Employment Strategies to Respond to COVID-19: Characterizing Input-Output Linkages of a Targeted Sector

Temel, Tugrul

ECOREC Economics Research and Consulting

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Tugrul Temel

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Abstract

At present, the world is facing an unprecedented employment challenge due to the COVID-19 pandemic. ILO (2020) expects the largest amount of youth unemployment at the global level to take place in manufacturing, real estate, wholesale, and accommodation sectors. This paper aims to produce information for employment strategy development in China, Japan, India, Russia, Germany, Turkey, UK and USA, which together account for about 60 percent of the world GDP. A novel method is introduced to identify critical input-output backward and froward linkages of a targeted sector. Based on the linkages identified, sectoral dependencies and pathways of interactions in a production system are characterized to uncover critical information for the design of employment policy interventions. Manufacturing is found to be top priority sector to be targeted in all the eight countries, followed by real estate and wholesale sectors, and these sectors should be coupled with isolated communities of sectors to capture external employment effects.

Key Words: input-output multipliers; network analysis; pathways and communities of sectors; COVID-19; employment policy interventions; global employment

JEL Codes: C67, P52 , J08, J21, J45, J48

1 Introduction

At present, the world is facing an unprecedented employment challenge due to the COVID-19 pandemic. ILO (2020) expects the largest amount of youth unemployment at the global level to take place in manufacturing, real estate, wholesale, and accommodation sectors. This paper aims to produce information for employment strategy development in China, Japan, India, Russia, Germany, Turkey, UK and USA, which together account for about 60 percent of the world GDP. We introduce a novel method to identify critical input-output backward and froward linkages of a targeted sector. Based on the linkages identified, sectoral dependencies and pathways of interactions in a production system are characterized to uncover critical information for the design of employment policy interventions. The method developed is enriched with the analysis of connected components and community structures of input-output (IO) multiplier matrix. A complete characterization of a targeted sector would provide critical new information on the backward and forward linkages of the sector targeted and the community it belongs to, and hence supporting policy discussions about the development of employment strategies to respond to the COVID-19 effects.

The empirical analysis uses IO data from 2015, which is the most recent available data in OECD database.[1] Therefore, our paper assumes that the properties of a production system in 2015 of a country remained unchanged during the period 2015-2020. The employment strategies elaborated in what follows should be interpreted relative to the 2015 IO properties of the country examined. The findings show that manufacturing (MA2) is top priority sector to be targeted in all the eight countries, followed by real estate (EST) and wholesale (WHS) sectors, and that these sectors should be coupled with isolated communities of sectors to capture external employment effects from the interacting communities (or clusters). Naturally, sector coupling would vary across countries, depending on the linkages between the communities identified.

This paper is organized in five sections. Following the Introduction, Section 2 describes the new method and the three network concepts used in the analysis. Section 3 applies the method using the 2015 IO data for eights countries. Drawing on the results from Section 3, Section 4 discusses how to integrate the new information obtained from partial sectoral analysis into wider employment policy interventions. Section 5 concludes the paper.

2 Method

2.1 Backward and forward layers of sectoral linkages

Input and output dependencies of a targeted sector i are characterized through the identification of backward and forward layers of sectoral linkages. These linkages are not typical as they are ordered in such a way as to show sectoral dependencies by hierarchically ordered layers. As illustrated in Figure 1, in the first backward layer around targeted sector A are those sectors that provide significant amounts of inputs directly to sector A; in the second backward layer are those sectors that provide significant inputs to the input providers of sector A and so on. Similarly, in the first forward layer around targeted sector A are those sectors that consume significant amounts of outputs of sector A; in the second forward

[1] see <https://stats.oecd.org/Index.aspx?DataSetCode=IOTSI4_2018> for OECD input-output data for 64 countries.

layer are those sectors that consume significant outputs of those sectors in the first layer and so on. The layered sectoral linkages represent the entirety of an input and output structure when a specific sector is targeted at a given significance level. The layered map of linkages in Figure 1 demonstrates sectoral pathways of dependencies, allowing for the analysis of the effect on a targeted sector A of a shock to the production system of another sector. It further helps characterize the interactions between groups of sectors in a backward and a froward layer. In sum, a targeted sector i would be fully characterized if we can identify all of its key input suppliers and buyers of its commodity.

In order to explain the method mathematically, let $\mathbf{M_b}$ define a *backward* linkage multiplier matrix with three sectors (i.e., $X = (I - A_c)^{-1}Y = \mathbf{M_b}Y$, where A_c is the column-wise standardized matrix of an input-output matrix - the so called input or technical coefficients matrix):

$$\mathbf{M_b} = \begin{bmatrix} 0 & 0.33 & 0.52 & 0.68 \\ 0.29 & 0 & 0.58 & 0.27 \\ 0.02 & 0.07 & 0 & 0.02 \\ 0.18 & 0.13 & 0.48 & 0 \end{bmatrix}.$$

Zeros in the diagonal cells imply that sectors do not use their own outputs as inputs in their production processes. Let $\{A, B, C, D\}$ denote a group of four sectors. Assign sector A to (1^{st} row, 1^{st} column) in $\mathbf{M_b}$; sector B, to (2^{nd} row, 2^{nd} column); sector C, to (3^{rd} row, 3^{rd} column); and sector D, to (4^{th} row, 4^{th} column). Choose an arbitrary threshold significance level (in percent terms) above which a multiplier will be classified as significant. Take, for example, 25 percent as a threshold level and target sector A represented by the 1^{st} column in the above backward multiplier matrix. The total of the multiplier values in the 1^{st} column is 0.49. The value in the (2^{nd} row, 1^{st} column), which is associated with sector B, is 0.29, and hence sector B's contribution to sector A is greater than 25 percent (i.e., $59 = (0.29/0.49) * 100$). This means that the linkage from B to A (or $B \to A$) is significant at the 25 percent significance level. In fact, it is observed that the linkage from D to A (or $D \to A$) in the 1^{st} column is also significant at the 25 percent level (i.e., $37 = (0.18/0.49) * 100$). This concludes that when sector A is targeted at the 25 percent significance level, there are two sectors (B, D) providing input to sector A's production.

For a complete characterization of the multiplier matrix $\mathbf{M_b}$, the above procedure should be applied to all of the four sectors. For illustrative purposes, we show the application of the procedure for targeting sector A only. The process of identification of significant input suppliers of A starts from the 1^{st} column. We select those linkages accounting for more than 25 percent of the column total. The numbers, 0.29 placed in (2^{nd}row - 1^{st} column) associated with a binary relation BA and 0.18 placed in (4^{th}row - 1^{st} column) associated with a binary relation DA, separately explain more than 25 percent of the total of the elements in the 1^{st} column. This means that sectors B and D are the immediate input suppliers of A (i.e., B and D are the sectors in the first backward layer of sector A). In the second round of sector identification, we start from sector B associated with the 2^{nd} column of $\mathbf{M_b}$ and choose the significant multiplier of 0.33 from A to B (denoted by AB placed in the 1^{st} row - 2^{nd} column), which is the only binary linkage significant at the threshold level of 25 percent. In the third round of identification, start from sector D associated with the 4^{th} column and choose the significant multipliers (0.68, 0.27) associated with linkages: (AD, BD). The process of identification of input suppliers triggered by targeting sector

A stops at the third round as sector C is not a significant input supplier of A, B, nor D. To sum up, when sector A is targeted, we identify the input supply binary links, $\{BA, DA, AB, AD, BD\}$, shown with solid blue arrows on the backward layers in Figure 1a.

In order to identify significant purchasers of outputs of sector A, we apply the same procedure to a $forward$ linkage multiplier matrix, $\mathbf{M_f}$ (i.e., $X = (I - A_r)^{-1}Y = \mathbf{M_f}Y$, where A_r is the row-wise standardized matrix of an input-output matrix - the so called output coefficients matrix):

$$\mathbf{M_f} = \begin{bmatrix} 0 & 0.41 & 0.39 & 0.51 \\ 0.23 & 0 & 0.35 & 0.16 \\ 0.02 & 0.11 & 0 & 0.02 \\ 0.24 & 0.22 & 0.48 & 0 \end{bmatrix}.$$

Applying the above procedure to $\mathbf{M_f}$ yields the set of binary output links: $\{AB, AC, AD, BA, BC, CB, DA, DC\}$ which are shown with solid red arrows in Figure 1a.[2]

A complete representation of all the linkages that matter for the targeted sector A is shown in Figure 1c, which is obtained by folding the backward layers on top of the forward layers in Figure 1a. Solid blue and red arrows, respectively, define backward and forward linkages, while dashed blue arrows represent the linkages that contain both backward and forward flows simultaneously. Figure 1c provides three different pieces of information. First, the input (output) flows in the network are demonstrated with blue (red) links. Second, the links that carry both input and output flows are illustrated with dashed blue links. The more the dashed links are, the higher the sectoral dependency and complexity of input-output flows. Sectors linked by dashed blue lines should receive more attention from decision makers as they carry out two types of flows at the same time. Dependency takes place in the sense that the performance of, for example sector A, strongly depends on the performance of sector B and D shown in Figure 1c. In fact, in this figure, we observe that sectors A, $B\, and\, D$ are tightly coupled, which is a stronger version of the dependency concerned. These sectors cannot be examined in an isolated manner, and they must be studied as a group which moves together. Third, Figure 1c shows that when sector A is targeted, sectors B and D exchange both inputs and outputs with sector A. The link from B to D is the only link that transfers input only. Sector C, however, involves only output flows, suggested by red links surrounding it. In the example concerned, there are four sectors and each one of them can be targeted separately to generate four sub-graphs as in Figure 1c. Designing effective interventions requires the identification of all the four sub-graphs and ranking of the links with respect to sectoral intervention priority.[3]

2.2 Connected components and their communities

The layered directed graph (or IO network) established in Section 2.1 can be further analyzed by deriving its connected components and community structures. A directed graph is said to be connected if there is a path between all pairs of vertices (or production sectors). A connected component of a directed graph is a maximal connected sub-graph. Connected components of a directed graph comprise an acyclic directed graph, meaning that individual connected components form a partition into sub-graphs that are

[2]The reader is referred to Miller and Blair (2009) for an extensive description of how to use input-output matrices in policy analysis.

