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Analyzing the structure and interregional effects of spatial competitiveness using a multiregional input-output approach, case study: Tehran Metropolitan Region, Iran

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Abstract

The Tehran Metropolitan Region, as Iran's most important economic and administrative center, holds a pivotal position in the spatial organization of the national economy. This article examines the structure and interregional effects of spatial competitiveness in this region using a multi-regional input-output approach. Methodologically, the study is quantitative, applied, and exploratory. Its scope is the Tehran Metropolitan Region within Iran's national territory during 2021 (the Iranian calendar year 1400). Research data were compiled from national and regional accounts for 2021 and the national input-output table for 2016 (the Iranian calendar year 1395), published by the Statistical Center of Iran, and used to estimate a seven-region input-output table. Economic relations were analyzed through two complementary methods: multiplier decomposition and spatial backward and forward linkage indices. On the one hand, multiplier decomposition showed that sectors such as chemicals, oil, agriculture, and construction have considerable internal capacity to form production clusters, and the activities in the food industries, chemicals, construction, and machinery can stimulate production in other regions. On the other hand, the spatial backward and forward linkage indices indicated that Tehran's main role at the macro level is better understood in terms of demand generation, the concentration of advanced services, management, coordination, and the organization of economic networks. Therefore, rather than being an input-oriented industrial pole, Tehran functions as a metropolitan node of service, management, demand, and network competitiveness within the national economy.

Keywords

Interregional effects
multiregional input-output table
spatial competitiveness
spatial linkages
spillover effects
Tehran Metropolis

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1. Introduction

By expanding transnational flows of goods, services, capital, knowledge, and technology, globalization has fundamentally reorganized the spatial structure of the economy. This process has connected economies through complex networks of production, exchange, and value creation, thereby increasing the interdependence of regions at both national and global scales (Tatic, Rovcanin, & Dzafic, 2006). Under these conditions, competitiveness is no longer merely a firm- or country-level attribute; it has increasingly become a spatial characteristic manifested in cities and regions. As the principal nodes in the spatial organization of the global economy, cities and regions mediate between national economies and global value networks. Through functional specialization and integration into the spatial division of labor, they acquire differentiated positions in the global economy (Sassen, 2009). In this context, the regional planning literature in Iran has extensively examined the factors that shape regional competitiveness. Early studies focused primarily on regions' internal characteristics, including industrial structure, human capital, infrastructure, and institutional capacity. Some studies, for example, used structural equation modeling to analyze how institutional, economic, and social variables interact in forming regional competitiveness (Sharifzadegan & Nedaei Toosi, 2015, 2016). Cheraghi et al. (2021), emphasizing institutions, collective learning, and organizational capacity alongside economic and human resources, screened indicators through expert judgment and then applied confirmatory factor analysis and structural equation modeling. Their findings showed that institutional capacity, human capital, and interinstitutional coordination play decisive roles in the competitiveness of intermediate cities, although the overall institutional capacity of Zanjan and Sanandaj is not satisfactory.

Another study used Stimson's multi-sectional analysis to identify the key drivers of regional competitiveness (Dadashpoor & Dadejani, 2015). Using a mixed-methods approach that combined content analysis and statistical techniques, Akbari et al. (2023) sought to link economy-led regeneration to Sanandaj's competitiveness. The study identified urban investment, tourism, the competitive development of land use, housing, and accessibility as major components of competitiveness-oriented regeneration, but remained focused on the city's internal capabilities and conditions. Addressing the weak economic competitiveness of border cities, Rahnam and Sofalgar (2025) proposed the sharing economy to enhance Birjand's competitiveness. Through expert interviews and cross-impact analysis, they found that sustainable consumption patterns, job creation, digital platforms, and efficient resource use are among the city's most important drivers of competitiveness.

Composite-index approaches have also been used to rank and compare regional competitiveness (Bahmanpour Khalesi & Aminzadeh Goharrizi, 2024). Alongside these approaches, some studies have applied regional economic tools, such as location quotients, shift-share analysis, and single-region input-output models, to examine industrial specialization and regional production linkages (Bahmanpour Khalesi & Nourian, 2017). To explain Kermanshah's inability to transform its border location and its historical and tourism assets into competitive advantage, Behdost et al. (2025) used an expert survey and the Meta-SWOT method. Their findings identified historical and natural attractions, cultural similarities with Iraq and Turkey, and local culture as major assets, while sanctions, limited financial resources, and weak institutional coordination were among the most significant barriers to Kermanshah's tourism competitiveness.

Despite their thematic and methodological diversity, most of these studies examine competitiveness in terms of the internal characteristics, resources, and capacities of individual regions. Consequently, they pay less attention to interregional economic relations, flows of goods and services, production dependencies, and interregional spillover and feedback effects in the formation of competitiveness. The theoretical gap addressed by the present study is therefore the explanation of competitiveness not merely as an internal regional attribute, but as an outcome of a region's position within a network of interregional economic relations and interactions. In this respect, multiregional input-output analysis is one of the most important analytical tools for examining the structure of economic interdependencies among regions. It enables the systematic analysis of intersectoral and interregional relations and the measurement of the internal, spillover, and feedback effects of economic activity (Shadabfar et al., 2020). Unlike composite-index or statistical approaches, the multiregional input-output model analyzes competitiveness through the actual structure of economic exchanges and production linkages, thereby allowing for the identification of relative positions of sectors (and regions) within the national production network (Yoo, 2003). From this perspective, spatial competitiveness can be understood not solely as an internal regional attribute, but as a function of a region's position within the economy's network structure. This issue is especially important for the Tehran Metropolitan Region, comprising Tehran and Alborz Provinces, which is the country's foremost economic pole. By concentrating a substantial share of economic activity, advanced services, and key infrastructure, the region plays a central role in the national economic structure. Iran's spatial development documents, including the National Spatial Planning Document and the spatial planning documents of Tehran and Alborz Provinces, likewise emphasize enhancing the region's competitive position at national and international scales (Plan and Budget Organization of Iran, Development and Foresight Research Center, 2020; Management and Planning Organization of Tehran Province, 2018; Management and Planning Organization of Alborz Province, 2019). As noted above, Iranian studies have concentrated mainly on regional internal characteristics or competitiveness rankings and have rarely analyzed the structure of interregional relations. This research gap limits a precise understanding of the spatial mechanisms through which competitiveness is formed and of the role regions play in the national economic network. Accordingly, this article asks: How can the structure and interregional effects of the Tehran Metropolitan Region be explained? More specifically, through which economic sectors, in relation to which regions, and through what types of relations does the Tehran Metropolitan Region affect other regional economies? What position does it occupy in the spatial structure of the national economy relative to other regions of Iran?

Epistemologically, this study adopts a positivist paradigm; methodologically, it is quantitative and applied. Because it focuses on the structure of spatial dependencies and the identification of reciprocal interregional effects, it is also exploratory. Its principal objective is to analyze the structure and interregional effects of the Tehran Metropolitan Region's spatial competitiveness within the national economy. The study examines the region's interactions with the rest of Iran in 2021. The analysis draws on official data from the Statistical Center of Iran, including the national and regional accounts for 2021 and the national input-output table for 2016. These data provide the basis for estimating a multiregional input-output structure and analyzing spatial linkages and effects among the country's regions. The article first reviews Porter's theoretical framework of competitiveness and the role of the multiregional input-output model in analyzing regional economic structures. It then uses official data from the Statistical Center of Iran to construct a seven-region input-output table for 2021. It analyzes the economic relations of the Tehran Metropolitan Region, with respect to Iran's northern territorial zone. After presenting Porter's perspective on competitiveness, the article considers how input-output analysis can operationalize relevant elements of his model. It then explains multiplier decomposition and spatial backward and forward linkage indices before analyzing the Tehran Metropolitan Region and presenting the results. The findings can clarify the region's position within the national economy's spatial structure and inform regional development policies to strengthen interregional linkages and enhance spatial competitiveness.

