

# Network-Based Industrial Policy: Structural Bottlenecks and Policy Transmission Channels in Türkiye's Production Network

Tugrul Temel

[t.temel@ecorec.org](mailto:t.temel@ecorec.org)

ECOREC Economics Research and Consulting

---

## Research Article

**Keywords:** industrial policy, production networks, competition policy, Türkiye

**Posted Date:** October 7th, 2026

**DOI:** <https://doi.org/10.21203/rs.3.rs-11099194/v1>

**License:** © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

**Additional Declarations:** No competing interests reported.

---

# Network-Based Industrial Policy: Structural Bottlenecks and Policy Transmission Channels in Türkiye’s Production Network

**Tugrul Temel**

ECOREC Economics Research and Consulting  
Amsterdam, The Netherlands  
t.temel@ecorec.org

September 20, 2026

## Abstract

Industrial policy is usually formulated around sectors, technologies, or firms, while the production linkages that transmit its effects receive less attention. This paper develops a network-based framework in which a sectoral intervention’s effectiveness depends on both targeted-market conditions and structural interdependencies with upstream suppliers, downstream users, and intermediary sectors. Modeling the production economy as a directed input-output network, it identifies policy-relevant pathways, interdependence layers, communities, and bottlenecks. Its central proposition is that policy effectiveness is a network property: distortions, weak links, or market power elsewhere can interrupt transmission and limit economy-wide gains. Applying the framework to Türkiye’s 2018 input-output network, with manufacturing as the focal sector, the analysis identifies finance and agriculture as potential bottlenecks and construction and energy as important absorbing/intermediary sectors. The upstream network has three layers and moderate resilience, with a few between-community edges carrying disproportionate importance. The paper therefore argues for network-aware industrial and competition policy: policymakers should assess the target sector’s network position, diagnose transmission channels, and coordinate reforms across connected markets. The framework is illustrated for Turkish manufacturing and is transferable to other industrial economies.

**Keywords:** industrial policy; production networks; competition policy; Türkiye

**JEL Classification:** O25; C67; L52; L16

## 1 Introduction

Industrial policy is commonly organized around identifiable economic objects: strategic sectors, emerging technologies, firms, industries, or markets. This sector-by-sector organization is useful for assigning policy responsibility, but it can obscure an essential feature of modern production: sectors do not operate independently. They purchase intermediate inputs from other industries, supply

outputs to downstream producers, depend on general-purpose services such as finance, energy and transport, and transmit both economic disturbances and policy effects through these relationships. The effectiveness of an intervention aimed at one sector therefore depends partly on the structure and functioning of the production network surrounding that sector.

This observation motivates a different way of thinking about industrial policy. The relevant policy question is not simply whether a targeted sector is inefficient, underinvested, insufficiently competitive, or strategically important. It is also whether the production network through which that sector operates permits the intended effects of policy to reach the sector and then propagate to the wider economy. A competition reform in manufacturing may lower prices or improve firm-level incentives, for example, but its productivity effects can be attenuated when a critical upstream input is supplied through a concentrated or heavily regulated market. Conversely, a reform in an upstream general-purpose service can generate effects across many downstream activities even when the service sector itself is not the conventional target of industrial policy.

The production-network literature has established that sectoral interdependence can magnify idiosyncratic shocks and generate aggregate fluctuations (Acemoglu et al., 2012; Carvalho, 2014). Related work has shown that distortions in production networks can have effects that differ markedly from those implied by a collection of independent sectoral markets (Bigio and La’O, 2016; Liu, 2019). Input-output analysis provides a natural empirical representation of these interdependencies, while recent work on production networks has supplied a theoretical language for understanding how local shocks propagate through economically connected sectors. What remains less developed is a policy framework that translates these structural relationships into a systematic procedure for identifying where an industrial or competition intervention enters the network, where its effects are likely to be transmitted, and where those effects may be blocked or amplified.

This paper addresses that gap by developing a network-based framework for policy diagnosis. The framework is organized around four questions. First, what are the upstream and downstream sectors that form the economically relevant network of a targeted sector? Second, which pathways and layers of interdependence determine how shocks, costs, or policy-induced changes can reach the target? Third, which groups of sectors form relatively cohesive communities, and which links connect those communities? Fourth, which structural links are sufficiently important that their disruption could interrupt the transmission of policy effects or amplify a shock? These questions convert the production network from background information into an object of policy analysis.

The empirical application focuses on Türkiye’s 2018 production network and the aggregated manufacturing sector MA2. MA2 combines 16 manufacturing subsectors in the OECD input-output classification and represents the manufacturing activities other than petroleum and refining used in the paper’s aggregation. The choice of MA2 reflects its position as a priority manufacturing sector and permits the analysis to move beyond the conventional question of how to improve manufacturing directly toward the broader question of what conditions in the surrounding production network determine whether manufacturing-oriented policy can work.

The paper makes three contributions. First, it proposes a conceptual contribution: industrial policy effectiveness is treated as a property of a sector embedded in a production network rather than solely as a property of the targeted market. Second, it develops a policy diagnostic framework that

links three structural objects—critical pathways, cascade layers, and communities—to distinct policy questions concerning transmission, bottlenecks, coordination, and resilience. Third, it demonstrates the framework using Türkiye’s input-output data and shows how a network perspective changes the interpretation of familiar competition-policy issues involving finance, energy, transport, agriculture, construction and manufacturing.

The algorithms used to operationalize the framework are deliberately secondary to this economic argument. Their purpose is to make the network structure observable and policy-relevant. The paper does not claim that a graph-theoretic statistic by itself identifies a causal policy effect. Rather, the network measures identify locations and channels that merit economic investigation, counterfactual simulation, or sector-specific institutional analysis. This distinction is important because aggregate input-output data cannot identify firm-level substitution, market power, or welfare effects with the precision of microeconomic evidence.

The remainder of the paper proceeds as follows. Section 2 develops the economic framework for network-based policy design. Section 3 relates the framework to the literatures on production networks, industrial policy, competition and input-output analysis. Section 4 presents the empirical strategy and explains the three diagnostic procedures. Section 5 describes the Turkish input-output data and the construction of the production network. Section 6 presents the empirical results for MA2, including pathways, cascade layers, community structure and resilience. Section 7 develops the policy interpretation and explains how network position changes the design of industrial and competition policy. Section 8 discusses limitations and directions for future research. Section 9 concludes. In Appendix, we describe and elucidate the operationalization of the proposed policy framework.

## 2 A Network-Based Framework for Industrial Policy

### 2.1 From sector targeting to network targeting

Traditional sectoral policy asks whether intervention in sector  $i$  can improve productivity, employment, technological capability, exports, or other policy objectives. A network perspective adds a prior question: what other sectors condition the response of sector  $i$ ? Let  $N$  denote the production network and let  $P_i$  denote the set of market, regulatory, competition, investment, and institutional interventions directed toward sector  $i$ . Sector  $i$ ’s outcome can be represented as

$$Y_i = N(P_i)F(K_i, L_i, M_i, Y_{-i}),$$

where  $N(P_i)$  represents the network position and effective connectivity of sector  $i$  under the prevailing policy and institutional environment;  $K_i$  and  $L_i$  are productive factors;  $M_i$  denotes intermediate inputs; and  $Y_{-i}$  represents outputs elsewhere in the economy that influence sector  $i$  through demand and supply relationships. The formulation is intentionally general. It does not impose a causal estimate on the network measures. Instead, it emphasizes that the production possibilities of sector  $i$  depend on the structure and functioning of the relationships through which inputs, outputs, prices, information and shocks are transmitted.

The policy implication is straightforward but consequential. If a reform changes conditions in sector  $i$  while leaving a critical upstream relationship unchanged, the measured improvement in  $i$  may not translate into an equivalent improvement in aggregate production. Similarly, an intervention outside  $i$  can have a large effect on  $i$  when the outside sector occupies a structurally important position in  $i$ 's production network. Industrial policy therefore requires two distinct forms of targeting: targeting the market in which a policy objective is defined, and targeting the network locations that determine whether the objective can be transmitted.

This distinction also clarifies the relationship between industrial and competition policy. Competition policy typically seeks to improve market functioning by reducing barriers to entry, limiting anticompetitive conduct, preventing exclusionary practices, and maintaining competitive neutrality. Industrial policy may seek to develop productive capabilities, coordinate investment, address externalities, or support strategically important activities. In a production network, these instruments interact. A competition reform can alter the cost and reliability of an input used elsewhere, while an industrial-policy intervention can change demand for upstream services and thereby alter the incentives and market structure of suppliers.