[3]The author developed an *Algorithm* to identify input-output layers of the linkages of a targeted sector. The Algorithm will be available upon request.

themselves connected. Figure 2 presents an example of a directed graph **G** with blue arrows for the multiplier interval of ($0.01 \leq m_{ij} < 0.06$). The underlying connected component of **G** is illustrated on the right pane with red linkages. The largest connected component consists of 10 sectors out of 17 sectors in the production system **G**. This example is based on a backward multiplier matrix only. A connected component should be treated as a single entity within which all sectors are linked to each other. Any influence exerted on a sector will flow across all the sectors within the component. There is no way for a sector to avoid the impact on itself of others within the component as they are all connected. In our actual graph, we identify connected components of a directed input-output system defined as a combined set of backward (blue) and forward (red) linkages.

After detecting connected components of a targeted sector i from its backward-forward linkages, we identify the community structure of each connected component based on Community Modularity statistic. The question here is whether there is a partition of a connected component into sub-graphs, each one of which maximizes Modularity statistic. We know that sectors within a connected component are all linked, but we do not know whether there are distinct sub-graphs within the connected component concerned. Uncovering the community structure of a connected component will tell us that there are sub-groups of sectors that are highly correlated or homogenous in terms of Modularity criterion (Capocci, Servedio, Caldarelli, and Colaiori, 2005; Charikar, 2000; Easley and Kleinberg, 2010; Fortunato, 2010; Fortunato, Latora, and Marchiori, 2004; Giatsidis, Thilikos, and Vazirgiannis, 2011; Newman, 2006,0; Newman and Girvan, 2004). Figure 3 illustrates with an example that a connected component on the left is one big group, elements of which are all connected to each other. This component has two sub-communities shown on the right pane, members of which are in closer relation to each other than to members of other component(s).

2.3 Key sectors

From a sectoral perspective, a sector is said to be key for another sector if it has the maximum contribution to the total output multiplier of the other sector. From an economy-wide perspective, however, a sector is said to be key if its total output multiplier is the largest compared to the total output multipliers of other sectors in the economy. We adopt the sectoral perspective and separately identify the key sectors from a backward multiplier matrix and those from a forward multiplier matrix. Then, we construct a directed graph using the pooled set of linkages obtained from the backward (blue arrows) and forward (red arrows) multiplier matrices. The final directed graph illustrated in Figure 4 represents a combined system consisting of the most influential linkages (blue and red arrows combined) on the input and the output side.

For simplicity, we examine the case in which a sector has one key input (output) sector ($k = 1$) only, meaning that the maximum backward (forward) multiplier is selected from each column (row). This yields two directed graphs: one for backward linkages (blue) and another for forward linkages (red). Thereafter, the two graphs are combined to generate the final network of input-output linkages of key sectors with $k = 1$. The same procedure can be applied for different k's, depending on the size of the multiplier matrix examined.

3 Implementation

3.1 Data: input-output matrices

The method and the two network concepts described in Section 2 are applied to characterize IO systems of eight countries: China, India, Japan, Russia in Asia; Germany, Turkey and UK in Europe, and USA. The IO data used in the implementation are obtained from OECD's IO database for the most recent available year 2015.[4] The OECD IO matrices with 36 sectors have been aggregated to 15 sectors by using the 2008 UN definitions for sector aggregation (United Nations, Development, and Bank, 2009). The aggregation allows for a comparative analysis of the IO systems across countries.

Concerning youth unemployment due to COVID-19, ILO's global estimates conjecture that manufacturing (**MA2**), wholesale and retail (**WHS**), real estate (**EST**), and accommodation (**HOT**) sectors will be hit hard (see Table 1 on page. 8 of ILO (2020)), which is the point of departure for the analysis conducted in this paper. It should be noted that the sample of the eight countries accounts for a substantial portion of the world GDP, and hence there is the need for developing strategies to avoid the bleak unemployment picture projected by ILO. The analysis of the current paper should provide critical information for use in the effective design of policy interventions targeting the four sectors. Government policies targeting employment in the hard-hit sectors should be informed of the characteristics of the backward and forward linkage structures of these sectors.

3.2 Sector targeting and dependency

The method developed is applied to target the four sectors identified by ILO (2020). If, for example, sector i is targeted for policy intervention, we first need to identify input suppliers of that sector, then identify input suppliers of sector i's input suppliers, followed sequentially by the identification of other input suppliers. This chain of backward linkages between the targeted sector and its first degree, second degree, third degree etc. input suppliers would show the network of upstream linkages of the targeted sector with the rest of the production system. The chain of linkages from the rest of the system to the targeted sector will fully identify the target sector's production dependencies. Likewise, the targeted sector is also characterized with respect to the type of consumers (both intermediate and final) of its commodities. We first need to identify the critical buyers (sectors) of the commodities produced by the targeted sector, and then sequentially identify the buyers of the commodities produced by the buyers of commodities of the targeted sector and so on. This type of downstream linkages would show how the target will be affected by changes in the demand for its commodities. With this type of forward sectoral links, we would characterize the commodity demand network of the targeted sector. Together, a combined map of backward and forward input-output flows from the perspective of the targeted sector will help us uncover the critical sectoral pathways of linkages which are most important for the performance of the targeted sector.

The empirical analysis is based on a given threshold significance level of a multiplier. This level is set to be 15 percent, meaning that the analysis carried out considers those multipliers having an explanatory power of 15 percent or higher out of the total input/output multiplier of the sector targeted. The

[4]see https://stats.oecd.org/Index.aspx?DataSetCode=IOTSI4_2018

linkages shown represent those linkages accounting for 15 percent or more of the multipliers influencing the targeted sector.

When **MA2 is targeted**, an interesting pattern of input-output flows arises across the countries examined (see the 1^{st} column in Table 1). In four countries in Asia, agriculture (**AGF**), crude oil and mining (**CO12**), and WHS sectors supply significant *input*; in two European countries, financial business (**FIN**), transportation-storage-communication (**TSC**) and WHS sectors transfer significant *input*; in Turkey, electricity-gas-water (**EGW**) and **HOT** sectors reveal significant *input* flows; and in USA, interestingly, the composition of the critical input suppliers includes **AGF**, **CO12**, **FIN** and **TSC**, which is "almost" the union of the critical sectors in Asia and Europe. With respect to *output* flows, we observe that construction (**CST**) and EST sectors unanimously arise as critical sectors whose outputs are demanded in the rest of the economy. **Concerning sectoral dependencies**, we observe that {**CO12**, **CST**, **EST**, **WHS**, **MA2**} reveal strong dependencies as shown in Table 2. **EST** is vitally important to control the changes in the rest of the economies of Japan, Russia, Germany, UK, Turkey and USA. Of these six countries, USA, UK and Russia reveal a much stronger dependency structure implied by the number of sector linkages given in Table 2. For example, in USA, we have the dependency structure of:

$$\textbf{EST} \dashrightarrow \textbf{WHS} \;\; \textit{and} \;\; \textbf{EST} \dashrightarrow \textbf{MA2}.$$

In UK, the dependency structure is of:

$$\textbf{CST} \dashrightarrow \textbf{EST} \dashrightarrow \textbf{WHS} \dashrightarrow \textbf{MA2} \dashrightarrow \textbf{CST},$$

and in Russia, it is:

$$\textbf{EST} \dashrightarrow \textbf{WHS} \dashrightarrow \textbf{MA2} \;\; \textit{and} \;\; \textbf{WHS} \dashrightarrow \textbf{CO12} \dashrightarrow \textbf{MA2}.$$

The larger the number of linkages, the higher the complexity of the dependency structure, and the more challenging will be to design policy interventions that involve multiple sectors.

When **WHS is targeted**, a pattern similar to one in Section 3.2 arises arises across the countries examined (see the 2^{nd} column in Table 1). In the Asian countries, **AGF**, **CO12** and **MA2** supply significant *input*; in two European countries, **FIN**, **MA2** and **TSC** transfer significant *input*; in Turkey, sectors **EGW**, **HOT** and **MA2** reveal significant *input* flows; and in USA, the composition of the critical input suppliers includes **AGF**, **CO12**, **FIN** and **TSC**, which is "almost" the union of the critical sectors in Asia and Europe. With respect to *output* flows, we observe that **CST**, **EST** and **MA2** play a critical role in all countries. **Concerning sectoral dependencies**, we observe that China and India do not show any sector dependencies, whereas others show varying degrees of dependencies among {**CO12**, **CST**, **EST**, **MA2**}. The highest degree of dependency is observed in UK, with a pathway:

$$\textbf{CST} \dashrightarrow \textbf{EST} \dashrightarrow \textbf{WHS} \dashrightarrow \textbf{MA2}.$$

This suggests that before targeting **WHS**, the implications on **WHS** of a change in **CST** and **EST** should be analyzed as the performance of **WHS** is strongly dependent on the type of changes in **CST** and **EST**. Russia is also facing somewhat weaker dependency, with a pathway:

$$\textbf{EST} \dashrightarrow \textbf{WHS} \dashrightarrow \textbf{CO12} \dashrightarrow \textbf{MA2}.$$

When **EST is targeted**, similarities exist among the Asian countries and USA (see the 3^{rd} column in Table 1). **AGF**, **CO12**, **MA2** and **WHS** play an important role in *input* supply; in Germany and UK, **FIN** and **TSC** still represent the core of input supply. Turkey reveals structural differences compared to other countries, in which case **EGW**, **HOT** and **MA2** supply critical amount of input to the rest of the economy. What is interesting in the case of Turkey is that the publicly managed **EGW** and private sector **HOT** occupy a central place in input supply, but these sectors play no role in input supply in the other six countries examined. With this feature, Turkey is distinguished from the other six countries. Concerning *output* supply, except UK and Germany, **CST** and **MA2** unanimously arise as two critical sectors whose outputs are consumed by others. **Regarding sectoral dependencies**, China, India, Germany and USA show no dependency, while others show dependency involving **WHS**.