2. Theoretical and empirical background

The conceptual roots of regional competitiveness can be traced to classical theories of international trade, particularly the work of Adam Smith and David Ricardo. In his theory of absolute advantage, Smith argued that countries should specialize in producing goods in which they are more efficient than other countries, because such specialization increases productivity and welfare through international trade. Ricardo's theory of comparative advantage, however, demonstrated that even a country that is less efficient than others in producing every good can still benefit from trade, provided that it specializes in goods for which it incurs the lowest relative cost. In other words, countries should specialize in goods for which they have the lowest opportunity cost, thereby obtaining the benefits of reciprocal trade (Kirjavainen & Saukkonen, 2020). Notwithstanding its importance in explaining trade patterns, comparative advantage theory has several limitations. First, production and exchange advantages depend on complex factors, including technology, industrial structure, institutions, and environmental conditions, and cannot be explained solely by cost differentials. Second, comparative advantage focuses mainly on differences between countries and affords only limited consideration to spatial structures, industrial agglomerations, and interactions among firms and regions. Third, it is relatively static and devotes insufficient attention to the dynamics of innovation, learning, and structural economic change. Moreover, selecting indicators and determinants of comparative advantage presents challenges in many empirical applications, as these factors can vary depending on the analytical frameworks and levels of analysis (Kirjavainen & Saukkonen, 2020). These limitations led to the development of competitive advantage as a dynamic framework for explaining the economic performance of countries and regions.

Against this background, Michael Porter extended the theory of competitive advantage, previously applied mainly at the firm level, to countries and places in the 1990s. Challenging classical assumptions such as homogeneous technology, uniform factors of production, and the limited role of the local environment, Porter argued that competitiveness in the modern economy depends primarily on firm productivity and the economic environment in which firms operate (Sharifzadegan & Nedaei Toosi, 2015). In his view, macroeconomic conditions, such as economic stability and access to resources, are necessary but insufficient to ensure competitiveness; the local environment, industrial structure, and intensity of domestic rivalry play decisive roles in creating competitive advantage (Porter, 1990, p. 73).

Porter's framework rests on several key propositions. First, competitiveness in a modern economy is not based solely on access to natural resources or inexpensive labor, but on firms' capacity to enhance productivity and innovate. Second, relative factor scarcity can itself stimulate innovation and technological upgrading. Third, sustained economic growth requires continuous productivity improvement. Fourth, the ultimate purpose of competitiveness is to enhance citizens' welfare and standard of living. Finally, productivity depends not only on the characteristics of a particular industry but also on the economic environment, institutional structure, and locational conditions in which firms operate (Porter, 1990, p. 73).

On this basis, Porter proposed the diamond model of national competitive advantage, comprising four main determinants. The first is the conditions of production factors, including human resources, infrastructure, capital, and technological capabilities. Porter emphasizes that advanced factors, such as skilled labor and technological capacity, are more important than basic factors (Porter, 1990, p. 74). The second is demand conditions, referring to the characteristics and sophistication of domestic demand. Sophisticated domestic demand can encourage firms to innovate and improve product quality (Porter, 1990, p. 75). The third is related and supporting industries: the presence of capable suppliers and complementary industries enhances productivity and innovation (Porter, 1990, p. 77). The fourth is firm strategy, structure, and rivalry, which shape how firms are organized and perform. Intense domestic rivalry can drive firms toward innovation and higher productivity (Porter, 1990, p. 78).

Two complementary factors also operate within this framework: government and chance. Through public policy, infrastructure, education, and legal frameworks, government can create the conditions required to enhance competitiveness, although it does not directly create competitive advantage (Porter, 1990, p. 79). Chance encompasses events beyond firms' control, such as technological change, economic shocks, and shifts in global markets, which can alter competitive patterns (Porter, 1990, p. 300). Porter stresses that patterns of national success are not random; rather, they result from systematic interactions among these factors (Porter, 1990, p. 293).

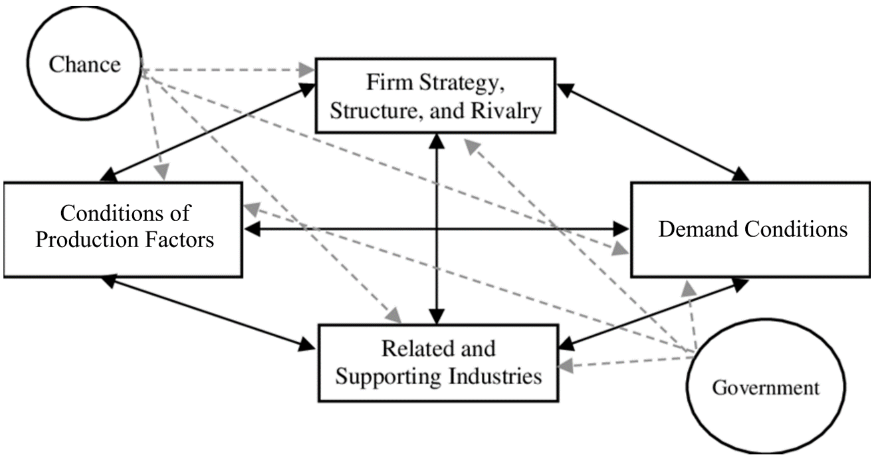

Figure 1. Porter's diamond model of competitiveness (Porter, 1990, p. 127).

Porter also identifies three principal stages in the development of national competitiveness. In the first, competitiveness is factor-driven, and countries rely primarily on natural resources and unskilled labor. In the second, competitiveness is investment-driven, with infrastructure development, industrial investment, and economies of scale playing important roles. In the third, competitiveness is innovation-driven, and countries achieve competitive advantage by developing technological capabilities, fostering innovation, and raising productivity (Porter, 1990, p. 302). Competitiveness is therefore a dynamic process in which competitive advantage is created and sustained through innovation and continuous improvement (Porter, 1990, p. 303). Ultimately, Porter directly associates competitiveness with productivity, stating that productivity is the only meaningful concept of competitiveness at the national level. A nation's principal goal is to achieve a high standard of living for its citizens, and productivity is the most important determinant of long-term living standards. A country's standard of living depends on the ability of its firms to attain high levels of productivity and improve them over time (Porter, 1990, p. 6).

From a spatial perspective, Porter places particular emphasis on the role of clusters in enhancing competitiveness. In his article, "Location, competition, and economic development: Local clusters in a global economy," he notes that resources, capital, technology, and other inputs can now be readily sourced from global markets, while corporate networks allow firms to access otherwise immobile inputs. These developments have reduced the need for geographic proximity to large markets and have led some observers to conclude that location has become less important to competitiveness. Cluster theory nevertheless maintains that the geographic concentration of interconnected firms, specialized suppliers, service providers, and associated institutions, such as universities and trade associations, in a particular field continues to play a critical role in competitive success. Such clusters, found in most advanced national, regional, and urban economies, function as centers of unusually strong competitive performance. Porter argues that clusters influence competitiveness in three principal ways: first, by raising firm productivity through improved access to inputs, specialized labor, and expert information; second, by strengthening innovative capacity through interaction among firms and related institutions; and third, by facilitating the creation of new firms and the development of new economic activities (Porter, 2000). In this framework, clusters are spatially organized systems that play a major role in creating and reinforcing competitive advantage.

A study conducted at the University of North Carolina at Chapel Hill reviewed various methods for identifying industrial clusters. It analyzed a range of analytical approaches to their detection and assessment. Drawing on theoretical perspectives and empirical evidence, the study offered a comprehensive classification of cluster analysis methods proposed by different researchers (Table 1).

Table 1. Methods for measuring industrial clusters in competitiveness analysis, based on Yoo (2003)

Method	Description	Applications	Advantages	Limitations	Applied examples
Expert opinion	Data collection through in-depth interviews, focus-group discussions, and the Delphi technique to identify industrial clusters	Qualitative analysis, industrial policy formulation, and identification of regional industries' strengths and weaknesses	Low cost and rapid implementation	Subjective and dependent on individual viewpoints	Empirical cluster studies based on interviews with industrial managers
			Suitable for qualitative and local analysis	Potential bias in expert selection	
			Can identify new patterns in emerging industries	Limited generalizability	
Location quotient (LQ)	Compares an industry's regional share of employment or value added with the national average. An LQ greater than 1 indicates regional industrial concentration.	Economic and regional planning studies; identification of leading industries	Simple and inexpensive	Does not account for intersectoral relations	Analysis of sectoral industrial concentration based on employment share relative to the national total
			Suitable for preliminary analysis	Limited precision in high-level analysis	
			Can be applied using employment and output data	Requires accurate regional data	