## 2.2 Policy transmission as a network process

Consider a simple pathway  $j \rightarrow k \rightarrow i$ , where  $j$  supplies an input to  $k$  and  $k$  supplies an input to  $i$ . A policy intervention in  $j$  need not affect  $i$  directly. Its effect is transmitted through  $k$ . If  $k$  is competitive and has sufficient capacity, the change in  $j$  may propagate. If  $k$  is constrained, regulated, highly concentrated, or otherwise unable to expand or adjust, the effect may be attenuated. The same structure can amplify adverse shocks: a distortion in  $j$  can increase costs in  $k$ , which can then increase costs or reduce availability in  $i$ .

This creates four policy-relevant network objects (Table 1). A pathway identifies the sequence through which an effect can travel. A layer identifies the distance of a sector or link from the target. A community identifies a group of sectors with relatively dense internal interactions. A between-community edge identifies a bridge on which cross-community transmission depends. Each object corresponds to a different policy question: where does the intervention enter; how far must it travel; which sectors should be considered jointly; and which links can interrupt transmission between otherwise connected groups?

## 2.3 Bottlenecks are relational, not merely sectoral

A central implication of the framework is that a bottleneck should not be defined solely by the size or concentration of a sector. A relatively small sector can become a structural bottleneck when many economically important pathways depend on its connections. Conversely, a large sector can have limited transmission importance if alternative routes or weak linkages prevent disturbances from propagating through it. The relevant unit of policy analysis is therefore the sector-link combination within the network.

This relational definition is particularly relevant for general-purpose services. Finance, energy, transport and business services can appear secondary when assessed only by their direct contribution

Table 1: Policy-relevant network objects and their economic interpretation

| Network object              | Economic question                                                                | Policy use                                                         |
|-----------------------------|----------------------------------------------------------------------------------|--------------------------------------------------------------------|
| Upstream/downstream pathway | Through which sectors can costs, demand, information or shocks reach the target? | Identify intervention points and transmission channels.            |
| Cascade layer               | How many intermediate relationships separate a sector from the target?           | Sequence reforms and contingency measures by structural distance.  |
| Community                   | Which sectors interact relatively intensively with one another?                  | Coordinate policy across markets that share structural exposure.   |
| Between-community edge      | Which link connects otherwise distinct groups?                                   | Identify potential systemic bottlenecks and resilience priorities. |

to manufacturing value added, yet their outputs can enter the production process of many sectors. Market imperfections in such services can consequently affect the cost and availability of inputs throughout the economy. The network perspective does not imply that these sectors should always be liberalized or prioritized; it implies that their structural position should be considered when evaluating the likely reach of a reform elsewhere.

## 2.4 Competition policy in an interconnected production economy

The framework also changes the interpretation of competitive neutrality <sup>1</sup>. The interpretation changes from a static, ownership-based level-playing-field principle to a dynamic, network-aware principle: competitive neutrality is not just about whether a given public firm has an advantage over a private rival, but about whether competitive conditions can be transmitted across the production network without being neutralised by bottlenecks or distortions elsewhere. Suppose a competitive manufacturing sector purchases an essential input from a regulated or concentrated upstream sector. A competition reform in manufacturing may increase productive efficiency, but part of the resulting gain may be absorbed through the upstream price or availability of the input. In the reverse direction, a reform that improves competition in the upstream market can increase the productivity of manufacturing even when manufacturing itself is unchanged institutionally.

The key point is not that regulation is inherently harmful or competition policy is universally beneficial. Rather, the policy effect depends on the interaction between market institutions and network position. A regulated sector may perform a legitimate public-service function while still becoming a transmission bottleneck. A competitive sector may be productive while remaining exposed to a weak upstream market. Network analysis can therefore complement, rather than substitute for, conventional market-structure analysis by showing where market-specific evidence should be connected to economy-wide production relationships.

<sup>1</sup>Competitive neutrality is the principle that government-owned, government-controlled, or government-linked enterprises should not have net competitive advantages or disadvantages over private competitors simply because of their public ownership or state backing. In other words, the state should not use its ownership, regulatory, tax, or financial powers to distort the level playing field between public and private firms.

### 3 Related Literature and Contribution

The framework builds on four strands of literature. The first is the production-network literature, which demonstrates that the structure of intersectoral relationships affects aggregate fluctuations. Acemoglu et al. (2012) show how network centrality can determine the aggregate importance of sectoral shocks, while Carvalho (2014) reviews the mechanisms connecting microeconomic production networks to macroeconomic outcomes. Oberfield (2018) emphasizes the architecture of input-output relationships and the implications of network structure for production. These contributions motivate treating inter-sectoral connections as economically consequential rather than as accounting identities alone.

The second strand concerns distortions and policy in production networks. Bigio and La'O (2016) show how distortions can propagate through input-output linkages. Liu (2019) develops a theory of industrial policy in production networks, demonstrating that policy can have effects that depend on the position of targeted sectors in the network. Grassi and Sauvagnat (2019) combine input-output structure with production-network mechanisms to study the implications of economic policy. The present paper is complementary: it develops a diagnostic framework for empirically locating the pathways and structural bottlenecks through which such policy effects may operate.

The third strand is the literature on competition and upstream regulation. Research by Bourles et al. (2010); Barone and Cingano (2011); Bucirossi et al. (2013); Gal and Hijzen (2016), and related work documents productivity effects associated with competition and regulation, including in upstream services. The network framework developed in the current paper provides a way to connect these market-level effects to the downstream industries that depend on regulated inputs. It therefore offers a bridge between competition-policy evidence and industrial-policy questions about productivity and productive capacity.

The fourth strand is input-output and graph-theoretic analysis. Leontief input-output analysis provides the demand-driven structure used to trace backward requirements, while the Ghosh framework can be interpreted as a price or supply-allocation framework under appropriate assumptions (Dietzenbacher, 1997). Graph theory provides concepts such as paths, neighborhoods, communities and edge betweenness that make structural features of the resulting network explicit. The innovation of the current paper is not to claim that these mathematical objects are themselves novel. The contribution lies in organizing them around a policy problem: identifying where sectoral interventions are likely to enter, where they may be transmitted, and where network structure may prevent or amplify their effects.

The resulting contribution can therefore be summarized as a shift from a sector-centered to a network-aware conception of industrial policy. Existing policy analysis often asks which sector should receive an intervention. The framework developed here asks a sequence of related questions: which sector is the policy target; which sectors condition its response; which pathways carry the intervention's effects; which layers determine the timing or vulnerability of transmission; which communities require coordinated treatment; and which links constitute potential bottlenecks? This sequence is the conceptual contribution around which the empirical methodology is organized.

## 4 Empirical Strategy: Making the Network Policy-Relevant

### 4.1 Input-output representation

Let  $X_{ij}$  denote the intermediate transaction from supplier sector  $i$  to user sector  $j$ . Backward technical coefficients are constructed as  $A_{ij}^b = X_{ij}/X_j^S$ , where  $X_j^S$  is the total supply of user sector  $j$ . The Leontief inverse is  $M^b = (I - A^b)^{-1}$ . It summarizes the direct and indirect input requirements associated with production in a target sector. To characterize downstream relationships, the analysis also uses the forward coefficient matrix  $A^f$  constructed as  $A_{ij}^f = X_{ij}/X_i^D$  with  $X_i^D$  being the total demand of producer sector  $i$ . The corresponding Ghosh inverse is  $M^f = (I - A^f)^{-1}$ . The two representations are used jointly because a sector's policy environment is determined both by the inputs it requires and by the users that depend on its output.

The analysis does not interpret every positive input-output coefficient as an equally important policy relationship. Because aggregate input-output tables are dense and include inputs that may be substitutable or non-essential, the empirical procedure uses a threshold to retain relatively important multiplier relationships. The threshold is therefore a diagnostic choice rather than a structural parameter. The paper's baseline selection uses the interquartile range of the multiplier distribution and then retains links accounting for at least 20 percent of the relevant multiplier sum. Alternative thresholds should be understood as sensitivity checks rather than as tests of a unique economic truth.

