting betweenness can be used as a microfoundation for the velocity of money. Consider a dollar of final demand that is spent with equal probability on the output of any sector, and assume that all transactions must be paid for with cash, not credit. Then the counting betweenness of sector i is the expected number of periods that this dollar will spend there. If it is a high number, then that sector requires many transactions before the money is eventually returned to the household sector as a payment to some factor of production. If each transaction takes a fixed amount of time, then a sector with a high counting betweenness is a drag on the velocity of money in the economy [3].

PageRank:

PageRank algorithm is used to evaluate the relative popularity of a node in a network: the popularity of a node can be enhanced by the endorsement it receives from the nodes that are pointing to it. The following figure shows the details of the five most popular sectors based on Page Rank measures:

Table 6: Top 5 sectors in the Page Rank measure.

Rank	Region	Sector
1	Casablanca Settat	Food industry and tobacco
2	Casablanca Settat	Textile and leather industry
3	Casablanca Settat	Mechanical, metallurgical and electrical industry
4	Souss-Massa	Food industry and tobacco
5	Casablanca Settat	Other manufacturing, excluding petroleum refining

From the perspective of shock diffusion, the PageRank centrality of a node captures the linear backward propagation to its in-coming neighbors.

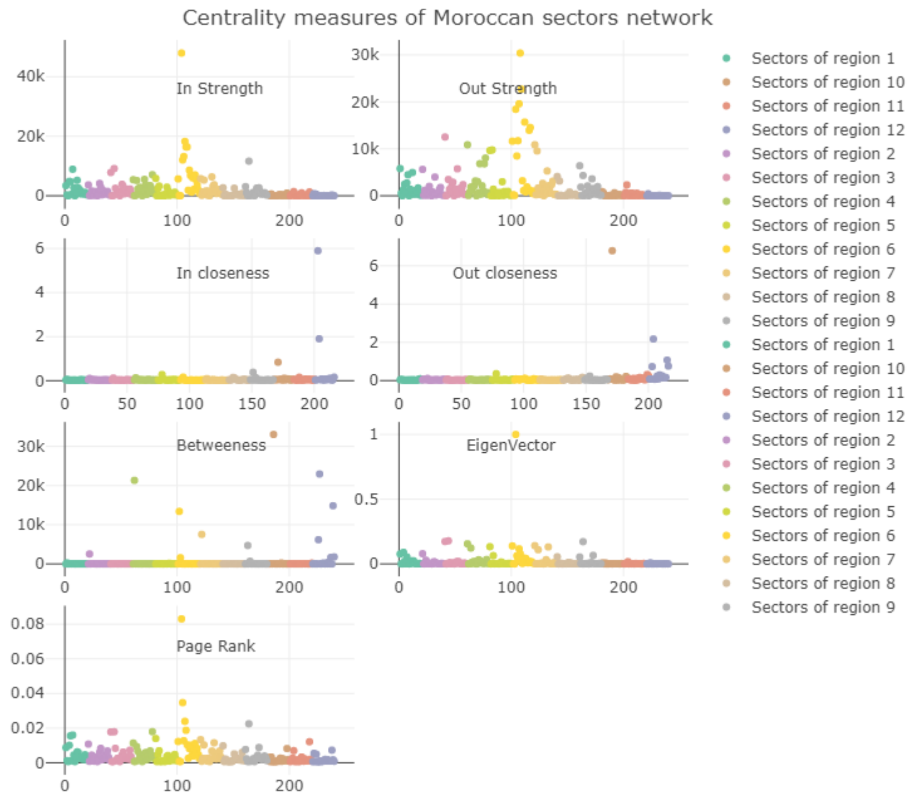

Figure 2: Centrality measures of Moroccan sectors.

Correlations test :

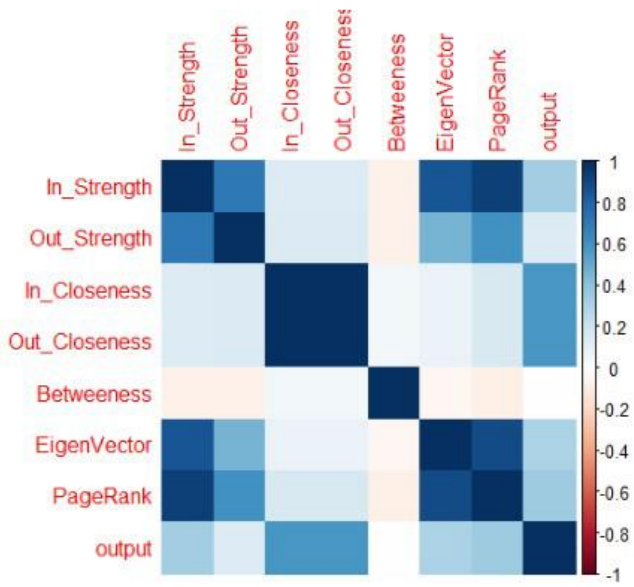

Figure 3: Pearson's correlations between centrality measures.

For the case of [14], there was a strong correlation between eigenvector centrality measure and the output multiplier, but we can see that the correlation closeness measure is stronger in our example. What makes the correspondence between the multipliers and the centrality measures a hard task as it is not generalized and changes dependently the case study.

5. Conclusions

In this work, we discovered the Moroccan IO table as a network and tried to analyze it, with the goal to understand the relationships between different sectors and the impact of disruptions on them. We calculated the centrality measures to extract some information of the network and we found that based on the used measures, the results differ and the experiences too. It is not that much easy to extract a clear view of the important nodes but combining many measures and trying to explore each of them can at the end converge to a given path. It will be good and to consider as a future work, if we tried to test these measures and validate them over years. More data about past investment and projects will be needed and a predictions analysis will be provided and tested using this measures.

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