Method	Description	Applications	Advantages	Limitations	Applied examples
Input-output analysis	Examines economic relations among industries through input-output flows; reveals interdependencies among production sectors.	Supply-chain analysis, industrial policy development, and identification of key economic sectors	Precise analysis of inter-sectoral relations Suitable for macroeconomic studies Can identify leading industries	Requires extensive, detailed data High computational complexity	Analysis of economic structure
Network analysis	Examines relations and dependencies among firms and economic sectors using network models	Studies of industrial-cluster dynamics and interfirm relations	Can be combined with other methods In-depth analysis of intra-cluster linkages Suitable for industries based on network interactions	Requires extensive data on interfirm relations Complex interpretation of results	Identifying dependencies among producers
Shift-share analysis	Examines regional changes in employment or output relative to national change to identify industrial growth and decline	Identification of rapidly growing industries and analysis of regional employment trends	Can identify emerging clusters Suitable for dynamic analysis	Cannot explain the causes of change Must be combined with other methods for deeper analysis	Analysis of sectoral growth relative to national trends
Correspondence analysis	A multivariate statistical method for examining relationships among categories of data	Analysis of innovative industrial clusters and identification of interindustry relations	Visually represents industrial relations Suitable for analyzing technology clusters	Requires accurate industrial-classification data Complex analysis and interpretation	Analysis of intersectoral relationships
Graph analysis	Uses graph theory to identify network relations among firms, suppliers, and economic institutions	Analysis of interaction-based industrial clusters and modeling of information flows	Can identify new clusters In-depth analysis of industrial relations	Requires specialized software Difficult to interpret results	Analysis of intersectoral relationships
Qualitative case-study method	Qualitative examination of industrial clusters through empirical studies, interviews, and document analysis	Industrial policy studies and analysis of emerging clusters	Provides in-depth analysis of specific contexts Suitable for policy studies	Limited generalizability Requires extensive qualitative data	Identifying clusters as a complementary method

The table shows that methods for measuring competitiveness encompass a continuum ranging from perception-based qualitative tools, such as expert opinion and case studies, to quantitative methods grounded in economic structure, such as input-output analysis. Location quotients and shift-share analysis are used primarily to identify industrial concentration or relative industrial dynamics, but cannot explain structural relations and interdependencies among economic sectors. Input-output analysis, by contrast, provides a systematic framework for measuring backward and forward linkages and multiplier effects, enabling the identification of key industries and analysis of the internal structure of a regional production system. This makes input-output analysis well-suited to operationalizing Porter's perspective, because his theory of competitive advantage and industrial clusters defines competitiveness not as an isolated attribute of an industry, but as the outcome of a system of related and supporting industries. By quantitatively measuring the intensity and direction of intersectoral relations, input-output analysis permits the empirical identification of the economy's cluster structure, leading sectors, and the structural foundations of regional competitiveness. It can therefore serve as a coherent analytical framework for assessing regional competitiveness within Porter's theoretical model.

Despite the importance of Porter's contribution to the conceptualization of competitiveness, his approach has also been criticized. Critiquing the application of competitiveness to countries, Krugman (1994) argued that national or regional economies should not be treated like firms competing in a zero-sum game, because economic welfare depends more on productivity and internal economic capacity than on defeating rivals. Similarly, Kitson, Martin, and Tyler (2004) characterized regional competitiveness as important but multidimensional and elusive, requiring analysis in relation to economic structure, institutions, the quality of place, and long-term development capacity. Aiginger (2006), redefining competitiveness as the capacity to create welfare and generate positive externalities, likewise considered a narrow focus on costs, exports, and market share inadequate. Accordingly, the present article does not treat Porter's model as a complete or definitive explanation of competitiveness. Instead, it uses the model as an analytical framework for examining two specific dimensions of the Tehran Metropolitan Region's spatial competitiveness: "related and supporting industries" and "demand conditions." From this perspective, multiregional input-output analysis can reveal the structural and network-based capacity underlying Tehran's competitiveness without claiming to measure its technological, institutional, service-related, and welfare dimensions in their entirety.

3. Methodology

As noted in the introduction, this study is situated within a positivist paradigm and is quantitative, applied, and exploratory in methodological terms. The study area comprises the Tehran Metropolitan Region and its economic interactions with other regions of Iran in 2021. Data were obtained from the national and regional accounts for 2021 and the national input-output table for 2016, published by the Statistical Center of Iran, and were used to estimate the multiregional input-output model and analyze spatial linkages. To construct a seven-region input-output table for 2021, single-region input-output tables were first estimated using the FLQ-RAS method. Developed by Banouei et al. (2017) and tailored to the structure of Iran's regional accounts, this method allows for the adaptation of regional input-output matrices to regional accounts. A gravity model was then used to estimate interregional trade flows and construct the seven-region input-output table (see Miller & Blair, 2022, p. 365). Because the study's principal objective is to analyze the interregional structure and effects of the Tehran Metropolitan Region's spatial competitiveness within the national economy, the following sections discuss two main analytical methods: first, multiplier decomposition to distinguish intraregional, spillover, and feedback effects; and second, spatial backward and forward linkages to analyze the structural position of regions within Iran's interregional production and exchange network.

3.1. Multiplier decomposition: Intraregional, spill-over, and feedback effects

A multiregional input-output table represents production, intermediate consumption, and interregional transactions as a block matrix, thereby enabling the analysis of economic flows among regions. Unlike conventional input-output models, which examine only intersectoral relations within a national economy, a multiregional model can reveal spatial dependencies and the intensity of economic interconnectedness among regions. In this framework, spatial linkages indicate the extent to which regions depend on interregional production and supply networks and identify the roles of these regions in the spatial structure of the national economy. This study divides the country's economy into seven regions and models trade relations among these regions using an interregional technical-coefficient matrix. The general structure of the technical-coefficient matrix for the seven regions is defined as follows:

Equation 1

$$a_{ij}^{rs} = \frac{Z_{ij}^{rs}}{x_j^s}$$

a_{ij}^{rs} is the technical coefficient for the input from sector i in region r used to produce the output of sector j in region s; Z_{ij}^{rs} is the intermediate flow from sector i in region r to sector j in region s; and x_j^s is the total output of sector j in region s.

Equation 2

$$A = \begin{bmatrix} a^{11} & a^{12} & \cdots & a^{17} \\ a^{21} & a^{22} & \cdots & a^{27} \\ \vdots & \vdots & \ddots & \vdots \\ a^{71} & a^{72} & \cdots & a^{77} \end{bmatrix}$$

Here, A_{rr} denotes the intraregional technical coefficient matrix for region r, while A_{rs} denotes the flow of intermediate inputs from region r to region s. The structure therefore simultaneously captures the economy's intraregional and interregional dependencies. Under the standard Leontief model, the production-balance equation for the multiregional input-output model is expressed as follows:

Equation 3

$$\mathrm{x} = \mathrm{Ax} + \mathrm{y}$$

Here, x is the vector of total regional outputs, A is the multiregional technical coefficient matrix, and y is the final-demand vector. Solving the equation for total output yields:

Equation 4

$$\mathrm{x} = (\mathrm{I} - \mathrm{A})^{-1}\mathrm{y}$$

where I is the identity matrix and the Leontief inverse is defined as:

Equation 5

$$L = (I - A)^{-1}$$

This matrix captures the total direct and indirect effects of changes in final demand on production across regions. It provides the basis for decomposing multipliers into intraregional, spillover, and feedback effects, as well as for measuring spatial backward and forward linkages in this study. The general form of the Leontief inverse for the seven-region structure can be represented as follows:

Equation 6

$$L = \begin{bmatrix} l^{11} & l^{12} & \cdots & l^{17} \\ l^{21} & l^{22} & \cdots & l^{27} \\ \vdots & \vdots & \ddots & \vdots \\ l^{71} & l^{72} & \cdots & l^{77} \end{bmatrix}$$

Multiplier decomposition was used to distinguish the structure of spatial effects. The method separates economic effects into three principal components: intraregional, spillover, and feedback effects. First, the intraregional Leontief inverse for each region (M^{rr}) was calculated as follows:

Equation 7

$$M^{rr} = (I - A^{rr})^{-1} \qquad r = 1,2,\dots,7$$

This matrix represents the direct and indirect effects of each region's final demand within that region solely. Interregional spillover effects (S^{rs}) were then calculated. Spillover effects indicate the extent to which increased production in one region raises demand for inputs produced in other regions. The interregional spillover matrix is defined as follows:

Equation 8

$$S^{rs} = M^{rr}A^{rs} \qquad r \neq s$$

A feedback effect occurs when an increase in final demand in one region is first transmitted to other regions through production linkages and intermediate transactions and subsequently returns to the originating region through direct or indirect pathways. Unlike the intraregional effect, which considers only relations internal to a region, the feedback effect represents the portion of production effects generated by a region's interdependence with other regions and the subsequent return of production flows to that region. Accordingly, the feedback effect for each region equals the difference between the corresponding diagonal block of the multiregional Leontief inverse and the Leontief inverse of that region when treated independently (Miller & Blair, 2022, pp. 285-288).