When **HOT is targeted**, the results look very similar to the case in which **EST** is targeted (see the 4^{th} column in Table 1). Four Asian countries have the same sectors {**AGF**, **CO12**, **MA2**, **WHS**} significant in input supply; two European countries share commonality but Germany has a wider input supply network {**FIN**, **MA2**, **TSC**, **WHS**} compared to UK having two input supply sectors {**FIN**, **TSC**}. USA shows a combination of Asian and European networks, including {**AGF**, **CO12**, **FIN**, **MA2**, **TSC**, **WHS**}. Turkey is distinguished with a very different set of input suppliers, including {**EGW**, **MA2**}. Regarding *output* supply, except UK and Germany, **CST**, **EST**, and **MA2** represent the core of output suppliers in Japan, India, Russia and Turkey, while **CST** and **MA2** represent the core suppliers in China and USA. With respect to **sectoral dependencies**, **EST** and **WHS** constitute the core of dependencies, which is extended by **CST**, **CO12**, and **MA2** in Russia and UK.

Drawing on the targeting-based networks across countries (see the 1^{st} column of Figure 5 through Figure 12), all of the IO systems examined show only **one connected component**. It means that sectors in a given network obtained after targeting are linked either by an input supply or output supply linkage or both types of linkages. Any intervention to a single sector within the connected component will have repercussions in the rest of the sectors in the network. However, the level of the repercussions may vary across sectors in the network. **Community analysis** of a connected component aims to reveal the partition of the network in such a way as to reflect potentially different repercussions within each partition (or community). The analysis shows that almost all connected components across countries and sectors have two communities (or clusters) (see the 3^{rd} column of Figure 5 through Figure 12). In a more detailed policy design, each community should be individually targeted as a group as its members show similarity with respect to network betweenness centrality criterion.[5]

Table 2 provides additional information for use in the characterization of the networks obtained from targeting the four critical sectors identified by ILO. Flows of inputs and outputs between sectors, their dependency structures, and the key sectors in an economy represent three parameters to be considered in the design of policy interventions. Take, for example, Germany given in the 1^{st} row of Table 2. It is

[5]The Girvan–Newman algorithm is applied to identify communities. This algorithm first identifies edges in a network that lie between communities and then removes them, leaving behind just the communities themselves. The algorithm employs the graph-theoretic betweenness centrality measure, which assigns a number to each edge which is large if the edge lies "between" many pairs of nodes.

characterized by three parameters: **EST** ⇢ **MA2**, simple dependency and key sectors {**EST**, **MA2**}. The first parameter tells us that, no matter which sector is targeted, **MA2**'s performance strongly depends on the input and output of **EST**. The second is the simple dependency of **MA2** on **EST** implied by a single binary linkage between them. The third parameter is that these sectors are key as they have the largest multiplier values compared to others in the network. UK given in the 6^{th} row of Table 2 reflects a very complex dependency structure implied by:

CST ⇢ **EST** ⇢ **WHS** ⇢ **MA2** ⇢ **CST**,

in which case **CST** plays a key role both as a source of policy change and as a sink of the impact of the change concerned (i.e., a loop starting from a change in **CST** and ending with an effect on itself). The fact that it is a closed loop makes it challenging to control the changes along the chain of linkages, **EST**⇢**WHS**⇢**MA2**, because this two-edge pathway represents a constraint for **CST**. When, for example, WHS is targeted, its impact on **CST** as well as **CST**'s impact on **WHS** via changes in **EST** must be considered because **WHS** is a member of the closed loop. The other countries can be analyzed in a similar fashion at will.

In the last column of Table 2, for each country, we identified key sectors in its IO system. **EST** and **MA2** are identified as key sectors in Germany, USA, Turkey, and UK; **MA2** and **WHS** are key sectors in Japan and Russia; and **MA2** is key for China and India. Apparently, there is some kind of homogeneity in the maximum multiplier sectors across the countries. Across all the countries analyzed, **MA2** is the key sector to be targeted to generate the maximum employment through its multiplier effects on the rest of the economy.

4 Discussion of the findings

Drawing on the findings elaborated in Section 3, we suggest ways to achieve the best employment outcome at the country level. The key to success lies in ensuring that each country prioritizes the identified critical sectors, while considering community structures and pathways of sector dependencies as constraints of policy interventions. In other words, we propose to formulate an employment strategy as a constraint optimization problem, the objective of which is to maximize employment in a targeted sector(s) subject to structural constraints, including the degree of sector connectedness, community structure (size and density), and pathways of sectoral dependencies. In what follows, we elaborate on how to employ the information generated in the formulation of employment policy interventions.

First, the domain of any policy targeting with a view to ensuring the pre-COVID-19 employment level should necessarily include {**AGF**, **CO12**, **CST**, **EST**, **FIN**, **MA2**, **WHS**, **HOT**}, in which case {**EST**, **MA2**} are the core sectors with the largest multiplier effects both in input and output markets. Together, these cores would act as catalyst for the growth in other sectors through the input-output linkages.

Second, in all the eight countries examined, except for USA, the policy intervention networks are composed of two communities (or clusters). Knowledge of the characteristics (i.e., number of sectors, their interactions, and linkage density) of the community structures identified should be utilized in employment policy design. In China, {**CST**, **MA2**, **WHS**} and {**AGF**, **CO12**} represent the two robust core communities reflecting the strongest linkages among its members, and these communities survive no matter which sector is targeted (see 3^{rd} column in Figure 5). This suggests that the highest gain in employment in China can be materialized by exploiting the linkage properties within individual communities, as well as the linkage strength between the communities.

In Japan, there are two robust core communities, {**CST**, **EST**, **MA2**} and {**AGF**, **CO12**}, no matter which sector is targeted (see 3^{rd} column in Figure 6). Interestingly, members of the first community are linked to each other in output markets, while members of the second community interact only in input markets. This makes the targeting easier and more appealing. It is easier in the sense that if employment creation is targeted in output markets, the interactions among sectors in the first community should be examined; if, however, employment in input markets is targeted, then the interactions among sectors in the second community should be analyzed. It is appealing because the sectors where the final impact of targeting is expected are isolated in two different communities, and because these communities are connected through the linkages in input markets only.

In India, there are two robust core communities, {**CST**, **EST**} and {**AGF**, **CO12**, **MA2**, **WHS**}, no matter which sector is targeted (see 3^{rd} column in Figure 7). Members of the first community are linked to each other in output markets, while members of the second community are linked only in input markets. Similar to the case of Japan, targeting is easy and appealing. It is easy in the sense that if employment creation is targeted in output markets, the interactions among sectors in the first community should be examined; if, however, employment in input markets is targeted, then the interactions among sectors in the second community should be analyzed. It is appealing because the sectors where the final impact of targeting is expected are isolated in two different communities. Interestingly, the linkages between the two core communities are all about the interactions in output markets only, as opposed to the Japanese case in which the communities are linked through input market linkages.

In Russia, there are two robust core communities, {**CST**, **EST**, **MA2**} and {**AGF**, **CO12**, **WHS**} (see 3^{rd} column in Figure 8). Members of the first community are linked to each other in both input and output markets, while members of the second community interact only in input markets. The two communities are linked through the input linkages only. If employment is targeted independent of market type, the first community should be examined; if, however, employment is targeted in input markets, the second community should be analyzed. These communities are linked in input markets because they are connected through the linkages in input markets only.

The two EU countries, Germany and the UK, share commonalities, while showing key differences from the Asian countries, including China, Japan, India and Russia. Both Germany and the UK have two identical communities: {**EST**, **FIN**, **TSC**} and {**CST**, **MA2**, **WHS**} when **EST**, **MA2** and **WHS** are targeted (see 3^{rd} column in Figures 9 and10). In both countries, the first community arises in input markets, while the second community has linkages in both input and output markets. The type of linkages connecting the two communities is different across Germany and the UK, however. In Germany, the two communities are connected through linkages both in input and output markets, while in the UK through input market linkages only. Germany and the UK show stronger differences when sector **HOT** is targeted (see (4^{th} row - 3^{rd} column) in Figures 9 and10). The communities differ both in terms of sector composition and the type of linkages connecting the communities. Therefore, **HOT** needs special attention when policies are designed to promote employment in this sector.