### 4.2 Diagnostic I: identifying the policy-relevant network

The first diagnostic identifies the upstream and downstream networks of a selected sector (see Temel and Phumpiu (2021) for Algorithm I implemented to identify the network). For MA2, backward multipliers identify sectors whose inputs contribute materially to the production requirements of MA2, while forward multipliers identify sectors that materially use MA2's output. The two networks are then combined so that the focal sector can be examined within its broader production environment. The resulting directed network in Figure 1 provides the empirical representation through which the structural position of the targeted sector MA2 and the channels connecting it to other sectors can be examined.

The economic purpose of this procedure is targeting, not visualization. It identifies the set of markets in which a policy change could plausibly affect the target through observed production relationships. It also reveals cycles and alternative routes. A pathway such as  $MA1 \rightarrow FIN \rightarrow MA2$  indicates a potential transmission channel from manufacturing activity in MA1 through finance to MA2. A cycle such as  $MA2 \rightarrow AGF \rightarrow CST \rightarrow MA2$  indicates that the relationship is not purely hierarchical: output from the target and its suppliers can feed back into the same network.

### 4.3 Diagnostic II: cascade layers

The second diagnostic reorganizes the upstream network into layers based on graph distance from the target (see Temel (2026) for Algorithm II implemented to identify the cascade of layers). Layer 1

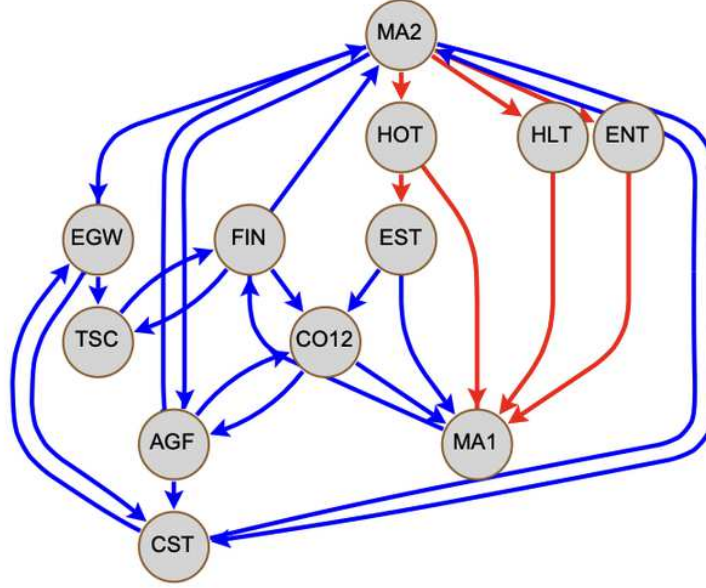


Figure 1: Network representation of the focal manufacturing sector (MA2)  
Blue and red arrows represent backward and forward linkages, respectively.

contains immediate neighbors; Layer 2 contains the next set of links reached through the network; and so forth until the relevant network is exhausted. The layers are not interpreted as a literal timing model. Rather, the resulting layered network in Figure 2 provides the empirical representation of a structural ordering of potential transmission channels. A shock or policy intervention farther from the target must pass through more intermediate relationships before reaching it.

This distinction matters for policy sequencing. Immediate suppliers may require direct attention when continuity of production is the objective. More distant sectors can nevertheless become policy priorities when they are the source of a critical disturbance or when the intermediate layers have limited capacity to absorb it. Layering therefore provides a way to distinguish direct exposure from indirect exposure without assuming that all indirect effects are economically negligible.

#### 4.4 Diagnostic III: communities and resilience

The third diagnostic identifies communities—groups of sectors with relatively dense internal connections and comparatively fewer links across groups—and evaluates the structural importance of between-community edges using edge betweenness centrality (see Temel (2026) for Algorithm III implemented to identify communities). An edge with high betweenness lies on a large share of shortest paths and therefore has a potentially important bridging role. The proposed resilience measure translates that structural importance into a simple indicator provided in Figure 3: the greater the dependence on a small set of bridging links, the lower the resilience to disruption of those links.

The measure should be interpreted as a structural indicator, not as a probability of failure or a causal estimate of aggregate output loss. A production network can remain economically resilient

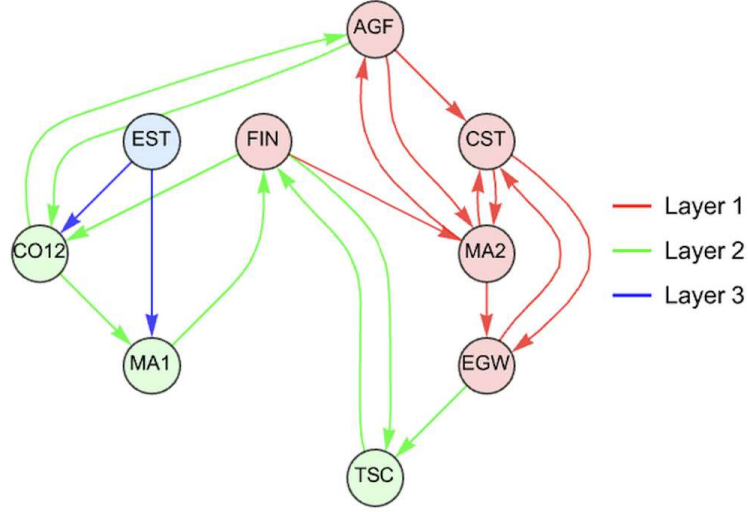


Figure 2: Cascade of layers in the upstream network of MA2

even when graph structure appears fragile if firms can substitute suppliers, inventories are available, or productive capacity can adjust. Conversely, a graphically connected network can be economically fragile if the apparent alternatives are not technologically or institutionally substitutable. The value of the measure is therefore diagnostic: it identifies links that deserve closer market-level investigation.

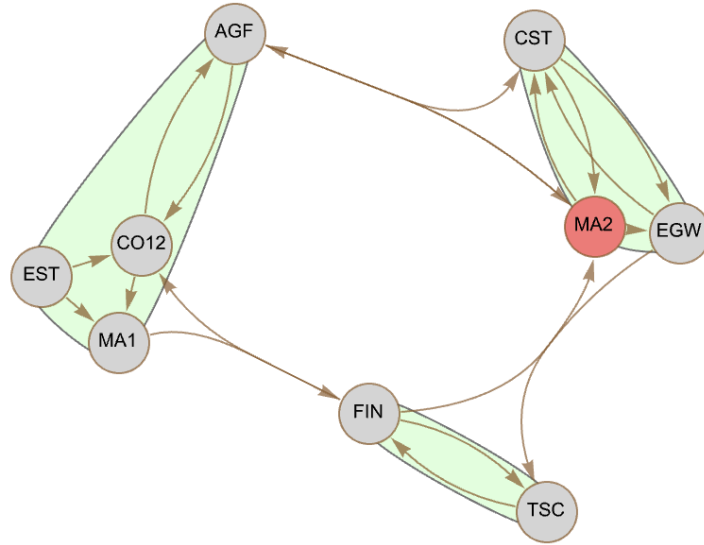


Figure 3: Community structure in the upstream network of MA2

#### 4.5 Interpretation and identification limits

The framework deliberately separates structural identification from causal inference. Input-output multipliers describe relationships in the observed production system; they do not establish that a

particular regulatory reform will generate a particular percentage change in productivity. Likewise, centrality does not establish market power, and a community is not equivalent to a market. The empirical results should consequently be read as a map of policy transmission channels. Causal policy evaluation would require additional information on market structure, prices, firm behavior, substitution possibilities, institutional arrangements, and counterfactual outcomes.

This distinction strengthens the policy contribution. Rather than claiming that the network alone determines policy priorities, the framework supplies a disciplined first-stage diagnostic that can be combined with competition indicators, regulatory measures, firm-level evidence, and policy simulations. It is intended to reduce the risk that an otherwise well-designed sectoral reform is evaluated without considering the network through which its benefits and costs must travel.

## 5 Turkiye’s Production Network

### 5.1 Data and aggregation

The empirical analysis uses the OECD input-output database for 2018 (OECD, 2021a). The original 35-sector representation is aggregated to 15 sectors using the 2008 UN sector definitions. Manufacturing is divided into MA1, covering petroleum and refinery activities, and MA2, covering the remaining manufacturing activities represented in the aggregation. Sectors and their roles are provided in Table 2.