Equation 9

$$F^{r} = L^{rr} - (I - A^{rr})^{-1}$$

For seven regions, multiplier decomposition is generalized from the two-region case to a 7×7 block matrix. The general relationship can therefore be rewritten as follows:

Equation 10

$$\begin{bmatrix} x^1 \\ x^2 \\ x^3 \\ x^4 \\ x^5 \\ x^6 \\ x^7 \end{bmatrix} = \begin{bmatrix} F^1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & F^2 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & F^3 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & F^4 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & F^5 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & F^6 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & F^7 \end{bmatrix} \times \begin{bmatrix} 1 & S^{12} & S^{13} & S^{14} & S^{15} & S^{16} & S^{17} \\ S^{21} & 1 & S^{23} & S^{24} & S^{25} & S^{26} & S^{27} \\ S^{31} & S^{32} & 1 & S^{34} & S^{35} & S^{36} & S^{37} \\ S^{41} & S^{42} & S^{43} & 1 & S^{45} & S^{46} & S^{47} \\ S^{51} & S^{52} & S^{53} & S^{54} & 1 & S^{56} & S^{57} \\ S^{61} & S^{62} & S^{63} & S^{64} & S^{65} & 1 & S^{67} \\ S^{71} & S^{72} & S^{73} & S^{74} & S^{75} & S^{76} & 1 \end{bmatrix} \times \begin{bmatrix} M^1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & M^2 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & M^3 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & M^4 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & M^5 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & M^6 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & M^7 \end{bmatrix} \begin{bmatrix} f^1 \\ f^2 \\ f^3 \\ f^4 \\ f^5 \\ f^6 \\ f^7 \end{bmatrix}$$

In this structure, the first matrix represents feedback effects, the second interregional spillover effects, and the third each region's intraregional effects. The total output of each region therefore results from the simultaneous interaction of intraregional effects, spatial spillovers, and interregional feedbacks within the national economic network.

3.2. Spatial backward and forward linkages

The spatial backward linkage index was calculated to assess regions' structural positions in the national economy and the intensity of their demand-side dependencies. Backward linkage indicates the extent to which an increase in final demand in one region stimulates production and demand for intermediate inputs in other regions. The index is derived from the column sums of the Leontief inverse matrix in Equation 6.

Equation 11

$$BL_j = \sum_{i=1}^{7} l_{ij}$$

where l_{ij} denotes the elements of the Leontief inverse matrix. To facilitate comparison among regions, backward linkage values are normalized as follows:

Equation 12

$$NBL_j = \frac{BL_j}{\frac{1}{7}\sum_{j=1}^{7} B\,L_j}$$

A value greater than one indicates that the region has above-average capacity to stimulate demand and activate the interregional supply chain.

For the analysis of spatial forward linkages, the Ghosh allocation coefficient matrix is first calculated. Whereas the Leontief technical coefficient matrix is constructed by dividing each column of intermediate transactions by the purchasing sector's output, the Ghosh matrix is calculated by dividing each row of intermediate transactions by the supplying sector's output. Thus, coefficient b_{ij}^{rs} is obtained by dividing the intermediate sales of sector i in region r to sector j in region s, denoted by z_{ij}^{rs}, by the total output of sector i in region r, denoted by x_i^r:

Equation 13

$$b_{ij}^{rs} = \frac{z_{ij}^{rs}}{x_i^r}$$

This coefficient indicates the share of the total output of sector i in region r allocated as an intermediate input to sector j in region s. Each Ghosh coefficient thus describes the distribution of a sector-region's output across other sectors and regions. In other words, it indicates the extent to which each region supplies intermediate inputs to other regions and, through this role, its position within the national supply network. The Ghosh coefficients for all regions are then organized as a block matrix. Because the national economy is divided into seven regions in this study, matrix B comprises 49 regional blocks:

Equation 14

$$B = \begin{bmatrix} b^{11} & b^{12} & \cdots & b^{17} \\ b^{21} & b^{22} & \cdots & b^{27} \\ \vdots & \vdots & \ddots & \vdots \\ b^{71} & b^{72} & \cdots & b^{77} \end{bmatrix}$$

In this matrix, diagonal blocks such as b^{11}, ... and b^{77} represent intraregional supply relations, whereas off-diagonal blocks such as b^{12}, b^{25}, and b^{71} represent interregional supply flows. For example, b^{12} shows how the intermediate output of Region 1 is distributed among the sectors of Region 2. The block structure of matrix B therefore enables the simultaneous analysis of intraregional and interregional linkages. Once the Ghosh coefficient matrix has been constructed, the Ghosh inverse is calculated as follows:

Equation 15

$$G = (I - B)^{-1}$$

Here, I is the identity matrix, and B is the Ghosh coefficient matrix. Matrix G captures direct and indirect supply-side effects throughout the multiregional system. Whereas matrix B represents only the direct distribution of production among regions, matrix G reveals the full chain of supply-side effects in the national economy. The elements of this matrix, g_{ij}, form the basis for calculating spatial forward linkages. The forward linkage index is obtained from the row sums of the Ghosh inverse, because each row sum indicates the extent to which an increase in supply in one region can affect other regions and sectors.

Equation 16

$$FL_i = \sum_{j=1}^{7} g_{ij}$$

where g_{ij} denotes the elements of the Ghosh inverse. The normalized forward linkage index is calculated as follows:

Equation 17

$$NFL_i = \frac{FL_i}{\frac{1}{7}\sum_{i=1}^{7} F\,L_i}$$

A value greater than one indicates that the region plays an above-average role in supplying intermediate inputs and generating production spillovers in the national economy (Miller & Blair, 2022, pp. 555-563).

4. Results and discussion

4.1. Updating the 2016 national input-output table to 2021

Given the analytical purpose of the study and the limited availability of complete, directly observed interprovincial trade data, the first step organized Iran's spatial structure into a set of functional economic regions. Provinces constituted the initial units of analysis. The regionalization sought to group provinces with the strongest potential economic interactions, functional proximity, and spatial continuity. Data for this stage were obtained from the Statistical Center of Iran's statistical yearbooks for 2021.

A gravity model was used to estimate the intensity of potential interactions among provinces. Each province's total output served as an indicator of economic size, while road-freight shipments from each province to all others measured functional distance or proximity. Rather than relying solely on geometric distance between provincial capitals, the analysis thus incorporated a more realistic measure of functional connectivity based on actual commodity flows within the road transport network. After the potential interaction index was calculated for each pair of provinces, the values were standardized to the range 0-1 using min-max normalization. The normalized gravity-model output was then imported into GIS, where inverse distance weighting (IDW) interpolation was used to represent the spatial pattern of functional interaction intensity among provinces. In the final stage, the interaction matrix and its spatial classification were evaluated against two constraints: territorial adjacency and geographic continuity. Provinces were grouped into a single region only when they displayed strong economic and functional linkages and could also form a coherent, contiguous geographic zone. On this basis, the national economy was divided into seven homogeneous regions, whose spatial composition is presented in Table 2.

Table 2. Regionalization of Iran based on economic homogeneity

Region code	Member provinces	Region label
R1	Tehran and Alborz	TEH-ALB
R2	Mazandaran, Qazvin, Markazi, and Qom	MAZ-QAZ-MAR-QOM
R3	North Khorasan, Golestan, and Semnan	NKH-GOL-SEM
R4	Gilan, Ardabil, and Zanjan	GIL-ARD-ZAN
R5	Razavi Khorasan	RKH
R6	East and West Azerbaijan	EAZ-WAZ
R7	Other provinces of Iran	OTH-SOU

This regionalization provides an appropriate basis for analyzing interregional dependencies and deriving the spillover and feedback effects of the Tehran Metropolitan Region at the national scale. The study uses three statistical bases: the national accounts for 2021, the regional accounts for 2021, and a national table updated to 2021 from the 2016 statistical table using the RAS method. Numerical computations were performed in Google Colab using Python. The Pandas and openpyxl libraries were used to manage data and Excel files; NumPy was used for matrix and algebraic operations; and NumPy and SciPy were used for numerical computation, sensitivity analysis, and error metrics. Matplotlib was used to plot error measures, convergence, and analytical results.