The U.S. shows characteristics that have commonalities both with the Asian and the EU countries. Two robust communities, {**AGF**, **CO12**, **MA2**, **WHS**} and {**CST**, **EST**, **FIN**, **TSC**}, arise when

EST, **MA2** and **WHS** are targeted (see 3^{rd} column in Figures 12). The first community consisting of only input linkages is similar to the Asian case, while the second one consisting of both input and output linkages is similar to the EU case. These communities are connected through input and output linkages. The picture becomes quite different when **HOT** is targeted. Three communities emerge, two of which {**AGF**, **CO12**, **WHS**} and {**EST**, **FIN**, **TSC**} are all about input linkages, and the third one {**CST**, **MA2**, **HOT**} has mixed linkages. This reflects different dependency structure **HOT** has with the rest of the economy.

Finally, Turkey shows a completely different linkage structure between two core communities: {**HOT**, **WHS**} and {**CST**, **EST**, **EGW**} no matter which sector is targeted (see 3^{rd} column in Figures 11). The first community is all about input linkages, while the second is mixed with input and output market linkages. These communities are also linked with mixed linkages. What is interesting and important is to observe **EGW** to play a significant role in the core economic activities. This observation is unique to Turkey as **EGW** has not been observed as critical in the other 7 countries examined.

A third suggestion is that knowledge of the critical binary sectoral links ensuring cross-community connectedness is essential for informed employment policy intervention. The policies aimed to ensure the continuity of cross-community links should be integrated into wider economic policies in order to materialize potential employment benefits from the interactions between the communities. The potential gains from such connectedness will be forgone if the policies implemented dismantle or do not consider the connectedness of the existing communities. In Figure 13, vital binary linkages are mapped that ensure cross-community connectedness in each country. For example, in China, the connectedness of the two communities discussed above requires the presence of at least one linkage out of two: {(**MA2**, **AGF**), (**MA2**, **FIN**)}; in Japan, the presence of at least one linkage out of four: {(**AGF**, **EST**), (**AGF**, **HOT**), (**WHS**, **MA2**), (**WHS**, **CO12**)}, and so on. When there are more than two communities, which is the case in USA, then at least three linkages must be present to tie all the communities together.

To sum up, based on the emerging input-output linkages and the implied community structures summarized above, scope for substantial gains in employment exists if policy interventions prioritize **MA2** and its key binary link to ensure cross-community connectivity, which is followed by **EST** and its key binary link and by **WHS** and its key binary link. Coupling the targeted sector with its key partner sector should be the way forward to reap the full benefits of employment policy interventions. Such interventions should exploit patterns of linkages between the targeted sector and its community in the production system.

5 Conclusions

Using concepts from network analysis and OECD input-output data, this paper develops an algorithm to uncover critical patterns of sector linkages and features of country-level production systems. In order to respond to the projected COVID-19-related youth unemployment in manufacturing, real estate, wholesale and accommodation sectors, the paper produces information that can be used in employment strategy development in the context of China, Japan, India, Russia, Germany, Turkey, UK and USA, which together account for about 60 percent of the world GDP. Employment strategy development is discussed with the help of a constrained optimization problem, the objective of which is to maximize employment under sector and production system constraints. The empirical configuration of sectoral pathways of interactions, sectoral input-output dependencies, and sectoral communities defines the domain of the constraints for optimal employment. Broad elements of an optimal employment strategy is then elaborated using this configuration. Manufacturing is found to be top priority sector to be targeted in all the eight countries, followed by real estate and wholesale sectors, and these sectors should be coupled with isolated communities of sectors to capture external employment effects.

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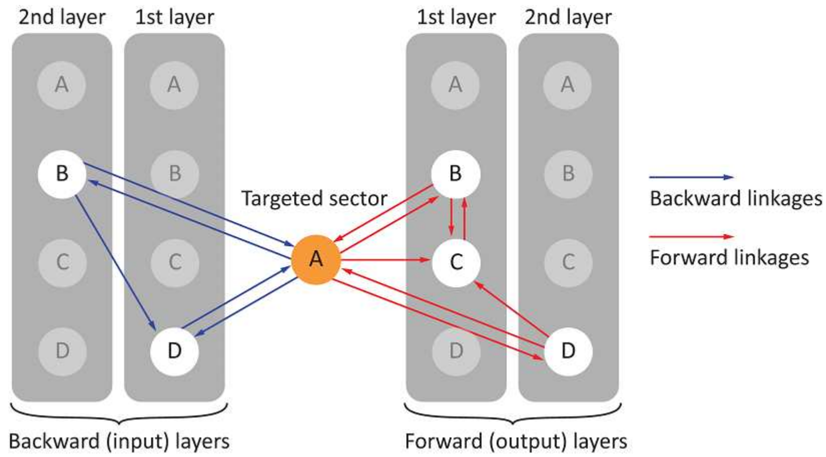
Table 1: Anatomy of targeted sectors across countries

		MA2	**WHS**	**EST**	**HOT**
China	Input	AGF, CO12, WHS	AGF, CO12, MA2	AGF, CO12, FIN, MA2, WHS	AGF, CO12, MA2, WHS
	Output	CST	CST, MA2	CST, MA2	CST, MA2
	Community 1	CST, **MA2**, WHS	CST, MA2, **WHS**	**EST**, FIN	CST, **HOT**, MA2, WHS
	Community 2	AGF, CO12	AGF, CO12	AGF, CO12	AGF, CO12
	Community 3	-	-	CST, MA2, WHS	-
Japan	Input	AGF, CO12	AGF, CO12, MA2	AGF, CO12, MA2, WHS	AGF, CO12, MA2, WHS
	Output	CST, EST	CST, EST, MA2	CST, MA2	CST, EST, MA2
	Input/Output	EST, WHS	EST	WHS	EST, WHS
	Community 1	CST, EST, **MA2**	AGF, CO12, **WHS**	CST, **EST**, MA2	CST, EST, **HOT**, MA2, WHS
	Community 2	AGF, CO12, WHS	CST, EST, MA2	AGF, CO12, WHS	AGF, CO12
India	Input	AGF, CO12, WHS	AGF, CO12, MA2	AGF, CO12, FIN, MA2, TSC, WHS	AGF, CO12, MA2, WHS
	Output	CST, EST	CST, EST, MA2	CST, MA2	CST, EST, MA2
	Community 1	AGF, CO12, **MA2**, WHS	AGF, CO12, MA2, **WHS**	CST, **EST**, TSC	CST, EST, **HOT**
	Community 2	CST, EST	CST, EST	AGF, CO12, MA2, WHS	AGF, CO12, MA2, WHS
Russia	Input	AGF, CO12	AGF, CO12, MA2	AGF, CO12, MA2, WHS	AGF, CO12, MA2, WHS
	Output	CST, EST	CST, EST, MA2	CST, MA2	CST, EST, MA2
	Input/Output	CO12, EST, WHS	CO12, EST	CO12, WHS	CO12, EST, WHS
	Community 1	CST, EST, **MA2**	AGF, CO12, **WHS**	CST, **EST**, MA2	CST, EST, **HOT**, MA2, WHS
	Community 2	AGF, CO12, WHS	CST, EST, MA2	AGF, CO12, WHS	AGF, CO12
Germany	Input	FIN, TSC, WHS	FIN, MA2, TSC	FIN, MA2, TSC, WHS	FIN, MA2, TSC, WHS
	Output	CST	CST	CST	CST
	Input/Output	EST	EST	-	EST
	Community 1	CST, **MA2**, WHS	CST, MA2, **WHS**	**EST**, FIN, TSC	CST, **HOT**, MA2, WHS
	Community 2	EST, FIN, TSC	EST, FIN, TSC	CST, MA2, WHS	EST, FIN, TSC
UK	Input	FIN, TSC	FIN, TSC	FIN, TSC	FIN, TSC
	Input/Output	CST, EST, WHS	CST, EST, MA2	CST, MA2, WHS	CST, EST, MA2, WHS
	Community 1	CST, **MA2**, WHS	CST, MA2, **WHS**	**EST**, FIN, TSC	**HOT**, MA2, WHS
	Community 2	EST, FIN, TSC	EST, FIN, TSC	CST, MA2, WHS	CST, EST, FIN, TSC
Turkey	Input	EGW, HOT;	EGW, HOT, MA2	EGW, HOT, MA2	EGW, MA2
	Output	CST, EST	CST, EST, MA2	CST, MA2	CST, EST, MA2
	Input/Output	EST, WHS	EST	WHS	EST, WHS
	Community 1	CST, EGW, EST, **MA2**	HOT, **WHS**	CST, EGW, **EST**, MA2	**HOT**, WHS
	Community 2	HOT, WHS	CST, EGW, EST, MA2	HOT, WHS	CST, EGW, EST, MA2
USA	Input	AGF, CO12, FIN, TSC	AGF, CO12, FIN, MA2, TSC	AGF, CO12, FIN, MA2, TSC, WHS	AGF, CO12, FIN, MA2, TSC, WHS
	Output	CST	CST	CST, MA2	CST, MA2
	Input/Output	EST	EST	-	EST
	Community 1	AGF, CO12, **MA2**, WHS	AGF, CO12, MA2, **WHS**	CST, **EST**, FIN, TSC	CST, **HOT**, MA2
	Community 2	CST, EST, FIN, TSC	CST, EST, FIN, TSC	AGF, CO12, MA2, WHS	EST, FIN, TSC
	Community 3	-	-	-	AGF, CO12, WHS

