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

On the conceptual account, this paper develops a methodology to identify input-output (IO) layers of a targeted sector, drawing on backward and forward multipliers of an IO matrix. On the implementation account, the methodology is applied to a sample of eight countries - China, Japan, India, Russia, Germany, Turkey, UK and USA, which together account for about 60 percent of the world GDP - with a view to characterizing the backward and forward linkages of manufacturing, real estate, wholesale, and accommodation sectors identified by ILO (2020) as key sectors likely to suffer from the highest level of youth unemployment due to the COVID-19 pandemic. New information is generated for the design of informed employment policy interventions to avoid the unemployment projected. The findings show that manufacturing sector, MA2, is vital for all the countries examined, followed by EST and WHS, and that these three sectors need to be coupled with at least one other sector to capture the external employment effects from the interacting communities (or clusters).

1 Introduction

This paper introduces a methodology to identify input-output (IO) layers of a targeted sector, drawing on backward and forward multipliers of an IO matrix. The methodology developed is enriched with the use of two concepts from network analysis: connected components and community structure. A complete characterization by the methodology of a targeted sector would provide critical new information on the backward and forward linkages of the sector targeted, and hence supporting policy discussions about the development of employment strategies to respond to the COVID-19 effects. The methodology is applied to a sample of eight countries - China, Japan, India, Germany, Russia, Turkey, UK and USA, which together account for about 60 percent of the world GDP - with a view to characterizing the backward and forward linkages of manufacturing, real estate, wholesale, and accommodation sectors identified by ILO (2020) as key sectors likely to suffer from the highest level of youth unemployment due to the COVID-19 pandemic.

The empirical characterization is based on the use of IO data for the most recent available year 2015, providing new information for the design of informed employment policy interventions to avoid the unemployment projected. The findings show that manufacturing sector, MA2, is vital for all the countries examined, followed by EST and WHS, and that these three sectors need to be coupled with at least one other sector to capture the external employment effects from the interacting communities (or clusters). Naturally, sector coupling varies across countries, depending on the linkages between the communities identified.

This paper is organized in five sections. Following the Introduction, Section 2 describes the methodology and the three network concepts integrated into the methodology. Section 3 applies the methodology 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 Methodology

2.1 Backward and forward layers of sectoral linkages

Backward and forward linkages of a targeted sector i characterize its inter-linked input and output linkages. These linkages are not typical as they are layered. In the first layer around the sector targeted, say sector i, are those sectors that provide inputs directly to sector i; in the second layer are those sectors that provide inputs to the input providers of sector i; in the third layer are those sectors that provide inputs to the sectors in the second layer and so on. The chains of linkages between layers represent the entirety of backward linkages (i.e., defining a specific input structure) of sector i. Likewise, sector i also has forward chains of linkages between forward layers. But this time, layers include sectors that use the output of sector i as input in their production processes. In the second forward layer are those sectors that use the outputs of the sectors in the first layers as inputs in their production and so on. The final map of the backward and forward layers of sector i would fully characterize sector i's input-output dependencies. Effects on sector i's production of a shock to one of the sectors in a backward layer can be traced forward to sector i. Again, similarly, effects on a forward layer of a shock to sector i can be traced forward. It is also possible to characterize the linkages between a backward and a forward layer via changes in sector i. The interaction between the two layers - either between a backward and forward layer or between two backward layers or between two forward layers - would provide us with more aggregated information about two groups of sectors possibly through changes in the the targeted sector i. In sum, a targeted sector i would be fully characterized if we can identify all of its key suppliers and the purchasers of its commodities. Figure 1a illustrates an example of a layered graph showing sectors in each layer when sector $i = A$ is targeted.

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):

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

where 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 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 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) significantly contributing 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 will only show the application of the procedure for one sector, say sector A. 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 $\mathbf{M_f}$ (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.

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 require the identification of all the four sub-graphs and ranking of the links with respect to intervention priority.[1]

2.2 Connected components and their communities

A directed graph is said to be connected if there is a path between all pairs of vertices. A connected component (CC) of a directed graph is a maximal connected sub-graph. Connected components of a directed graph comprise an acyclic directed graph, meaning that individual CCs form a partition into sub-graphs that are 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 the graph **G** is shown on the right with red linkages. The CC consists of 10 sectors out of 17 sectors in **G**. This example is based on a backward multiplier matrix only. Connected components built in the complete input-output network of targeted sector i are identified. 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 impacts on itself of others within the component as they are all connected. In our actual graph, we identify CCs of a directed graph defined by a combined set of backward and forward linkages.

After detecting CCs of targeted sector i from its BF linkages, we identify the community structure of each CC based on Community Modularity statistic. The question here is whether there is a partition of a CC into sub-graphs, each one of which maximizes Modularity statistic. We know that sectors within a CC are all linked, but we do not know whether there are distinct sub-graphs within the CC concerned. Uncovering the community structure of a CC will tell us that there are sub-groups of sectors that are highly correlated or homogenous in terms of Modularity criterion (Centrality criterion, for example). 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).

[1] The author developed the Algorithm to identify input-output layers of the linkages of a targeted sector. The methodology and the Algorithm are available upon request.

2.3 Key sectors

From a sectoral perspective, a sector is defined 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 called to be key if its total output multiplier is the largest compared to the 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 defined by 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 side (backward links) and the output side (forward links).

We identify the maximum multiplier ($k = 1$) from each column (each row) in the backward (forward) multiplier matrix. Two directed graphs are generated, 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 based on $k = 1$. The same procedure can be applied for $k = 2$, meaning that the highest two multiplier are selected from each column (row) in the backward (forward) multiplier matrix. The final network will be denser than that of $k = 1$.