In addition to spatial regionalization, selecting the level of economic sectors disaggregation is a fundamental step in estimating a multiregional input-output model. This study defines 17 economic sectors for each region. This level of aggregation reflects two principal considerations: the study's analytical objectives and its data and computational constraints. It preserves the capacity for structural economic analysis while allowing stable model estimation. The base year is 2021. Because the most recent official input-output table published by the Statistical Center of Iran is for 2016, the table was first updated to 2021 using the RAS method. RAS is among the most widely used methods for adjusting and updating input-output tables to reconcile the technical coefficient matrix with new row and column information. The new technical coefficient matrix A_{2021} is estimated by adjusting the initial matrix A_{2016} using the two diagonal matrices of row and column adjustment coefficients, $[\hat{r}_n \cdots \hat{r}_1]$ and $[\hat{s}_1 \cdots \hat{s}_n]$, respectively. The row adjustment matrix aligns row totals with the new information, while the column adjustment matrix adjusts column totals. Consequently, the initial technological structure and relative economic relationships are largely preserved, while the final matrix is reconciled with the new statistical constraints (Figure 2) (Miller & Blair, 2009, pp. 313-315).

Equation 18

$$A_{1400} = [\hat{r}_n \cdots \hat{r}_1]\, A(1395)\, [\hat{s}_1 \cdots \hat{s}_n]$$

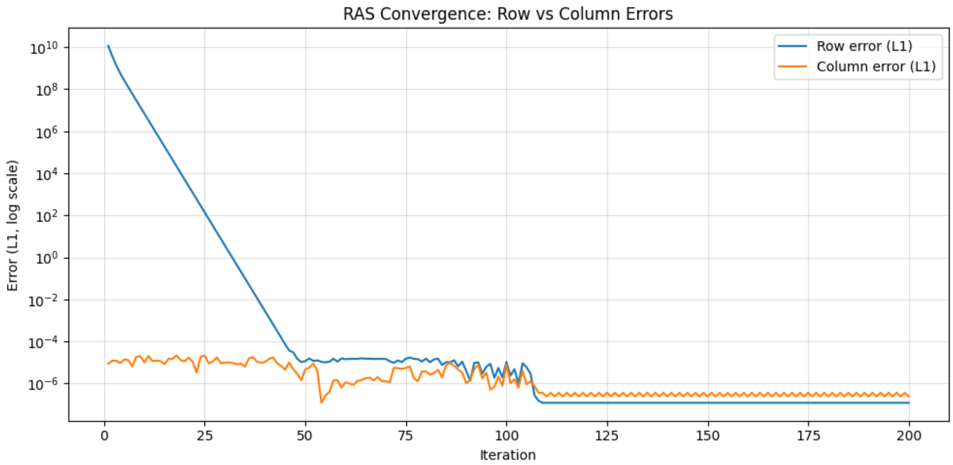

Figure 2. Row and column convergence of the updated 2021 national table

4.2. Regionalizing the national domestic table and selecting the appropriate delta

After calculating the nationally updated 2021 table, regional tables were estimated. In the literature on estimating regional input-output tables from national coefficients, delta (δ) is a calibration parameter in the Flegg location quotient/augmented Flegg location Quotient (FLQ/AFLQ) family of methods. It determines the extent to which national technical coefficients are reduced when estimating regional coefficients. The economic rationale is that the smaller a region is relative to the national economy, the larger the share of its intermediate demand that it sources from outside the region through imports from other regions. Applying unadjusted national coefficients would therefore overestimate intraregional transactions. Delta controls this adjustment by determining the strength with which regional size affects inter-sectoral coefficients.

Within the FLQ method, a size-based coefficient, λ, is first constructed as a function of the ratio of the regional economy to the national economy, such as the ratio of regional to national output or employment, and is adjusted by delta. Its common form is presented below. Delta therefore indirectly affects the entire A^r matrix through λ and then FLQ, determining how regional economic patterns are reconstructed from the national pattern. Methodologically, δ is not a simple statistical parameter that can usually be derived uniquely from available data. It should instead be estimated from regional statistical surveys. In Iran, however, such surveys are scarce and limited, and the data required to estimate delta are effectively unavailable. Iran's regional accounts nevertheless allow estimation of delta by comparing estimated output with actual output reported in the regional accounts. The standard procedure for determining delta in this study is therefore a search-and-optimization process (Bazzazan et al., 2007). The updated 2021 national matrix was converted into the 2021 domestic matrix using the "proportional-import and self-sufficiency coefficient" method. Rather than treating imports as a single aggregate, this method divides them into intermediate consumption, final consumption, and capital (Banouei, 2012). The optimal was then selected using the supply-driven Ghosh model. The supply-side Ghosh models for periods t and t+1 are as follows:

Equation 19

$$O_t^r = V_t^r (I - B_t^r)^{-1}$$
$$\hat{O}_{t+1}^r = V_{t+1}^r (I - B_t^r)^{-1}$$

Here, O_t^r and $\hat{O}_{t+1}^r$ denote regional sectoral output in periods t and t+1, respectively. B_t^r is the coefficient matrix obtained for period t and is defined as $B = \frac{z_{ij}^r}{z_i^r}$. V_t^r and V_{t+1}^r are the regional value-added vectors for periods t and t+1, respectively. The statistical error between estimated sectoral output and actual output is therefore defined as follows (Bazzazan et al., 2007):

Equation 20

$$E_t = \hat{O}_{t+1}^r - O_{t+1}^r$$

In the preceding equation, E_t is the absolute error vector obtained by subtracting the corresponding elements of the actual output vector in period t+1 from those of the estimated output vector for the same period. To evaluate the agreement between estimated and actual output more thoroughly, the following four statistical error measures were calculated (Bazzazan et al., 2007).

Table 3. Equations for the four error measures used to select the optimal delta (Bazzazan et al., 2007)

Weighted squared percentage error (WSPE)	Weighted absolute percentage error (WAPE)	Weighted percentage error (WPE)	Simple total error
$\mathrm{WSPE} = \sum_i w_i \left(\frac{\hat{O}_i - O_i}{O_i}\right)^2$	$\mathrm{WAPE} = \sum_i w_i \left\lvert \frac{\hat{O}_i - O_i}{O_i} \right\rvert$	$\mathrm{WPE} = \sum_i w_i \left(\frac{\hat{O}_i - O_i}{O_i}\right)$	$E = \sum_j E_j$

Figure 3 presents the numerical values of the four error measures and identifies the most appropriate delta for the Tehran Metropolitan Region.

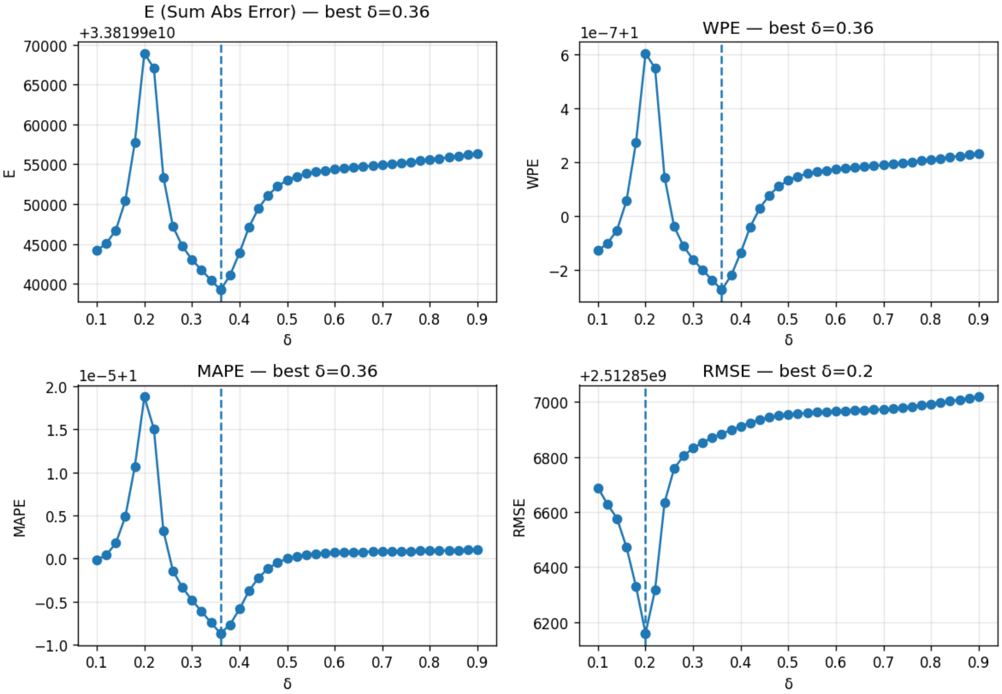

Figure 3. Selecting the optimal delta for the Tehran Metropolitan Region by minimizing four error measures

The most appropriate delta values for regionalizing the domestic national table across the seven regions were ultimately calculated as shown in Table 4.