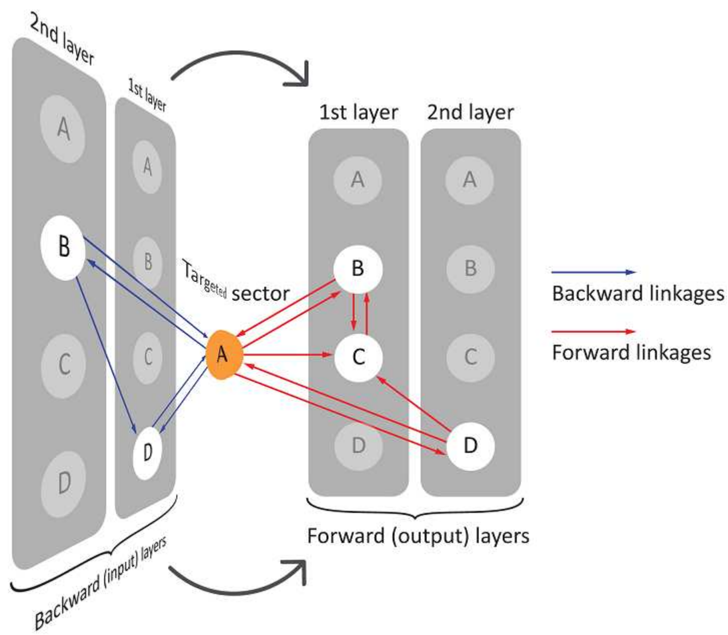
Table 2: Sectoral dependencies implied by targeting and key sectors

	MA2	WHS	EST	HOT	Dependency	Key sectors
Germany	EST--→MA2				simple	EST, MA2
USA	EST--→WHS and EST--→MA2				simple	EST, MA2
Japan	EST--→WHS--→MA2				difficult	MA2, WHS
Turkey	EST--→WHS--→MA2				difficult	EST, MA2
Russia	EST--→WHS--→MA2 and WHS--→CO12--→MA2				complex	CST, MA2, WHS
UK	CST--→EST--→WHS--→MA2--→CST				very complex	EST, MA2
China		WHS--→MA2			simple	MA2
India		WHS--→MA2			simple	MA2

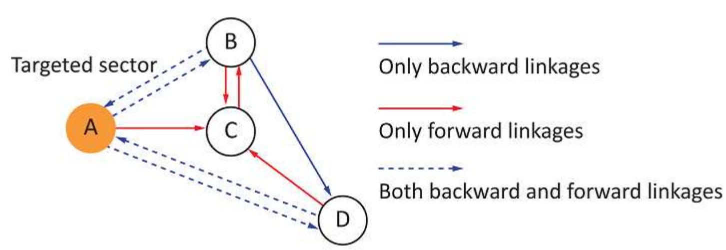
Figure 1: Layers of backward and forward linkages of a targeted sector A



(a) Layers of backward and forward linkages



(b) Folding backward layers on top of forward layers



(c) Complete characterization of all the linkages

Figure 2: An example graph **G** and its connected component

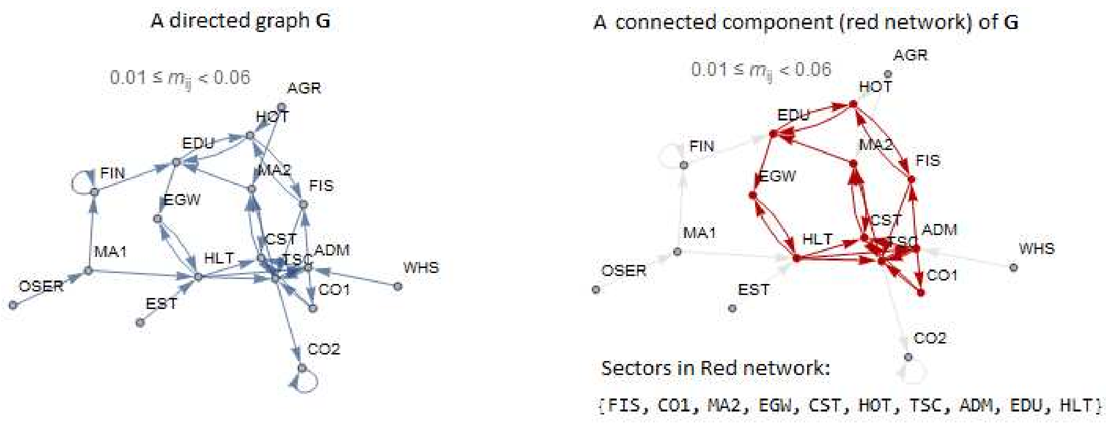


Figure 3: A connected component and its communities

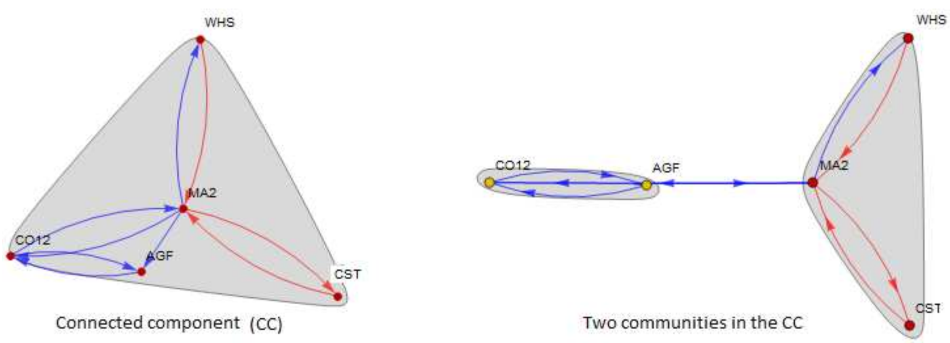


Figure 4: A network of key sectors from both backward and froward linkages

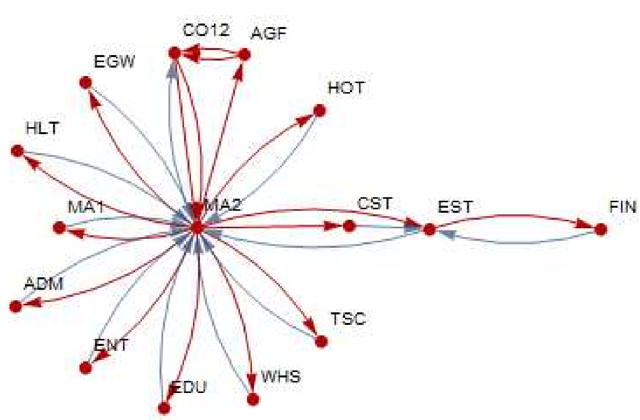


Figure 5: China: Sectors targeted at significance level of 0.15 and key sectors of the economy

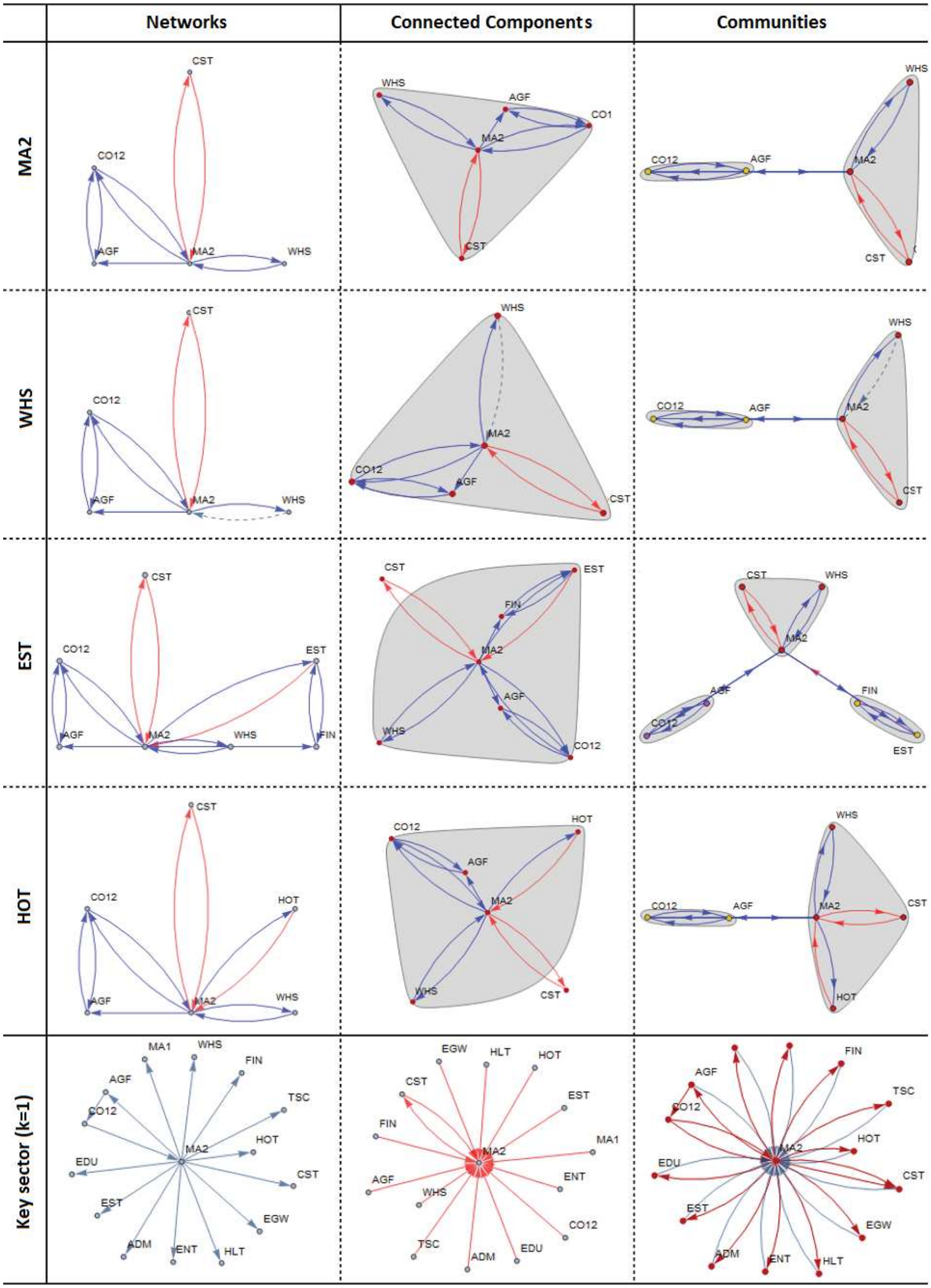


Figure 6: Japan: Sectors targeted at significance level of 0.15 and key sectors of the economy