Table 2: Sectors and their roles in the network interpretation

| Notation | Sector                                 | Role in network interpretation          |
|----------|----------------------------------------|-----------------------------------------|
| MA2      | Manufacturing excl. petroleum/refining | Focal industrial sector                 |
| MA1      | Petroleum/refining manufacturing       | Upstream manufacturing activity         |
| FIN      | Financial intermediation               | General-purpose upstream service        |
| TSC      | Transport, storage and communication   | Network infrastructure/service          |
| EGW      | Electricity, gas and water             | General-purpose regulated service       |
| AGF      | Agriculture, forestry and fishing      | Upstream and reciprocal linkage         |
| CST      | Construction                           | Important intermediate/absorbing sector |
| CO12     | Crude oil/mining                       | Upstream resource sector                |
| EST      | Real estate/business services          | Ancillary upstream linkage              |
| HLT      | Health/social work                     | Downstream user of MA2 output           |
| WHS      | Wholesale and retail trade             | General-purpose service                 |
| HOT      | Hotels and restaurants                 | Downstream user of MA2 output           |
| ADM      | Public administration                  | General-purpose regulated service       |
| EDU      | Education                              | General-purpose regulated service       |
| ART      | Arts and entertainment                 | General-purpose service                 |

## 5.2 Structural properties

The empirical network is strongly asymmetric in its backward and forward relationships. The reported correlations between upper and lower triangular elements of the backward and forward multiplier matrices are low ( $\rho_B = 0.14$  and  $\rho_F = -0.04$ ), supporting the use of a directed rather than undirected representation. The corresponding correlations for the technical coefficients are also low. At the same time, multiplier values are strongly correlated with their underlying weights, with reported correlations of 0.93 for backward relationships and 0.89 for forward relationships. These properties justify representing the production network as a weighted directed graph for diagnostic purposes.

Sectoral eigenvector centrality further indicates that MA2, CST, and EGW occupy relatively central positions. The reported scores are 0.18 for MA2, 0.22 for CST, and 0.18 for EGW, while FIN has a lower score of 0.07 and TSC a moderate score of 0.11. These statistics should not be interpreted as rankings of economic importance. They indicate how the location of a sector is connected to the locations of other sectors within the observed network.

The combination of flow dominance and centrality yields a useful policy distinction (Table 3). MA2 is characterized as a large-flow, high-centrality sector, while CST and EGW also combine substantial flow with relatively high centrality. AGF occupies an intermediate position, while FIN and CO12 have lower centrality despite their relevance to particular pathways. This distinction motivates the central policy argument of the paper: a sector can be important to a target not because it is large in aggregate, but because it occupies a strategically located position in the target’s production network.

Table 3: Structural properties of the network

| Communities | Sectors     | (Source, Sink) | Flow Dominance | Centrality       |
|-------------|-------------|----------------|----------------|------------------|
| $C_1$       | <i>MA2</i>  | (0.16, 0.11)   | large          | 0.18 (high)      |
|             | <i>CST</i>  | (0.10, 0.15)   | medium         | 0.22 (high)      |
|             | <i>EGW</i>  | (0.09, 0.11)   | medium         | 0.18 (high)      |
| $C_2$       | <i>FIN</i>  | (0.12, 0.14)   | medium         | 0.07 (low)       |
|             | <i>TSC</i>  | (0.07, 0.07)   | small          | 0.11 (moderate)  |
| $C_3$       | <i>AGF</i>  | (0.12, 0.11)   | medium         | 0.12 (moderate)  |
|             | <i>EST</i>  | (0.15, 0.00)   | medium         | 0.001 (very low) |
|             | <i>CO12</i> | (0.13, 0.15)   | medium         | 0.08 (low)       |
|             | <i>MA1</i>  | (0.07, 0.15)   | small          | 0.04 (low)       |

Note: Source and Sink define the sum of multipliers associated with outgoing and incoming directed links in *MA2*’s upstream network, respectively.

## 6 The MA2 Network: Structural Bottlenecks and Policy Transmission

### 6.1 The upstream and downstream policy environment

The network surrounding MA2 contains several relationships that materially change how a manufacturing-oriented intervention should be interpreted. In the upstream network, MA2 has two-way relationships with CST and AGF and important linkages with FIN and EGW. The structure contains cycles such as  $MA2 \rightarrow AGF \rightarrow CST \rightarrow MA2$  and  $MA2 \rightarrow EGW \rightarrow CST \rightarrow MA2$ . These cycles mean that the network cannot be represented adequately as a one-directional chain from an upstream supplier to a downstream manufacturer. Conditions in MA2 can affect sectors that subsequently feed back into MA2 (see Figure 1).

A second important pathway is  $MA1 \rightarrow FIN \rightarrow MA2$ , accompanied by  $TSC \rightarrow FIN \rightarrow MA2$  (see Table 4). Finance therefore occupies an intermediate position between upstream sectors and MA2. The policy significance is not that finance is mechanically the source of every manufacturing disturbance, but that a disturbance or institutional constraint in finance can be transmitted into manufacturing through an observed production-network relationship. The same structure implies that reforms in MA1 or TSC can have indirect consequences for MA2 if they alter the conditions under which finance supplies manufacturing.

The combined network demonstrated in Figure 1 suggests that the policy environment relevant to MA2 extends beyond manufacturing regulation. A network-aware policy assessment would therefore examine at least the set  $\{MA1, TSC, FIN, MA2, AGF, EGW, CST\}$ . This is not a recommendation to apply the same policy instrument to all seven sectors. It is a statement about the minimum structural environment that must be considered when evaluating the transmission of a policy targeted at MA2.

The results also reveal a distinction between input-generating and input-absorbing sectors. The network identifies MA2, CO12, FIN and AGF as relatively important generators, while CST, MA2, EGW and AGF appear among the important absorbers. The mismatch indicates a structural gap: the sectors that generate substantial input flows are not necessarily the same sectors in which those flows accumulate. From a policy perspective, this raises questions about whether existing productive capacity, market incentives, or connectivity permit inputs to move efficiently from generators to productive uses.

### 6.2 Communities and coordination

The upstream network of MA2 contains three communities (Figure 3). Community 1 comprises MA2, CST and EGW; Community 2 comprises CO12, AGF, EST, and MA1; Community 3 comprises TSC and FIN. The first community has the highest average centrality in the reported analysis. The important economic insight is not that one community should automatically receive greater policy support. Rather, the community structure shows that interventions affecting a sector can interact with other interventions within the same structural cluster, while links between communities may

Table 4: Principal policy-transmission channels associated with MA2

| Channel                                                           | Transmission role      | Distance from MA2 | Policy interpretation                      |
|-------------------------------------------------------------------|------------------------|-------------------|--------------------------------------------|
| FIN $\rightarrow$ MA2                                             | Direct input channel   | 1                 | Finance/input access                       |
| AGF $\rightarrow$ MA2                                             | Direct input channel   | 1                 | Agricultural input                         |
| CST $\rightarrow$ MA2                                             | Direct input channel   | 1                 | Construction/input interface               |
| MA1 $\rightarrow$ FIN $\rightarrow$ MA2                           | Indirect input channel | 2                 | Petroleum–finance–manufacturing            |
| TSC $\rightarrow$ FIN $\rightarrow$ MA2                           | Indirect input channel | 2                 | Logistics/finance–manufacturing            |
| CO12 $\rightarrow$ AGF $\rightarrow$ MA2                          | Indirect input channel | 2                 | Mining/agriculture–manufacturing           |
| EST $\rightarrow$ MA1/CO12<br>$\rightarrow \dots \rightarrow$ MA2 | Distant channel        | 3+                | Professional/business-service transmission |

require coordination across otherwise separate policy domains.

This has an institutional implication. Responsibility for manufacturing, energy, transport, finance, agriculture and construction is often distributed across different regulatory or administrative institutions. A network view suggests that this division of responsibility can create a coordination problem when the production system itself is cross-sectoral. The community structure provides one empirical way to identify where joint policy assessment may be useful, particularly where a small number of bridging links connect otherwise distinct groups.