Table 4. Optimal delta values calculated for the seven national regions

Region	Delta
R1	0.36
R2	0.26
R3	0.14
R4	0.22
R5	0.24
R6	0.16
R7	0.28

After the optimal delta had been determined, the FLQ-RAS method was used to construct a single-region input-output table for each region. All regional matrices converged. Figure 4 presents the convergence of the Tehran Metropolitan Region's domestic transactions matrix for 2021.

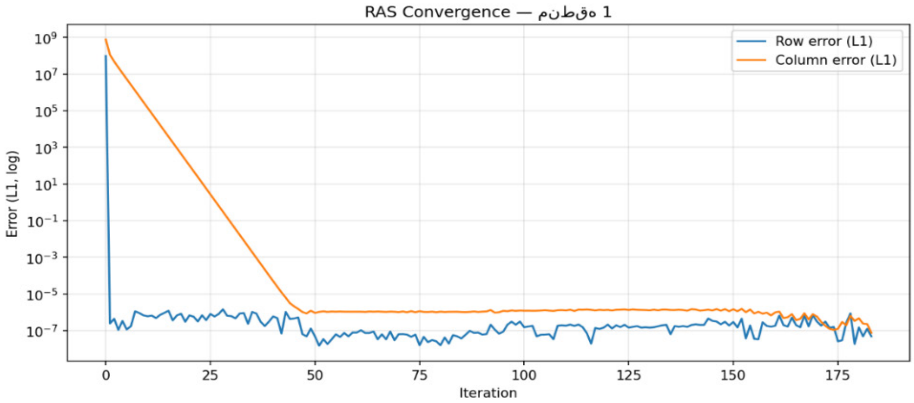

Figure 4. Row and column convergence of the single-region input-output table for the Tehran Metropolitan Region

4.3. Constructing the seven-region input-output table using the gravity method

A gravity model was used to construct the multiregional input-output table. By accounting for distance between regions, the model estimates interregional coefficients. Introduced by Leontief and Strout in 1963, its general form is as follows:

Equation 21

$$T_i^{rs} = \frac{x_i^r \cdot x_i^s}{x_i} * Q_i^{rs}$$

$$Q_i^{rs} = \frac{k_i^{rs}}{(d^{rs})^{e_i}}$$

Here, T_i^{rs} denotes the trade in sector i between regions r and s; x_i^r is the total supply of sector i in region r; x_i^s is the total demand for sector i in region s; x_i is the combined production of sector i in the two regions; and Q_i^{rs} is a component consisting of the constant k_i^{rs} and d^{rs} the distance between regions r and s. e_i denotes distance elasticity (Miller & Blair, 2022, p. 365). Interregional distance was operationalized as the ratio of intermediate expenditures between regions r and s. After the equation had been calculated, the entire table was rebalanced using RAS (Table 5 and Figure 5).

Table 5. Interregional distance matrix based on functional logic (ratios of interregional intermediate uses)

Region	R1	R2	R3	R4	R5	R6	R7
R1	0	0.96547383	0.99358346	0.98981428	0.990441	0.97934312	0.83929159
R2	0.89847466	0	0.98673118	0.9804961	0.98153282	0.9631744	0.73149705
R3	0.61511204	0.76893556	0	0.9172626	0.9210817	0.85345294	0.1
R4	0.7180401	0.83115671	0.95712189	0	0.94303984	0.89330794	0.26570749
R5	0.70487567	0.82319867	0.95496161	0.93729372	0	0.88821051	0.23172369
R6	0.83922293	0.90441308	0.97700798	0.96727384	0.96889237	0	0.57853946
R7	0.97933283	0.98911107	0.99	0.99853992	0.99878269	0.99448367	0

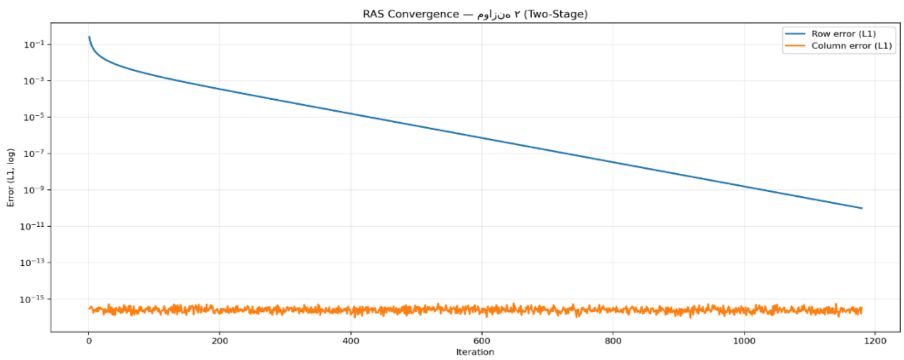

Figure 5. RAS convergence in estimating the 2021 seven-region national input-output matrix

4.4. Accounting validation and sensitivity analysis

An input-output model is accounting-analytical in nature, and its validation rests on the table's internal consistency, accounting balance, and the robustness of results to estimation assumptions. Two evaluations were therefore incorporated into the algorithm to assess the structural validity of the multiregional input-output table and the stability of the results with respect to regionalization assumptions. First, sensitivity to the delta parameter was analyzed during regionalization of the national table (Figure 3). Second, the accounting consistency of the seven-region input-output table was verified by checking the equality of row and column totals, the agreement between sector-region outputs and regional account data, the absence of negative values, and convergence of the RAS procedure. These evaluations indicate that the final table is reliable in terms of its accounting structure, internal consistency, and algorithmic stability.

4.5. Multiplier decomposition results: Intraregional, spillover, and feedback effects

Estimating the seven-region national input-output table for 2021 across 17 economic sectors enabled more precise examination of how the economic sectors of the Tehran Metropolitan Region affect both the region itself and other regions. Using the multiplier decomposition equations, the effect of one unit of investment in each economic sector of the Tehran Metropolitan Region was divided into three components: intraregional effects, spillover effects on other regions, and feedback effects arising from interregional interactions. These components indicate the capacity of each sector to activate production chains within the Tehran Metropolitan Region, the extent to which it stimulates demand for production in other regions, and the share of these effects that returns to the metropolitan economy after circulating through the interregional network.

From the perspective of regional competitiveness and in relation to Porter's model, this analysis can explain part of the structural capacity of industries in the Tehran Metropolitan Region to create competitive advantage. In Porter's diamond, competitiveness depends not merely on the size of the economy or volume of output, but on the quality of production linkages, the presence of related and supporting industries, demand capacity, clustering potential, and the ability to raise productivity. Multiplier decomposition can therefore identify which economic sectors in the Tehran Metropolitan Region have greater potential to play a competitive role based on their input-output linkages, intraregional effects, and relationships with other regions.

First, the intraregional effects of the Tehran Metropolitan Region capture the circulation, reinforcement, and activation of production chains within the region. Table 6 shows that chemicals, oil, agriculture, and construction have the largest intraregional effects. These sectors therefore have the greatest capacity to stimulate production chains within the region. They may be regarded as promising candidates for clustering and for creating production-based competitive advantage in the Tehran Metropolitan Region. Education, transportation, and professional and financial services, by contrast, produce moderate intraregional effects, reflecting their supporting role in the regional economic structure. Real estate, energy, and tourism display the smallest intraregional effects, which may indicate weaker linkages to the region's internal production chain or greater dependence on external demand and inputs. From a competitiveness policy perspective, sectors with stronger intraregional effects may therefore be more appropriate targets for strengthening production clusters, deepening value chains, and raising regional productivity.

Second, the spillover effects of the Tehran Metropolitan Region show the extent to which Tehran's economic activity stimulates production elsewhere in Iran. Within Porter's framework, this dimension can be interpreted in relation to "demand conditions." Increased investment or activity in Tehran can activate production in other regions by raising demand for inputs, intermediate goods, and producer services. Tehran's spillover effects thus represent more than the leakage of effects from the region; they also demonstrate Tehran's role as a center of demand, consumption, investment, and the organization of interregional production chains. According to Table 6, Tehran's economic activities exert their strongest spillover effects on the "Other southern regions of Iran (R7)," particularly by food manufacturing, chemicals, construction, and machinery, whose spillover coefficients exceed those of other sectors. Demand or investment in these Tehran sectors therefore significantly stimulates production in Iran's southern regions. The Mazandaran-Qazvin-Markazi-Qom Region and the East-West Azerbaijan Region rank next in their exposure to Tehran's spillovers. Razavi Khorasan and the Gilan-Ardabil-Zanjan Region exhibit the least exposure, indicating weaker connections to Tehran's demand and production cycle. Overall, the concentration of spillovers in basic industrial and construction sectors indicates that Tehran's demand has its strongest effects on activities that require intermediate inputs, raw materials, and production capacity located outside Tehran.