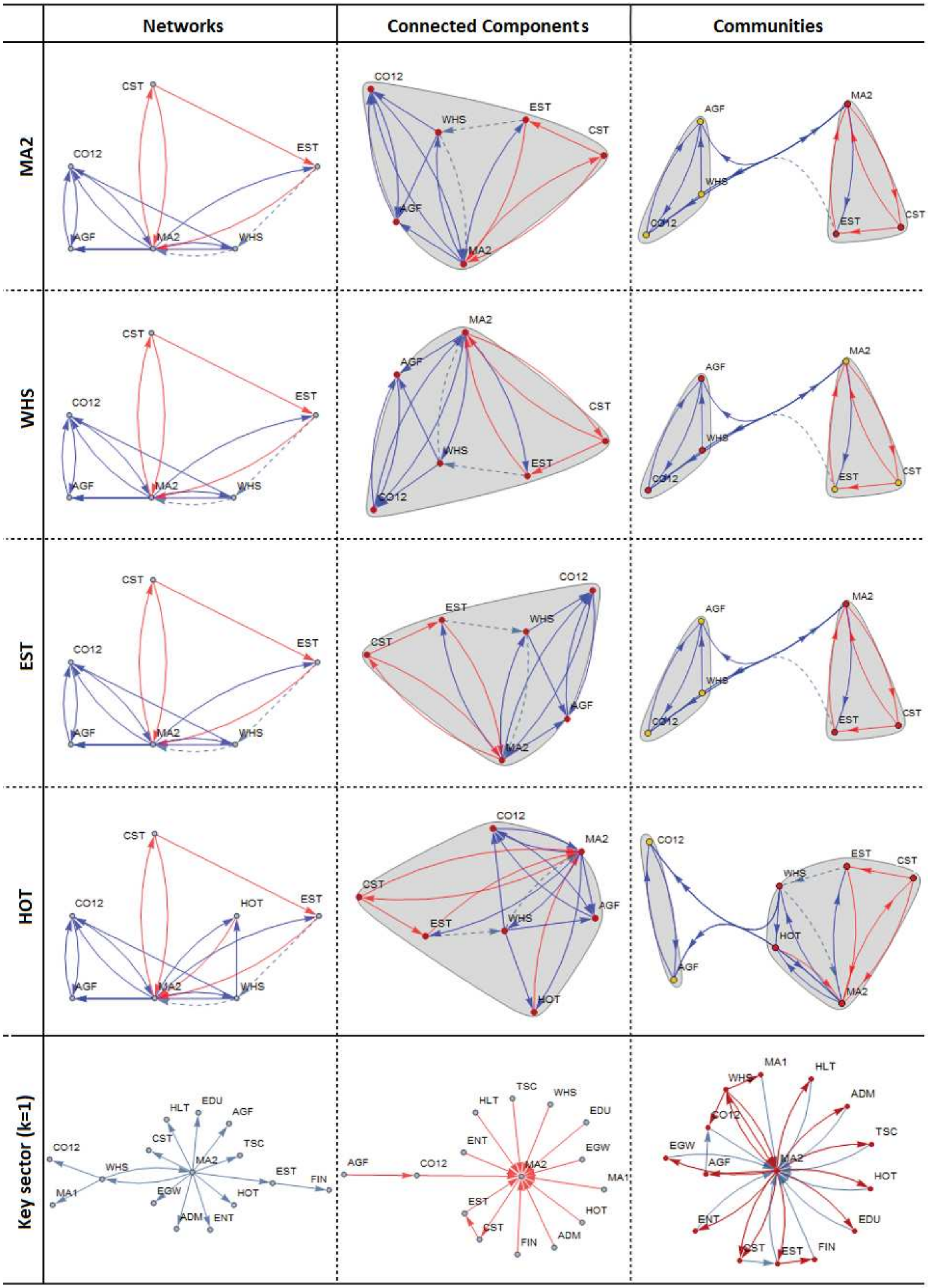


Figure 7: India: Sectors targeted at significance level of 0.15 and key sectors of the economy

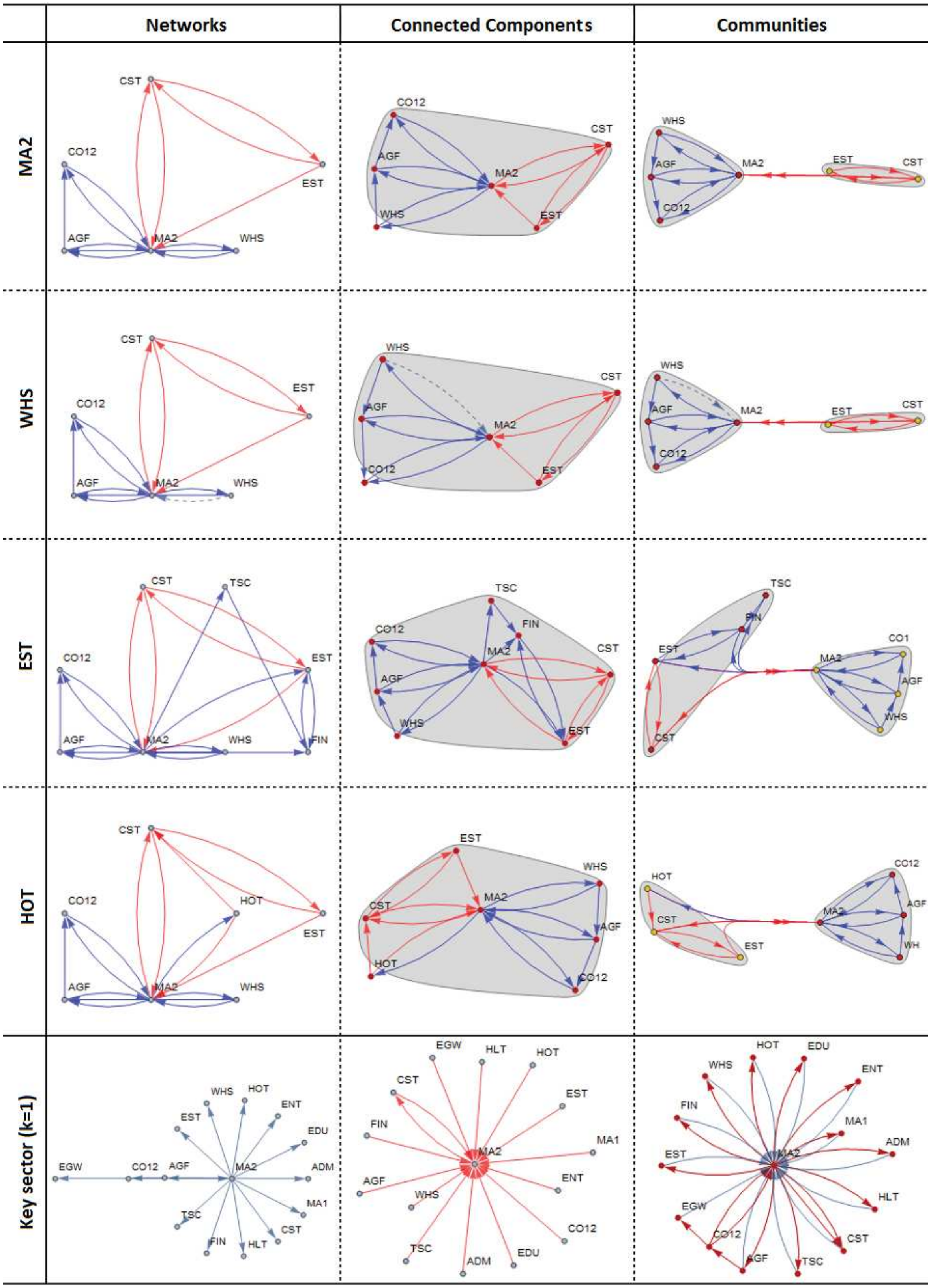


Figure 8: Russia: Sectors targeted at significance level of 0.15 and key sectors of the economy