### 6.3 Cascade layers and the sequencing of policy

The MA2 upstream network contains three structural layers (Figure 2). Layer 1 contains the immediate neighborhood around MA2, including FIN, AGF, CST and EGW. Layer 2 contains CO12, MA1 and TSC, while EST occupies the more distant Layer 3. The layer structure does not establish the exact timing of transmission, but it does provide an economically meaningful sequence of exposure: a change in Layer 2 must pass through intermediate relationships before reaching MA2, whereas a change in Layer 1 has a more direct structural route. The layered network provides the empirical representation of a structural ordering of potential transmission channels. A shock or policy intervention farther from the target must pass through more intermediate relationships before reaching it.

The distinction is useful for contingency policy. A shock affecting MA1, for example, can reach MA2 through MA1  $\rightarrow$  FIN  $\rightarrow$  MA2 and through a longer pathway involving FIN, CO12 and AGF. Strengthening the ability of FIN and AGF to absorb or adapt to disturbances could therefore reduce the transmission of a shock originating farther upstream. Similarly, the two-way relationships CO12  $\leftrightarrow$  AGF and TSC  $\leftrightarrow$  FIN indicate that disturbances can propagate in both directions, making the intermediate sectors relevant to both prevention and recovery.

The broader policy principle is sequencing. Policies aimed at immediate production continuity should focus on the target and its first-order suppliers and users. Policies aimed at systemic resilience should also address more distant sectors when the intermediate layers are highly dependent on them.

The network framework thus distinguishes a policy’s point of entry from its point of impact and makes the intervening transmission structure explicit.

## 6.4 Structural resilience

The upstream MA2 network contains 19 links, seven of which connect different communities. The reported resilience indicator is  $R1 = 0.43$ . Under the interpretation adopted here, this represents a moderate degree of structural resilience: the network is not dependent on a single bridge, but neither are its communities connected through a sufficiently dense set of alternative routes to make all disruptions inconsequential.

The individual link diagnostics are particularly informative. The reported resilience values identify  $TSC \rightarrow FIN$  and  $CO12 \rightarrow AGF$  at approximately 0.35, followed by  $MA2 \rightarrow EGW$  and  $MA1 \rightarrow FIN$  at approximately 0.32, with  $FIN \rightarrow CO12$  and  $EGW \rightarrow TSC$  at approximately 0.29 (see Table 5). Because lower resilience value for a between-community link corresponds to greater structural dependence on that link, these relationships warrant particular attention as potential transmission bottlenecks. Again, the measure does not predict that a disruption will occur or quantify the resulting GDP loss. It identifies structural dependence that can be investigated using market-specific evidence.

The analysis of a hypothetical complete disruption of the intermediate layer produces an  $R2$  value of 0.27. The interpretation is that the network would be substantially less connected if the relevant Layer 2 relationships were simultaneously unavailable. This result illustrates why resilience policy cannot be reduced to protecting the focal sector itself. The ability of MA2 to withstand disruption depends partly on the capacity of the surrounding network to maintain alternative routes, substitute inputs, and absorb disturbances.

Table 5: Edge resilience scores

| Edges                  | Scores | Edges                  | Scores |
|------------------------|--------|------------------------|--------|
| $TSC \rightarrow FIN$  | 0.35   | $AGF \rightarrow CO12$ | 0.20   |
| $CO12 \rightarrow AGF$ | 0.35   | $CST \rightarrow MA2$  | 0.18   |
| $MA2 \rightarrow EGW$  | 0.32   | $EST \rightarrow CO12$ | 0.15   |
| $MA1 \rightarrow FIN$  | 0.32   | $MA2 \rightarrow CST$  | 0.12   |
| $FIN \rightarrow CO12$ | 0.29   | $FIN \rightarrow TSC$  | 0.09   |
| $EGW \rightarrow TSC$  | 0.29   | $EST \rightarrow MA1$  | 0.09   |
| $FIN \rightarrow MA2$  | 0.26   | $EGW \rightarrow CST$  | 0.09   |
| $CO12 \rightarrow MA1$ | 0.26   | $CST \rightarrow EGW$  | 0.09   |
| $AGF \rightarrow MA2$  | 0.23   | $AGF \rightarrow CST$  | 0.09   |
| $MA2 \rightarrow AGF$  | 0.20   |                        |        |

## 6.5 Evolution of the MA2 network, 2005–2018

The time-series application of the network diagnostic shows that FIN remained connected to MA2 throughout 2005–2018. AGF and CST were linked to MA2 in several periods, while EGW became more consistently connected in the later years. During 2016–2018, the network exhibited a more pronounced and stable structure in which MA2 was consistently linked to FIN, AGF, CST and EGW, and the relevant network contained nine sectors. The persistence of these relationships suggests that the policy environment identified in the 2018 cross-section is not simply an isolated snapshot.

The community structure also changed over time. MA2 and FIN shared a community during 2011–2015 but were located in different communities during 2016–2018, while FIN and TSC increasingly shared a community in the latter period. At the same time, MA2, EGW and CST remained together during 2016–2018. These changes suggest that the strength and organization of production relationships evolved even when the focal sector remained structurally important. For policy analysis, this means that network diagnostics should ideally be repeated over time rather than treated as permanent characteristics of an economy.

## 7 Discussion: What Does a Network View Change About Industrial Policy?

### 7.1 From choosing sectors to identifying transmission channels

The central implication of the analysis is a change in the unit of policy reasoning. Sector selection remains important, but it is not sufficient. Once a sector is selected, policymakers need to identify the network through which the intervention is expected to operate. In the case of MA2, the relevant network includes finance, agriculture, construction, energy, transport and selected upstream manufacturing and mining activities. A manufacturing policy evaluated without these relationships risks measuring the direct effect of the intervention while overlooking the conditions that determine whether the effect propagates.

This perspective also changes how policy failure is interpreted. If a sectoral reform produces less improvement than expected, the explanation need not be that the intervention was ineffective in the target market. The transmission mechanism may have been interrupted elsewhere. Conversely, a policy in an apparently peripheral sector may generate substantial benefits if it removes a bottleneck through which many downstream pathways pass. Network analysis therefore provides a structured way to distinguish failure of the policy instrument from failure of the transmission environment.

### 7.2 Competition policy and regulated upstream sectors

The MA2 network illustrates a recurring policy configuration: a competitive or potentially competitive downstream sector connected to regulated or concentrated upstream services. Consider a stylized pathway  $MA2 \rightarrow EGW \rightarrow MA2$ . If MA2 supplies output competitively to a regulated downstream user, the price-setting or regulatory conditions in EGW can affect how much of the value created

by competition in MA2 is retained by MA2, passed to users, or captured through upstream or downstream rents. Conversely, on a pathway  $\text{FIN} \rightarrow \text{MA2} \rightarrow \text{EGW}$ , high input costs in finance can affect MA2's competitive position and then feed into the cost structure of EGW.

These relationships do not establish that a particular regulated sector is extracting rents in the observed economy. They establish why market-specific competition analysis should be connected to the production network. Evidence of market power or regulatory restriction in an upstream sector is more consequential when the sector is structurally connected to a policy target through important pathways. The appropriate policy response may consequently combine competition enforcement, regulatory reform, access measures, infrastructure investment, and productive-capacity development rather than relying on a single instrument.

### **7.3 Industrial policy as network coordination**

Industrial policy often faces a coordination problem because complementary investments and reforms fall under different markets and institutions. The network structure around MA2 illustrates this problem. Improving manufacturing productivity can increase demand for finance, transport, energy and business services. Improving those services can, in turn, relax constraints on manufacturing. The policy problem is therefore partly one of synchronization: reforms may have larger system effects when complementary bottlenecks are addressed together than when each sector is treated independently.

### **7.4 Network-aware policy does not mean universal intervention**

An important qualification is that a network perspective should not be interpreted as an argument for intervening in every connected market. Dense interdependence is a feature of industrial economies, and excessive intervention can create new distortions. The purpose of the framework is precisely to improve selectivity: it identifies where additional evidence is most valuable and where a local intervention may have wider consequences. Network position is therefore a screening and coordination criterion, not a substitute for welfare analysis.

Likewise, a structurally important link is not necessarily a policy problem. A bridge may exist because firms have developed an efficient specialization relationship. A regulated sector may be regulated for legitimate reasons. A concentrated market may reflect economies of scale. The network framework identifies dependence; it does not determine whether that dependence is inefficient. That judgment requires institutional and market evidence. This distinction is essential for keeping network-based industrial policy consistent with competition principles.