Third, the feedback effects of the Tehran Metropolitan Region represent the portion of economic effects that returns to Tehran through interregional production chains after initially spilling over to other regions. This component is important for understanding Tehran's position in the network. It shows that Tehran not only stimulates demand in other regions, but also recaptures part of the benefits generated by activating production elsewhere through renewed demand for its own inputs, services, or products. In Porter's competitiveness framework, feedback effects may be interpreted as an indicator of Tehran's embeddedness in the national production network and its capacity to recapture value generated in interregional chains. Table 6 shows that chemicals, machinery, food manufacturing, and construction produce the strongest feedback effects. Growth in output or investment in these sectors first stimulates other regions; then, part of that production stimulus returns to Tehran through renewed demand for its inputs and services. Real estate, education, health, and tourism have the smallest feedback coefficients, indicating the more localized character of these activities and their weaker linkages to the interregional production network.

Table 6. Multiplier decomposition results: Intraregional, spillover, and feedback effects

Region/effect		AGR	PET	FOO	CHM	MAC	ENE	CON	TRD	TRN	TOU	TEL	FIN	REA	PRO	ADM	EDU	HEA
Intraregional effects of the Tehran metropolitan region	R1 (THE-ALB)	1/368636	1/508902	1/364246	1/368634	1/251995	1/044781	1/233207	1/060956	1/122576	1/040258	1/070931	1/071759	1/006364	1/092656	1/180795	1/125808	1/053656
Spillover effects of the Tehran metropolitan region on other regions	Spillover TEH-ALB → MAZ-QAZ-ARQ-QOM	0/000193	0/000162	0/000904	0/000889	0/001053	0/000285	0/000996	0/000124	0/000471	0/000209	0/000464	0/000373	0/000022	0/000465	0/000376	0/000165	0/000154
Spillover effects of the Tehran metropolitan region on other regions	Spillover TEH-ALB → NKH-GOL-SEM	0/000009	0/000008	0/000044	0/000043	0/000051	0/000014	0/000048	0/000006	0/000023	0/000010	0/000022	0/000018	0/000002	0/000023	0/000012	0/000008	0/000007
Spillover effects of the Tehran metropolitan region on other regions	Spillover TEH-ALB → GIL-ARD-ZAN	0/000028	0/000023	0/000130	0/000128	0/000153	0/000041	0/000144	0/000018	0/000069	0/000030	0/000067	0/000054	0/000005	0/000067	0/000040	0/000024	0/000021
Spillover effects of the Tehran metropolitan region on other regions	Spillover TEH-ALB → RKH	0/000019	0/000016	0/000089	0/000087	0/000102	0/000028	0/000098	0/000012	0/000047	0/000021	0/000045	0/000037	0/000003	0/000046	0/000027	0/000016	0/000014
Spillover effects of the Tehran metropolitan region on other regions	Spillover TEH-ALB → EAZ-WAZ	0/000120	0/000101	0/000560	0/000551	0/000652	0/000176	0/000617	0/000077	0/000295	0/000130	0/000288	0/000231	0/000020	0/000288	0/000171	0/000102	0/000089
Spillover effects of the Tehran metropolitan region on other regions	Spillover TEH-ALB → OTH-SOU	0/089470	0/071351	0/398281	0/391642	0/462461	0/125285	0/438227	0/058090	0/209057	0/092157	0/204460	0/164506	0/014225	0/204761	0/121742	0/077744	0/062019
Feedback effects of the Tehran metropolitan region	Feedback R1 (TEH-ALB)	0/025030	0/006624	0/035516	0/060694	0/042006	0/013368	0/024891	0/013284	0/014984	0/006287	0/010017	0/009274	0/001596	0/010148	0/011386	0/005149	0/005886

Overall, multiplier decomposition shows that the Tehran Metropolitan Region possesses differentiated sectoral capacities in terms of production structure and connections to the national economic network. Strong intraregional effects in chemicals, oil, agriculture, and construction indicate these sectors' capacity to activate internal production chains and form production clusters. Spillover effects show that demand and investment in Tehran, particularly in industrial and construction sectors, can stimulate production elsewhere and position Tehran as a major organizer of interregional demand. Feedback effects further indicate that part of these spillovers returns to Tehran's economy, strengthening the network role of its more highly connected sectors. Viewed through Porter's model, these findings demonstrate the capacity of selected Tehran sectors in related and supporting industries, production linkages, and value-chain activation.

4.6. Spatial backward and forward linkage results

A further means of understanding the Tehran Metropolitan Region's spatial position relative to other regions is to calculate spatial backward and forward linkage indices for all seven regions. Figure 6 shows the structural position of the seven regional economies within the multiregional input-output table. All economic sectors within each region are aggregated; each point therefore represents the position of the region's entire economy in the interregional production and exchange network, rather than its internal sectoral structure. This analysis helps clarify each region's role in the national division of labor, its position in the production chain, and its structural capacity for regional competitiveness.

In Figure 6, the horizontal axis represents the normalized forward linkage index (NFL), and the vertical axis represents the normalized backward linkage index (NBL). Bubble size indicates each region's total output. From the perspective of Porter's approach to regional competitiveness, these indices can be interpreted as signs of regions' structural capacities within the national production network. Backward linkage partially reflects the "demand conditions" determinant in Porter's model because it indicates the extent to which increased final demand in a region stimulates demand for intermediate inputs and activates supply chains in other regions. A normalized backward linkage greater than one therefore indicates that the region's demand has an above-average capacity to stimulate production activity in the national economic network. Forward linkage, by contrast, partially reflects the "related and supporting industries" determinant as it demonstrates the extent to which a region supplies intermediate inputs to other regions. A normalized forward linkage greater than one thus indicates an upstream role in the production network, a capacity to supply intermediate inputs, and an ability to generate production spillovers elsewhere. Backward and forward linkage indices, however, do not provide a comprehensive measure of regional competitiveness. They indicate primarily the structural capacity of regions to play competitive roles in the national production network and division of labor.

Within this framework, different regions of Iran occupy different positions in the spatial structure of the national economy. Region 7, covering the southern zone of the country, has the highest forward linkage, while its backward linkage is approximately average or slightly below average. This indicates that the region is the country's principal supplier of intermediate inputs and serves as a major supply and upstream production pole for basic inputs in the national economy. The very large bubble of this region also reflects its substantial share of national output. Region 7 consequently occupies a dominant position in the country's spatial economic network in terms of both forward linkages and production scale. From Porter's perspective, this may indicate strong capacity in basic factor conditions and supporting industries. If this role rests mainly on energy, extractive activities, basic industries, and raw-material production, however, it should be interpreted as a factor- and resource-driven advantage rather than necessarily as advanced competitiveness based on innovation, productivity, and technological upgrading. The Tehran metropolitan region (R1), by contrast, records values below one for both forward and backward linkages. Despite the large size of its economy, the comparatively low values of both indices indicate that Tehran's economic weight does not necessarily align with strong interregional production linkages. In Porter's terms, this finding does not mean that Tehran is uncompetitive; rather, it indicates that these two indices do not identify it as an industrial, input-oriented, and production-based competitive pole within the national multiregional network. Forward and backward linkage indices primarily reveal regions' industrial, production, and value-chain capacities, whereas an important share of Tehran's advantage may lie in domains these indices do not directly measure. Tehran's role must therefore be interpreted cautiously. The relatively weak forward and backward linkages may reflect the predominance of services, management, finance, final consumption, decision-making, and economic coordination over industrial activity and the production of intermediate inputs. Tehran's principal role is consequently better understood through the concentration of advanced services, management, economic network organization, consumer markets, decision-making institutions, and national coordination than through its function as an upstream industrial production pole. This pattern is consistent with many metropolitan economies worldwide, where managerial, service, and decision-making functions concentrate in metropolitan centers while much raw-material production, energy generation, basic industry, and manufacturing is located elsewhere (see Henderson & Ono, 2008; Sassen, 2005; Duranton & Puga, 2005). Regions 2 and 6 have values greater than one for both forward and backward linkages. They therefore play important roles in supplying intermediate inputs to other regions, while increases in their own demand substantially stimulate production activity across the national economic network. Within Porter's model, these regions display the strongest alignment with production- and cluster-based competitiveness, ranking above average in both demand conditions and related and supporting industries. This structure positions them as active industrial poles, processing nodes, and central points in the country's spatial production network. They receive inputs from other regions and supply intermediate or final products elsewhere, thereby playing important intermediary, processing, and value-chain roles in the national division of labor and displaying a high degree of spatial integration within the national economy. Regions 3, 4, and 5, by contrast, have forward linkage values below one and backward linkage values close to or below one. These regions play more limited roles in supplying intermediate inputs elsewhere, while demand growth within them exerts a comparatively weak stimulus on national production chains. In Porter's terms, they occupy lower positions in their structural capacity to form production clusters, supporting industries, and demand-driven activity. They are neither principal input-supply poles nor central stimulators of production in the national economic network and may therefore be regarded as semi-peripheral within the spatial structure of Iran's economy. Their network influence is weaker than that of the core regions, and their production linkages to the national economy are less intense.