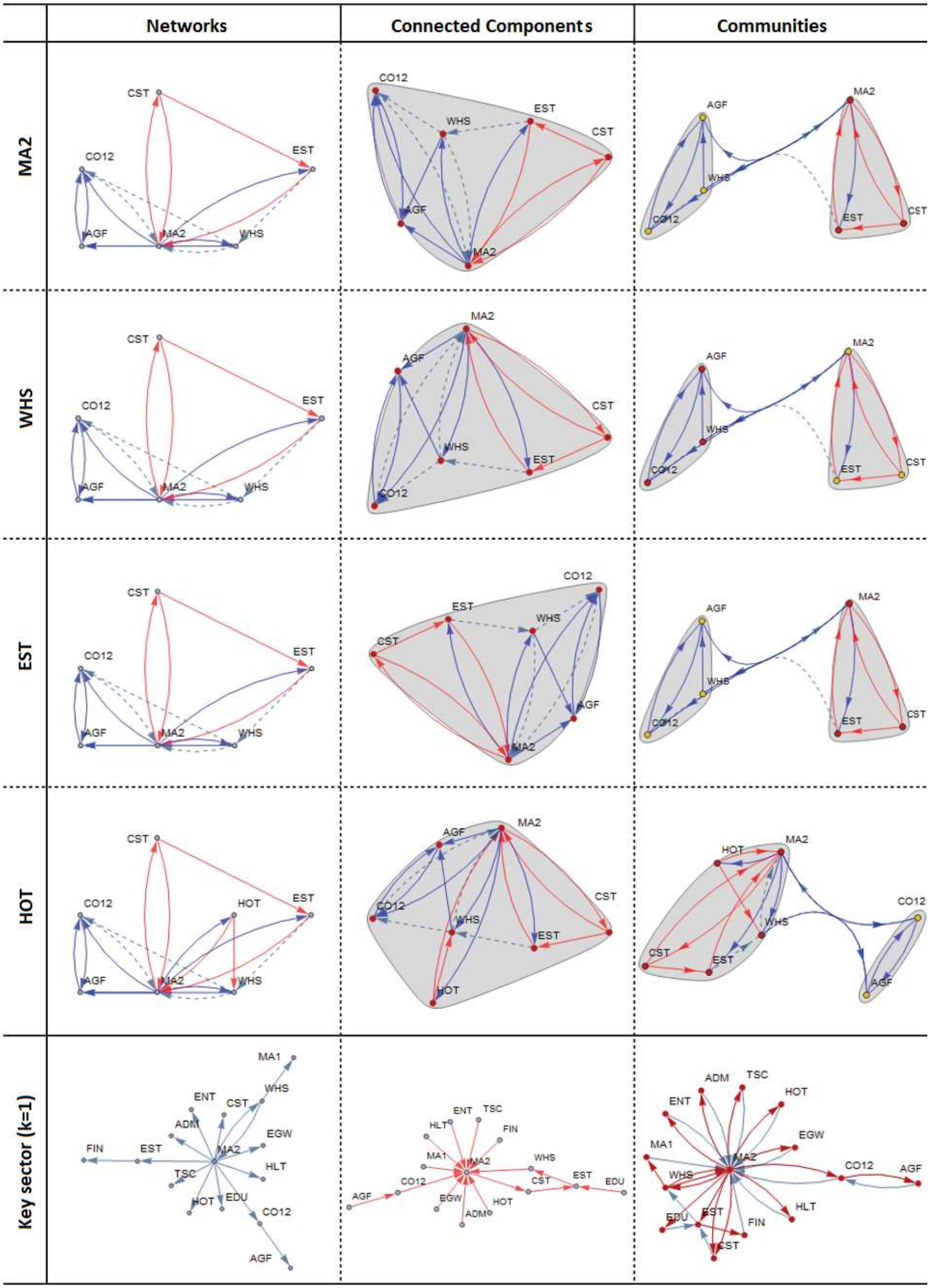


Figure 9: Germany: Sectors targeted at significance level of 0.15 and key sectors of the economy

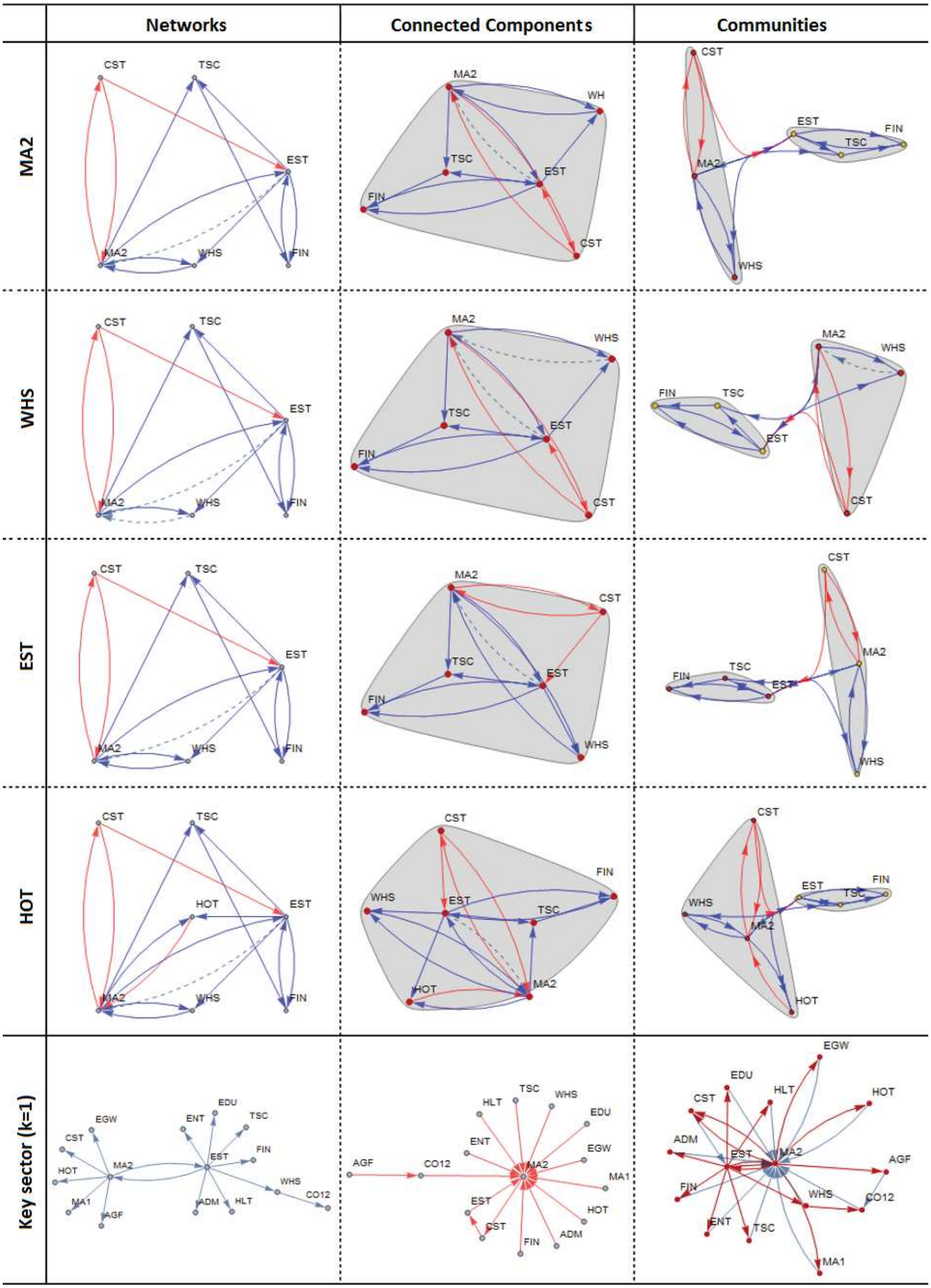


Figure 10: UK: Sectors targeted at significance level of 0.15 and key sectors of the economy