### **7.5 Implications for evidence-based policy institutions**

The framework has an institutional implication beyond the selection of individual reforms. Production networks cross the boundaries of sectoral ministries and regulatory agencies, while policy evaluation is frequently organized within those same boundaries. A network diagnostic can provide a common map for coordination: the relevant institutions can identify shared exposure to particular sectors,

communities or bridge links and then evaluate reforms jointly. This is especially relevant for general-purpose services whose regulatory conditions influence a broad set of downstream activities.

In this sense, the contribution is as much about policy organization as about policy targeting. A network-aware industrial-policy process would not replace sectoral expertise. It would connect sectoral expertise through an economy-wide map of production dependencies. The map can then guide where detailed competition studies, regulatory impact assessments, investment plans, or resilience exercises should be undertaken.

## 8 Limitations and Research Agenda

Several limitations delimit the interpretation of the results. First, the analysis uses aggregate input-output data. Aggregation can create links that do not correspond to direct firm-level relationships and can conceal heterogeneity in technology, market power and substitutability. A sector may purchase an input that is recorded as important in the aggregate table even though individual firms can readily substitute away from it.

Second, the threshold used to identify policy-relevant links is a diagnostic convention. Different thresholds can generate different networks. The robustness of policy conclusions should therefore be examined over a range of thresholds and, where possible, compared with alternative network constructions. The interquartile-range procedure used here is intended to focus attention on material relationships while reducing the dominance of trivial or very small coefficients.

Third, the resilience measure is structural rather than behavioral. It does not incorporate inventories, supplier substitution, capacity slack, contractual flexibility, geographic diversification, or dynamic adjustment. A bridge with high edge betweenness may be replaceable in practice, while a seemingly redundant link may be difficult to substitute. Future work should integrate these dimensions into a dynamic resilience model.

Fourth, the framework does not estimate welfare effects or causal treatment effects of particular competition or industrial policies. The policy examples are transmission hypotheses grounded in observed network relationships. Testing them requires firm-level data, regulatory indicators, price and quantity information, and counterfactual methods. In particular, future research should combine network structure with measures of markups, entry barriers, ownership concentration, input substitutability, and productivity to distinguish structural dependence from economically inefficient dependence.

Fifth, the temporal analysis in the paper is descriptive. Repeating the network diagnostic across years reveals how production relationships evolve, but it does not by itself explain why they change. A promising extension would model network evolution as endogenous to policy, investment, technological change and market structure. Such a model could allow industrial policy to be evaluated not only by its effects on current production but also by its effects on the future architecture of the production network.

Finally, the most promising empirical extension is greater disaggregation. Firm-to-firm transaction data, customs data, business registers and regulatory information could be combined to distinguish

essential from non-essential inputs and to identify economically meaningful substitution sets. This would allow the network framework to move from sectoral diagnostics toward firm-level policy transmission and more precise systemic-risk analysis.

## 9 Conclusion

This paper proposes a network-based way of thinking about industrial policy. Industrial policy is not only about selecting sectors. It is also about understanding the network structures through which interventions, distortions, and shocks propagate. The central claim is that the effectiveness of a sectoral intervention depends partly on the structure of the production network surrounding the target. Industrial and competition policy therefore cannot be evaluated only within the boundaries of the market where the intervention is introduced. The relevant policy environment includes the upstream suppliers, downstream users, intermediary sectors, communities and bridge links through which the intervention’s effects are transmitted.

The empirical application to Türkiye’s 2018 production network illustrates the value of this perspective. MA2 is embedded in a network involving finance, agriculture, construction, energy, transport, mining and other manufacturing activities. Several relationships are reciprocal, and the network contains three structural layers and three communities. Finance and agriculture emerge as potential bottleneck locations in particular pathways; construction and energy occupy important absorbing or intermediary positions; and a limited set of between-community links carries disproportionate structural importance. The reported resilience measure indicates moderate structural resilience, while the hypothetical disruption of the intermediate layer substantially reduces network connectivity.

These findings should not be interpreted as a ranking of sectors or as a prescription to intervene wherever a network statistic is large. Their significance is methodological in the economic sense: they show how policy questions can be reorganized around transmission channels. A manufacturing reform can be assessed together with the finance, energy, transport and other relationships that condition its effectiveness. A competition reform can be evaluated not only by its within-market effects but also by the downstream industries that depend on the reformed input. A resilience strategy can focus not only on protecting a target sector but also on maintaining alternative routes across the network.

The broader contribution is therefore a framework for network-aware industrial policy. This framework is outlined in Appendix, and a step-by-step description is provided that aims to operationalize it. It turns the production network into a policy object: a map of dependencies that can reveal where bottlenecks are located, how policy effects can travel, where coordination is needed, and where disruptions may be amplified. The computational procedures provide a practical means of constructing that map, but the economic contribution lies in the way the map changes policy reasoning—from isolated sector intervention toward structural diagnosis and coordinated policy transmission.

For Türkiye, the results suggest that improving manufacturing productivity requires attention to the network conditions under which manufacturing operates. More generally, the same logic applies to industrial economies in which general-purpose services, regulated infrastructure, finance and

productive sectors are tightly connected. The next step is to combine network diagnostics with detailed market evidence and counterfactual policy evaluation. Doing so would allow network-aware industrial policy to move from a structural diagnostic toward a quantitative framework for assessing productivity, welfare and resilience effects.

## Declarations

**Data availability.** The analysis uses publicly available OECD input-output data. The data used in the study can be made available upon request, subject to the terms of the underlying database.

**Competing interests.** The authors declare no competing interests.

**Funding.** The study did not receive funding from an organization.

**Author contributions.** Both authors contributed to the development of the analytical approach. Programming and data analysis were undertaken by the first author, who prepared the initial manuscript. The second author contributed revisions to the manuscript.

## References

- Acemoglu, D., Carvalho, V. M., Ozdaglar, A., & Tahbaz-Salehi, A. (2012). The network origins of aggregate fluctuations. *Econometrica*, 80(5), 1977–2016.
- Acemoglu, D., Ozdaglar, A., & Tahbaz-Salehi, A. (2010). Cascades in networks and aggregate volatility. NBER Working Paper.
- Acemoglu, D., & Ucer, M. (2015). The ups and downs of Turkish growth, 2002–2015: Political dynamics, the European Union and the institutional slide. NBER Working Paper 21608.
- Aghion, P., & Schankerman, M. (2004). On the welfare effects and political economy of competition-enhancing policies. *The Economic Journal*, 114(498), 800–824.
- Aleman, E., Klein, C., Koske, I., Vitale, C., & Wanner, I. (2016). New indicators of competition law and policy in 2013 for OECD and non-OECD countries. In *Competition Law Enforcement in the BRICS and in Developing Countries*.
- Antras, P., Chor, D., Fally, T., & Hillberry, R. (2012). Measuring the upstreamness of production and trade flows. *American Economic Review*, 102(3), 412–416.
- Atalay, E. (2017). How important are sectoral shocks? *American Economic Journal: Macroeconomics*, 9(4), 254–280.
- Atalay, E., Hortacsu, A., Roberts, J., & Syverson, C. (2011). Network structure of production. *Proceedings of the National Academy of Sciences*, 108(13), 5199–5202.
- Barone, G., & Cingano, F. (2011). Service regulation and growth: Evidence from OECD countries. *The Economic Journal*, 121(555), 931–957.