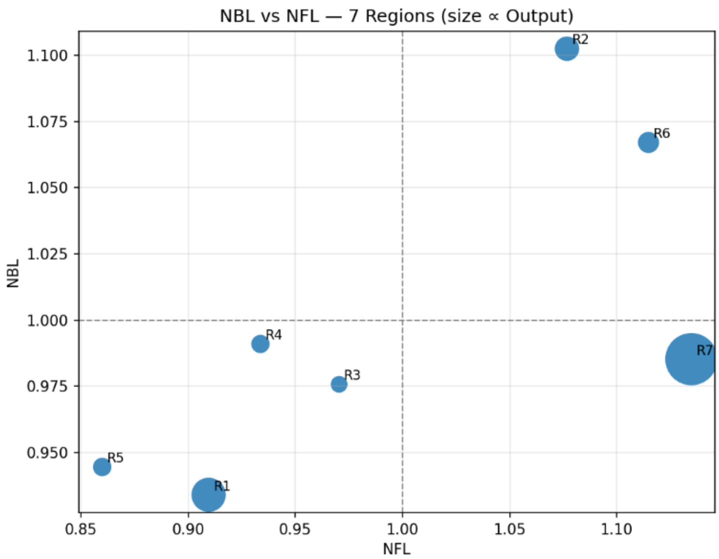

Figure 6. Structural positions of the seven regional economies within the multiregional input-output framework

Overall, the observed pattern reveals a spatial division of labor in the national economy, with production, processing, input supply, demand, services, and management distributed among regions. Region 7 is the main supplier of basic inputs, energy, raw materials, and upstream products, whereas Regions 2 and 6 function more as industrial processing poles and active nodes of production network. The Tehran Metropolitan Region, by contrast, performs primarily service, managerial, financial, consumption, and coordination functions. According to its forward and backward linkage indices, it participates less in the production of basic intermediate inputs and in the industrial activation of the national production network. These findings show that regional competitiveness in Iran is neither uniform nor homogeneous; it arises from each region's position within production chains, supply networks, interregional demand, and the national division of labor. Spatial forward and backward linkage indices can therefore reveal part of regions' structural capacity for competitiveness. They capture only the structural and network dimensions of competitiveness, however. A comprehensive assessment of Tehran's competitiveness must complement them with measures of productivity, innovation, export capacity, firm quality, human capital, advanced services, and regional governance capacity.

5. Conclusion

A principal methodological contribution of this study was to demonstrate the capacity of multiregional input-output analysis to explain spatial competitiveness. The method enables competitiveness to be analyzed not merely as a composite indicator or simple ranking, but as a network of sectoral and spatial linkages. More specifically, it permits the decomposition of intraregional, spillover, and feedback effects and, through spatial backward and forward linkage indices, reveals each region's structural position in the national division of labor (Figure 7). The central question was how the structure and interregional effects of spatial competitiveness in the Tehran Metropolitan Region can be explained. Two levels of analysis were used: first, multiplier decomposition for the Tehran Metropolitan Region to identify intraregional, spillover, and feedback effects; and second, spatial backward and forward linkage indices to determine Tehran's position within the seven-region national economic network. Combining these analyses showed that Tehran's spatial competitiveness is multidimensional. Selected sectors possess substantial production, linkage, and clustering capacities; yet relative to the national economic space as a whole, Tehran functions less as an input-oriented industrial pole and more as a service, managerial, demand, and network center in the national division of labor.

Within Porter's competitiveness model, these findings can be interpreted in particular through "related and supporting industries" and "demand conditions." Tehran's intraregional effects are most directly related to related and supporting industries. The stronger a sector's intraregional effect, the greater its capacity to activate production chains within Tehran, to create demand for complementary inputs, to reinforce inter-sectoral relations, and to provide a basis for clustering. Chemicals, oil, agriculture, and construction, which display stronger intraregional effects in the multiplier decomposition, may therefore be treated as promising areas for strengthening production clusters and deepening value chains within the Tehran region. Their significance lies in the fact that their activity does not remain isolated; through input-output linkages, it stimulates other economic activities in Tehran. This capacity does not mean complete or realized competitiveness. Strong intraregional effects indicate only that, in terms of production structure and inter-sectoral relations, some sectors in Tehran have greater potential to put the foundations of competitive advantage. Spillover analysis shows that increased activity or investment in selected sectors, particularly food manufacturing, chemicals, construction, and machinery, stimulates production elsewhere in Iran. Tehran is therefore not merely a production location but also a center for generating, organizing, and transmitting demand within the national economy. In this respect, part of Tehran's spatial competitive strength derives from its ability to mobilize the production capacities of other regions.

The spatial forward and backward linkage indices, however, reveal a different and important picture. Tehran is below average on both indices, demonstrating that its considerable economic weight does not necessarily entail intense interregional production linkages. Despite the size of its economy, Tehran is not, at the aggregate level, the principal national pole of industrial, input-oriented, and intermediate production competitiveness. This should not be interpreted as evidence that Tehran is uncompetitive; it indicates that the nature of its competitiveness differs from that of regions based on industrial production, the supply of basic inputs, or industrial processing. The article's answer to its central question is therefore that the spatial competitiveness of the Tehran Metropolitan Region has a hybrid structure. In selected sectors, particularly those with strong intraregional, spillover, and feedback effects, Tehran has the capacity to strengthen related and supporting industries and form production clusters. At the macro level and in comparison with other regions, however, its principal role is better understood through demand generation, the concentration of advanced services, management, coordination, consumption, decision-making, and the organization of economic networks. Tehran should therefore not be characterized in general terms as Iran's competitive industrial pole. It is more accurately understood as a metropolitan node of service-based, managerial, demand-driven, and network-based competitiveness with industrial and cluster-based competitive capacity in selected sectors.

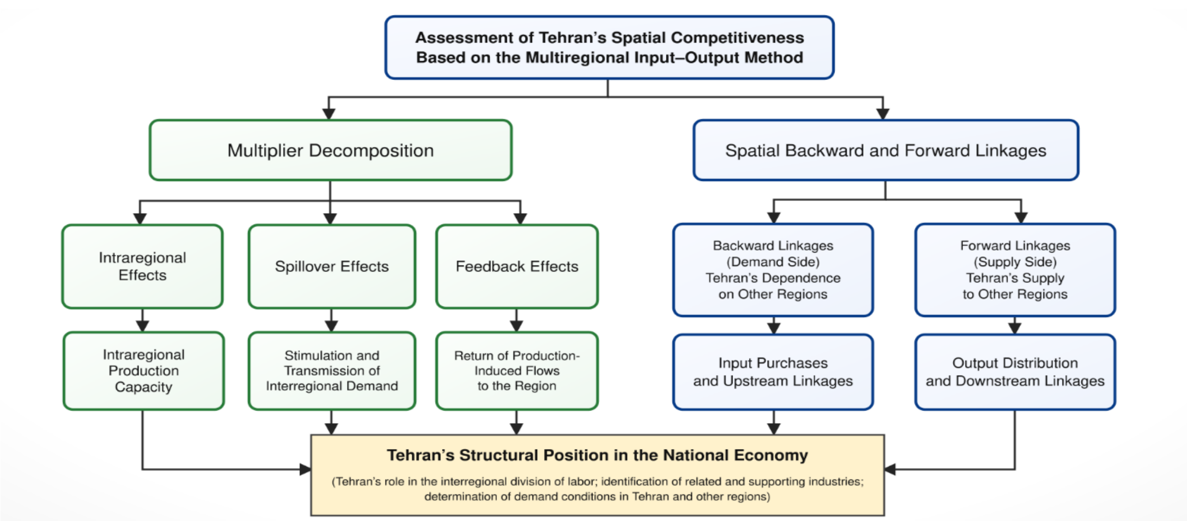

Figure 7. Capacity of multiregional input-output analysis to explain spatial competitiveness

Authors' Contributions

First author: 25%; second author: 25%; third author: 25%; fourth author: 25%.

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Conflict of Interest

The authors declare no conflict of interest.

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