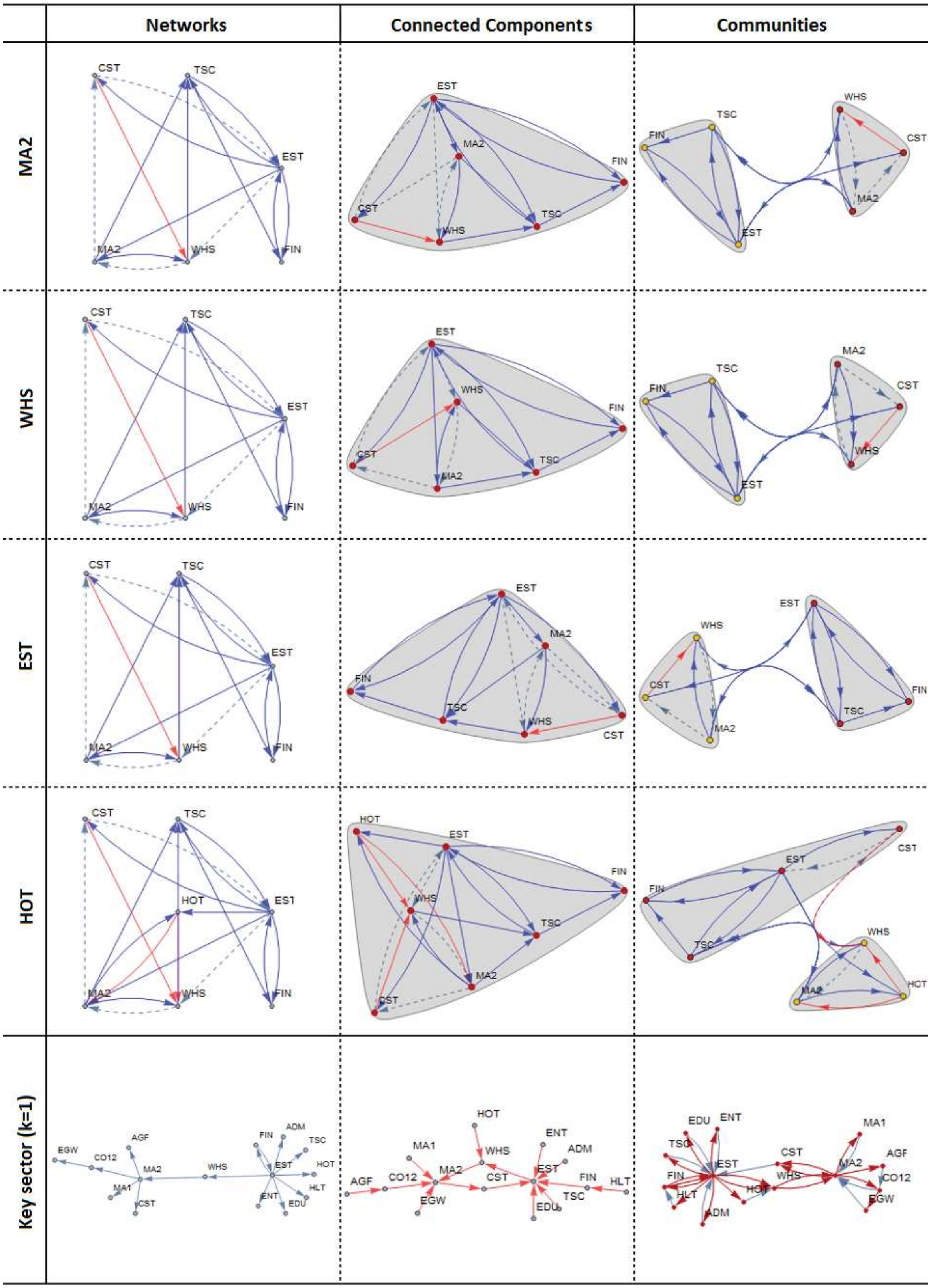


Figure 11: Turkey: Sectors targeted at significance level of 0.15 and key sectors of the economy

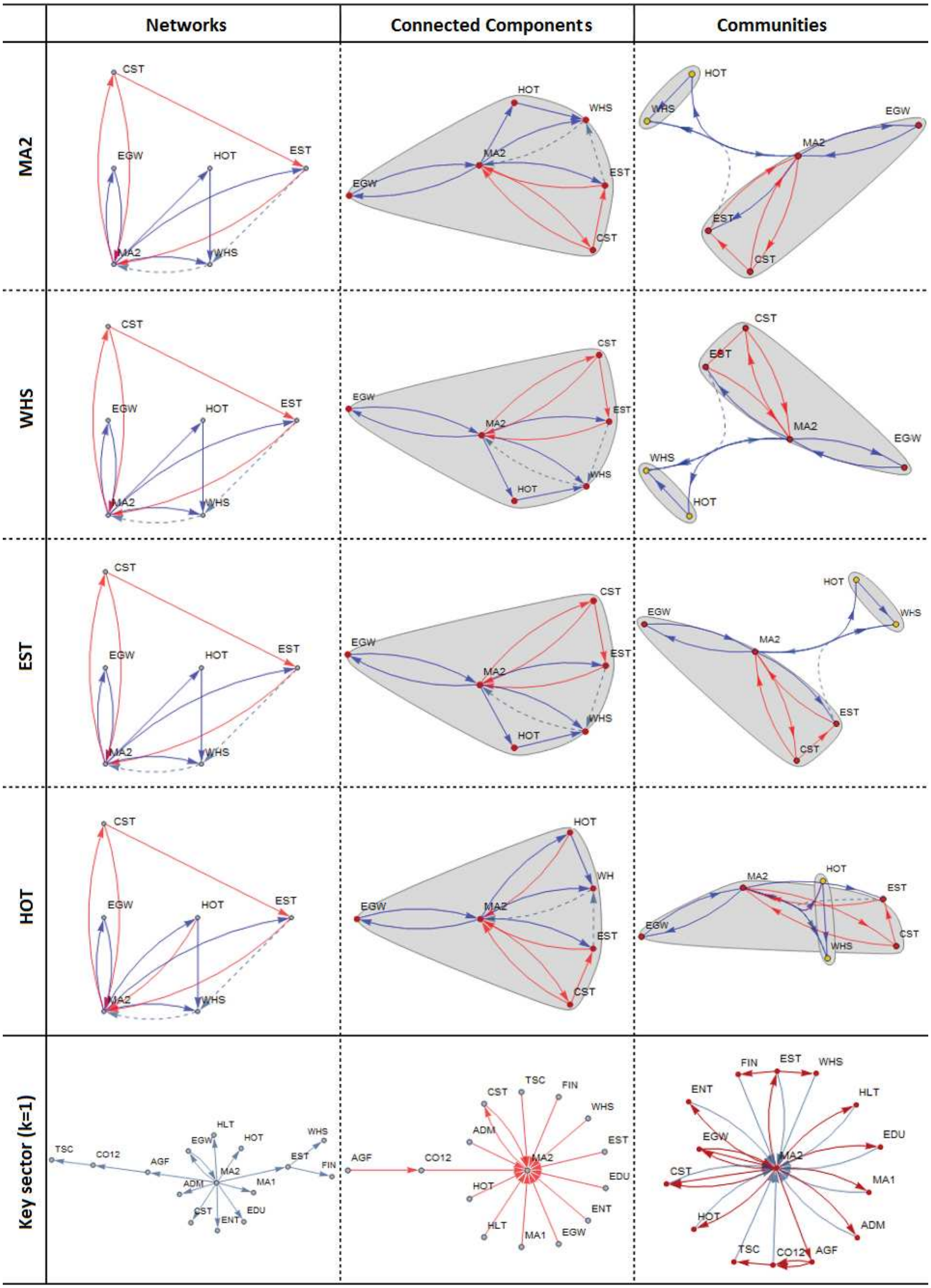


Figure 12: USA: Sectors targeted at significance level of 0.15 and key sectors of the economy

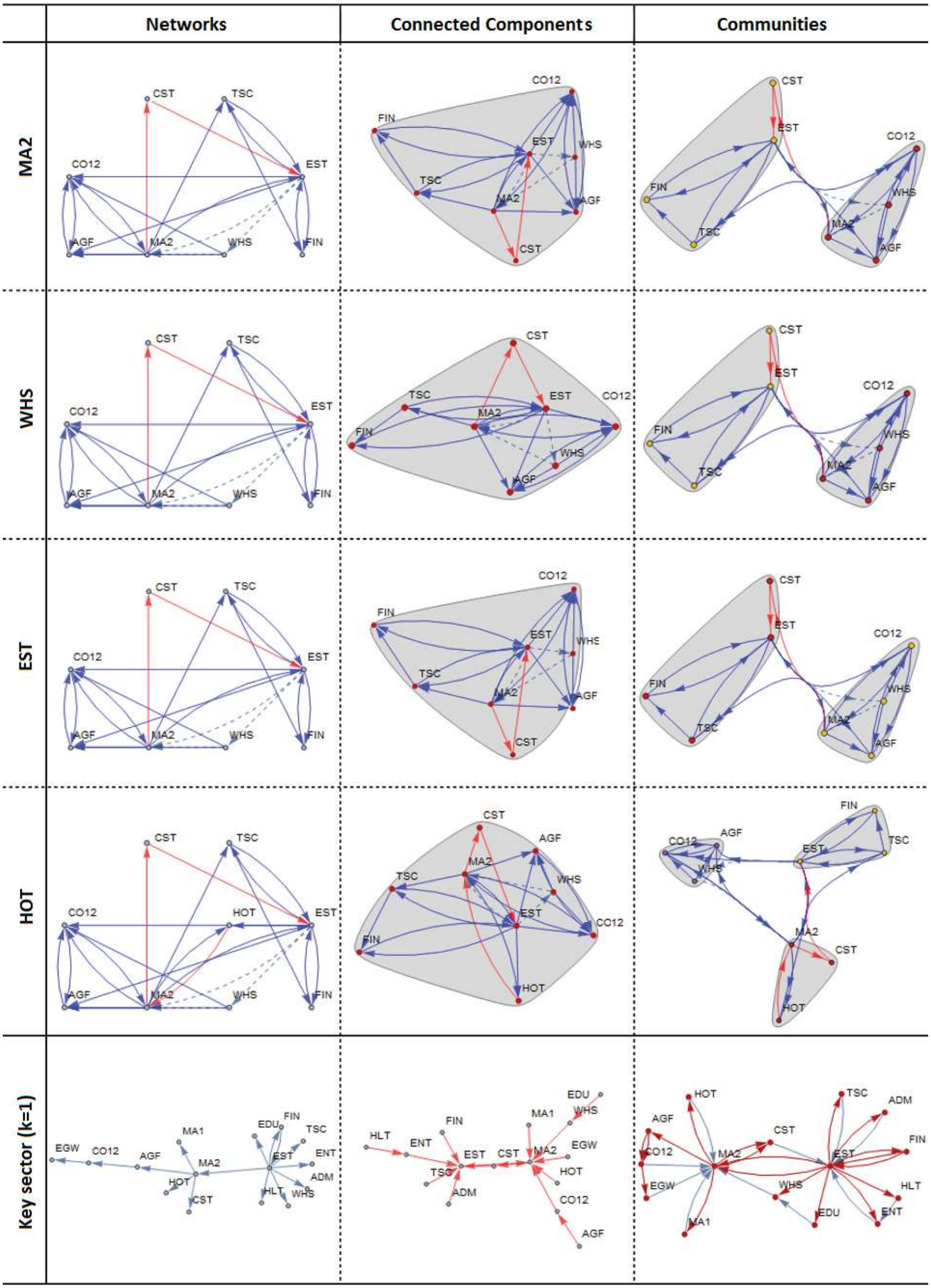


Figure 13: Binary sectoral links ensuring the connectedness of different communities