- Bigio, S., & La'O, J. (2016). Distortions in production networks. NBER Working Paper.
- Bourles, R., Cette, G., Lopez, J., Mairesse, J., & Nicoletti, G. (2010). Do product market regulations in upstream sectors curb productivity growth? Panel data evidence for OECD countries. OECD Economics Department Working Papers.
- Bucirossi, P., Ciari, L., Duso, T., Spagnolo, G., & Vitale, C. (2013). Competition policy and productivity growth: An empirical assessment. *Review of Economics and Statistics*, 95(4), 1324–1336.
- Carvalho, V. M. (2008). Aggregate fluctuations and the network structure of intersectoral trade. Working paper.
- Carvalho, V. M. (2014). From micro to macro via production networks. *Journal of Economic Perspectives*, 28(4), 23–48.
- Dietzenbacher, E. (1997). In vindication of the Ghosh model: A reinterpretation as a price model. *Journal of Regional Science*, 37(4), 629–651.
- Gal, P. N., & Hijzen, A. (2016). The short-term impact of product market reforms: A cross-country firm-level analysis. IMF Working Paper.
- Ghosh, A. (1958). Input-output approach in an allocation system. *Economica*, 25(97), 58–64.
- Grassi, B., & Sauvagnat, J. (2019). Production networks and economic policy. *Oxford Review of Economic Policy*, 35(4), 638–677.
- Fortunato, S. (2010). Community detection in graphs. *Physics Reports*, 486(3–5), 75–174.
- Keyder, N. (2022). Türkiye’nin kriz deneyimleri: 1994, 2000–2001, 2008–2009 ve 2018–2022 krizleri. *İktisat ve Toplum*, 141, 4–13.
- Kim, Y., Chen, Y.-S., & Linderman, K. (2015). Supply network disruption and resilience: A network structural perspective. *Journal of Operations Management*, 33, 43–59.
- Liu, E. (2019). Industrial policies in production networks. *The Quarterly Journal of Economics*, 134(4), 1883–1948.
- Miller, R. E., & Blair, P. D. (2009). *Input-Output Analysis: Foundations and Extensions* (2nd ed.). Cambridge University Press.
- Newman, M. E. J. (2004). Detecting community structure in networks. *European Physical Journal B*, 38, 321–330.
- Oberfield, E. (2018). A theory of input-output architecture. *Econometrica*, 86(2), 559–589.
- Organisation for Economic Co-operation and Development. (2021a). OECD Input-Output Tables. OECD Publishing, Paris. Online database. Retrieved January 16, 2021, from <https://www.oecd.org/en/data/datasets/input-output-tables.html>

- Organisation for Economic Co-operation and Development. (2021b). *OECD Economic Surveys: Türkiye 2021*. OECD Publishing, Paris. <https://doi.org/10.1787/2cd09ab1-en>
- Pichler, A., Pangallo, M., del Rio-Chanona, R. M., Lafond, F., & Farmer, J. D. (2022). Forecasting the propagation of pandemic shocks with a dynamic input-output model. *Journal of Economic Dynamics and Control*, 144, 104527.
- Porter, M. A., Onnela, J.-P., & Mucha, P. J. (2009). Communities in networks. *Notices of the AMS*, 56(9), 1082–1097.
- Schweitzer, F., Fagiolo, G., Sornette, D., Vega-Redondo, F., Vespignani, A., & White, D. R. (2009). Economic networks: The new challenges. *Science*, 325(5939), 422–425.
- Tugrul T., (2026). Industrial Policy from a Network Perspective: Targeting, Cascades, and Resilience—Evidence from Türkiye’s Production Network. MPRA Working Paper no. 128113. <https://mpra.ub.uni-muenchen.de/128113/>
- Temel, T., & Phumpiu, P. (2021). Pathways to recovery from COVID-19: Characterizing input–output linkages of a targeted sector. *Journal of Economic Structures*, 10(29). <https://doi.org/10.1186/s40008-021-00256-2>
- Wagner, S. M., & Neshat, N. (2010). Assessing the vulnerability of supply chains using graph theory. *International Journal of Production Economics*, 126(1), 121–129.
- Xiao, H., Sun, T., Meng, B., & Cheng, L. (2017). Complex network analysis for characterizing global value chains in equipment manufacturing. *PLoS ONE*, 12(1), e0169549.

## Appendix

### A Framework for Operationalizing Network-Based Industrial Policy

Contemporary industrial policy faces a fundamental analytical challenge: interventions are typically designed and evaluated within the boundaries of individual sectors, yet their effects propagate through an intricate web of production relationships that connect upstream suppliers, downstream users, and intermediary service providers. The current paper demonstrates that this mismatch between the organizational logic of policy and the structural reality of production can undermine the effectiveness of otherwise well-designed interventions. A manufacturing reform that appears sound when evaluated in isolation may generate limited economy-wide gains if critical upstream relationships—whether in finance, energy, transport, or agriculture—remain distorted or constrained. Conversely, an intervention in an apparently peripheral sector may produce substantial benefits if it removes a bottleneck through which numerous downstream pathways pass.

This insight motivates the development of a systematic framework that translates production-network analysis into actionable policy guidance. The framework proposed here responds to three interrelated gaps in existing practice. First, while the production-network literature has established

that intersectoral linkages matter for aggregate outcomes, it has not yet provided policy practitioners with a structured procedure for identifying where interventions should enter the network and how their effects are likely to travel. Second, competition and industrial policy analysis typically proceeds market-by-market, without systematically considering how structural dependencies condition the transmission of policy effects across sectoral boundaries. Third, existing diagnostic tools—input-output multipliers, centrality measures, community detection algorithms—remain disconnected from the institutional processes through which policy decisions are actually made.

The framework developed addresses these gaps by organizing network analysis around a sequence of policy-relevant questions: Which sectors constitute the effective policy environment of a target sector? Through which pathways do shocks, costs, and policy effects propagate? Which groups of sectors form relatively cohesive communities that may require coordinated treatment? Which structural links are sufficiently important that their disruption could interrupt transmission or amplify disturbances? By answering these questions systematically, the framework converts the production network from background information into an object of policy analysis.

The framework proceeds through five analytical stages, each corresponding to a distinct policy question and each generating outputs that inform subsequent stages. It begins with input-output data and culminates in network-aware intervention and systematic monitoring of network response. Figure 4 presents the complete framework architecture.

The framework is operationalized through eight sequential phases, each with defined inputs, activities, and outputs. These phases are designed to be implementable by policy institutions with access to standard input-output data and basic network analysis capabilities.

### **Phase 1: Identify Target Sector**

The first phase establishes the focal point of the analysis. Target sector selection may reflect existing policy priorities, identified productivity challenges, or strategic development objectives. In the Türkiye application, manufacturing excluding petroleum and refining (MA2) was selected because of its role as a priority sector and its position as a significant contributor to employment and exports. The critical output of this phase is a clearly defined focal sector and an explicit statement of the policy objective—whether productivity enhancement, competitiveness improvement, resilience strengthening, or another goal.

### **Phase 2: Construct Upstream and Downstream Network**

The second phase constructs the production network surrounding the target sector using input-output data. Backward linkages identify sectors whose inputs contribute materially to the target’s production requirements, while forward linkages identify sectors that depend on the target’s output. The empirical procedure applies a threshold to retain economically material relationships while excluding trivial coefficients. For MA2, this procedure identified a network comprising finance (FIN), agriculture (AGF), construction (CST), electricity, gas and water (EGW), transport, storage and communication (TSC), petroleum refining (MA1), crude oil and mining (CO12), and real estate and business services (EST). The output is a directed, weighted network representation that captures

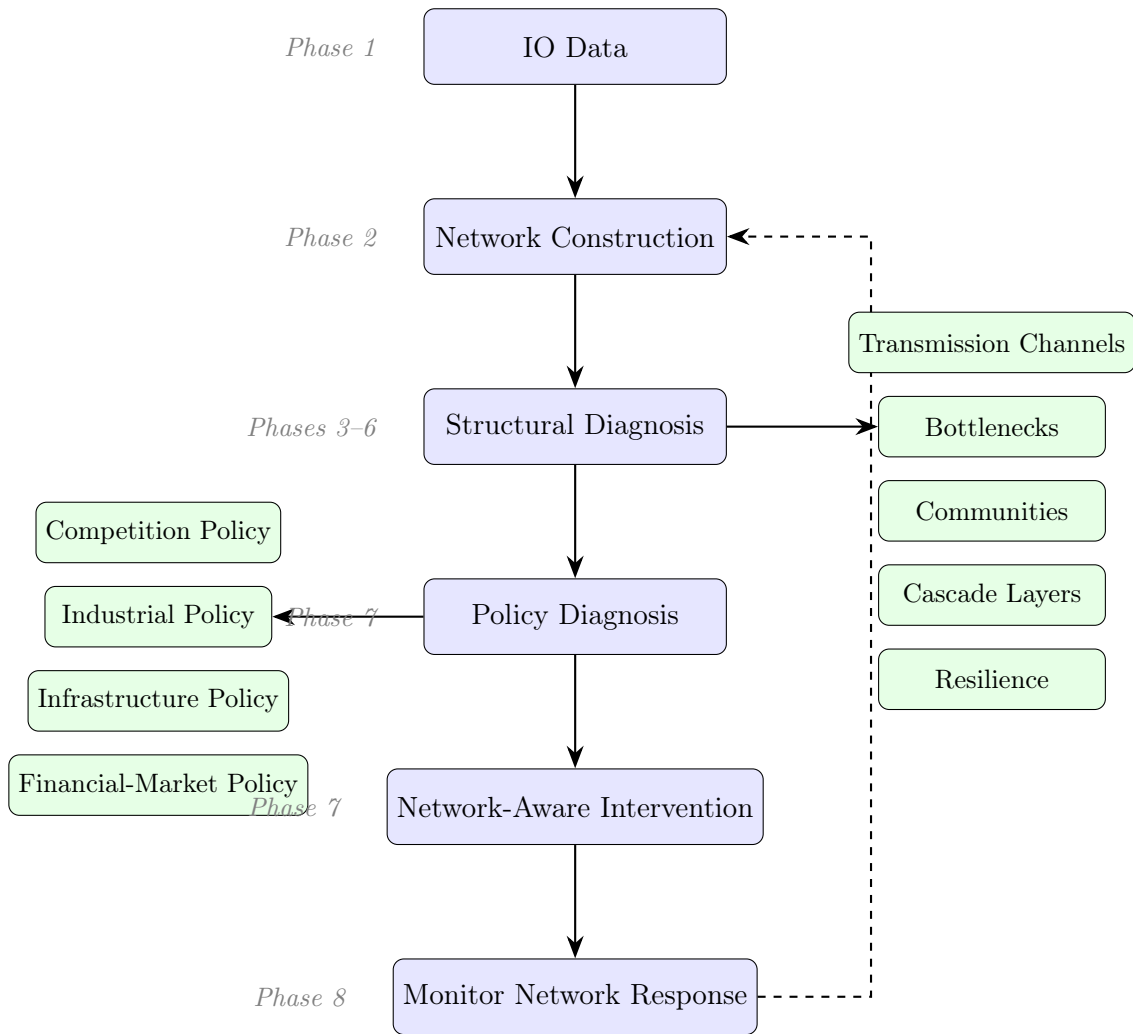


Figure 4: Network-Based Industrial Policy Framework

both supply-side and demand-side relationships.

### **Phase 3: Identify Direct and Indirect Channels**

The third phase traces the pathways through which policy effects, shocks, or cost changes can travel between the target sector and other parts of the network. Direct channels connect the target to its immediate neighbors; indirect channels involve one or more intermediary sectors. The Türkiye analysis identified several economically significant pathways, including  $MA1 \rightarrow FIN \rightarrow MA2$  and  $TSC \rightarrow FIN \rightarrow MA2$ , which establish finance as an intermediary through which upstream disturbances reach manufacturing. The phase also identifies cycles—such as  $MA2 \rightarrow AGF \rightarrow CST \rightarrow MA2$ —that indicate reciprocal relationships rather than simple hierarchical chains. The output is a map of transmission channels that identifies where policy effects enter the network and how they propagate.

### **Phase 4: Detect Structural Communities**

The fourth phase applies community detection algorithms (Newman, 2004; Fortunato, 2010) to identify groups of sectors with relatively dense internal connections and comparatively fewer links across groups. The Türkiye analysis identified three communities in the MA2 upstream network: Community 1 (MA2, CST, EGW), Community 2 (CO12, AGF, MA1), and Community 3 (TSC, FIN). This community structure has direct institutional implications: sectors within the same community may require coordinated policy treatment, while links between communities represent points where different regulatory domains intersect. The output is a partition of the network into structural communities and an identification of the institutional coordination requirements implied by that partition.

### **Phase 5: Identify Critical Bridges**

The fifth phase evaluates the structural importance of between-community edges using edge betweenness centrality. Edges with high betweenness lie on a large share of shortest paths and therefore serve as bridges whose disruption could interrupt transmission between otherwise connected groups. The Türkiye analysis identified  $TSC \rightarrow FIN$  and  $CO12 \rightarrow AGF$  as particularly important bridges, with resilience values of approximately 0.35, followed by  $MA2 \rightarrow EGW$  and  $MA1 \rightarrow FIN$  at approximately 0.32. The output is a ranked list of critical links that merit closer market-level investigation and potential policy attention.

### **Phase 6: Evaluate Resilience**

The sixth phase synthesizes the preceding structural analysis into an overall assessment of network resilience. The proposed resilience indicator translates structural dependence on bridging links into a summary measure: the greater the dependence on a small set of bridges, the lower the resilience to disruption of those links. For the Türkiye MA2 network, the resilience indicator of 0.43 suggests moderate structural resilience—the network is not dependent on a single bridge, but its communities

are not connected through a sufficiently dense set of alternative routes to make all disruptions inconsequential. The phase also evaluates hypothetical disruptions, such as the complete removal of intermediate-layer relationships, to assess how network connectivity would change under stress. The output is a quantitative resilience assessment and identification of the structural conditions that most affect network vulnerability.

### **Phase 7: Match Interventions to Network Position**

The seventh phase translates structural diagnosis into policy design. Different network positions call for different policy instruments and different institutional actors. Sectors identified as bottlenecks—such as FIN and AGF in the Türkiye analysis—may require competition enforcement, regulatory reform, or access measures to ensure that their structural position does not become a transmission failure. Sectors that absorb substantial input flows—such as CST and EGW—may require capacity investment or infrastructure development to ensure that they can accommodate increased demand. Communities identified in Phase 4 may require coordinated policy treatment across the institutions responsible for their constituent sectors. Critical bridges identified in Phase 5 may require resilience-building measures, including supplier diversification, inventory buffers, or alternative route development.

This phase also involves matching interventions to policy domains. Industrial policy instruments may be appropriate for developing productive capabilities in target or bottleneck sectors. Competition policy may be appropriate for addressing market power or entry barriers in structurally important markets. Infrastructure policy may be appropriate for addressing capacity constraints in absorbing sectors. Financial-market policy may be appropriate for addressing constraints in the financial intermediation that occupies a central position in many transmission pathways. The output is a policy portfolio that is matched to the structural diagnosis rather than organized solely by sectoral or institutional boundaries.

### **Phase 8: Re-estimate Network After Intervention**

The eighth phase closes the policy loop by re-estimating the production network after interventions have been implemented. This involves updating the input-output data, repeating the network construction and structural diagnosis procedures, and comparing the new network structure to the baseline. The comparison reveals whether interventions have altered the structural conditions that motivated them—whether bottlenecks have been relieved, whether new transmission channels have opened, whether community structure has shifted, and whether resilience has improved or deteriorated. The output is an updated network diagnostic that informs subsequent rounds of policy design and adjustment.

This phase is essential because production relationships evolve over time. The Türkiye analysis demonstrates that the MA2 network changed between 2005 and 2018: FIN remained connected to MA2 throughout, while AGF and CST were linked to MA2 in several periods; EGW became more consistently connected in later years; and community structure shifted, with MA2 and FIN sharing a community during 2011–2015 but located in different communities during 2016–2018. These changes

suggest that network diagnostics should be repeated periodically rather than treated as permanent characteristics of an economy. The output is a dynamic understanding of how policy interventions and other factors reshape the production network over time.

## **From Structural Diagnosis to Policy Action**

The framework proposed and implemented in this paper responds to a fundamental challenge in contemporary industrial policy: the mismatch between the sectoral organization of policy and the networked reality of production. By operationalizing network analysis as a sequence of eight policy-relevant phases, the framework provides practitioners with a structured procedure for identifying where interventions should enter the network, how their effects are likely to travel, which structural conditions may amplify or attenuate transmission, and how the network responds to policy action.

The framework is deliberately diagnostic rather than prescriptive. It does not claim that network statistics alone determine policy priorities or that structural importance implies economic inefficiency. Rather, it supplies a disciplined first-stage diagnostic that can be combined with market-specific evidence, competition indicators, regulatory assessments, and firm-level analysis. The value of the framework lies in its capacity to organize policy reasoning around transmission channels rather than sectoral boundaries, and to identify where additional evidence is most valuable.

For Türkiye and other industrial economies, the framework suggests that improving productivity and competitiveness requires attention to the network conditions under which productive sectors operate. Industrial policy, competition policy, infrastructure policy, and financial-market policy are not independent instruments but interacting components of a coordinated approach to structural transformation. The next step is to combine network diagnostics with detailed market evidence and counterfactual policy evaluation, moving network-aware industrial policy from a structural diagnostic toward a quantitative framework for assessing productivity, welfare, and resilience effects.