3 Implementation

The method and concepts introduced in Section 2 are applied to characterize the input-output systems of eight countries: China, India, Japan, Russia in Asia; Germany, Turkey and UK in Europe, and USA. The input-output (IO) data used are obtained from the OECD IO database[2] for the most recent available year 2015. The original IO matrices with 36 sectors have been reduced to 15 sectors following the UN definitions for sector aggregation. This allows for a simplified, comparative analysis of the IO systems across countries.

Concerning youth unemployment due to COVID-19, ILO's global estimates conjecture that the 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 the hard-hit sectors should be informed of the characteristics of the backward and forward linkage structures of these sectors. This paper seeks to produce critical knowledge that can be exploited in the design of informed policy interventions.

3.1 Sector targeting and dependency

Targeting a sector for policy reforms requires critical information on its input-output linkages. If, for example, sector i is targeted for policy intervention, we first need to identify input suppliers of that sector,

[2]seee https://stats.oecd.org/Index.aspx?DataSetCode=IOTSI4_2018

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 target sector can also be 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 target, and then sequentially identify the buyers of the commodities produced by the buyers of commodities of the core 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 target. 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 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 output multiplier of the sector targeted. The linkages shown represent those linkages accounting for 15 percent or more of the multipliers influencing the targeted sector.

When manufacturing sector, denoted by MA2, is targeted, an interesting pattern arises across the countries examined (see the 1^{st} column in Table 1). In the four countries in Asia, sectors AGF, CO12 and WHS supply significant *input*; in two European countries, FIN, TSC and WHS transfer significant *input*; in Turkey, sectors EGW and HOT 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 CST and EST unanimously arise as critical sectors whose outputs are demanded by other sectors. Concerning sectoral dependencies, we observe {CO12, CST, EST, WHS, MA2} revealing strong dependencies as shown in Table 2. Sector 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 $EST \dashrightarrow WHS$ and $EST \dashrightarrow MA2$; in UK, it is $CST \dashrightarrow EST \dashrightarrow WHS \dashrightarrow MA2 \dashrightarrow CST$; and in Russia, it is $EST \dashrightarrow WHS \dashrightarrow MA2$ and $WHS \dashrightarrow CO12 \dashrightarrow MA2$. 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 wholesale and retail sector, denoted by WHS, is targeted, a pattern similar to one in Section 3.1 arises arises across the countries examined (see the 2^{nd} column in Table 1). In the Asian countries, sectors 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 of $CST \dashrightarrow EST \dashrightarrow WHS \dashrightarrow MA2$. This suggests that before targeting WHS, the implications on WHS of a change in CST and EST should be analyzed as WHS is strongly dependent on CST and EST. Russia is also facing somewhat weaker dependency, with a pathway of $EST \dashrightarrow WHS \dashrightarrow CO12 \dashrightarrow MA2$.

When real estate and business sector, denoted by 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 sector 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 accommodation sector, denoted by 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, sectors 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. Any intervention to a single sector will have repercussions for 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 partitions) (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.[3]

[3]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

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 for the design of policy interventions. Take, for example, Germany given in the 1^{st} row of Table 2. It is characterized by three parameters: $EST \dashrightarrow MA2$, 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 sector 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 the sink of the impact of the change concerned. 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 a closed loop. The other countries can be analyzed in a similar fashion at will.

Drawing on the backward linkage multiplier matrix, we identify for each sector the most significant input supplier - the key sector, shown in the graph with blue arrows. Likewise, using the forward linkage multiplier matrix, for each sector, we also identify the most significant user of the commodity of that sector - the key sector, shown in the graph with red arrows. A sector is called to be key in input (commodity) market if it has the largest impact on input (commodity) supply. 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 sectors.

4 Recommendations

The findings elaborated in Section 3 provide critical information for the design of effective policy responses aimed to minimize the adverse employment effects of COVID-19. The issue here is not to ensure coordinated actions across the countries examined but to ensure that each country prioritizes the identified critical sectors for policy interventions. The following suggestions would pave the way for the achievement of the best employment outcome not only at the country level but also across the globe.

First, the domain of any policy targeting with a view to ensure 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 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

edge lies "between" many pairs of nodes.

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 these communities are connected through the linkages in input markets only.

The two EU countries, Germany and the UK, have commonalities between themselves, 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 is composed of sectors {CST, MA2, WHS} with linkages in both input and output markets. The type of linkages connecting the two communities is different across Germany and the UK. 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 sector 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 that ensure the connectedness of the communities identified is essential for informed employment policy intervention. The policies aimed to ensure the continuity of these 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 the connectedness will be forgone if the policies implemented dismantle the connectedness of the existing communities. In Figure 13, vital binary linkages are mapped that ensure the connectedness between the two communities identified 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 the connectivity of the communities, 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

This paper introduced a methodology to identify backward and forward layers of linkages of a targeted sector in a production system represented by an IO matrix. Given a multiplier interval, targeting sector i means to identify its critical backward (input dependency) and forward (output dependency) linkages. Knowledge of these linkages (or dependency structure) is used in the design of employment policy interventions. The targeting procedure starts with sector i's production function, $b_i(.)$, in which we uncover critical sectors that contribute to the production of sector i; that is, $b_i(b_{-i}(.))$, where $b_{-i}(.)$ is a vector of production functions of other sectors in the economy ($-i$ denotes other sectors except

i). The identification of other sectors significantly contributing to i's production describes the input linkages (or input dependencies) of i. Likewise, we identify output linkages (or output dependencies) of i by using its forward multipliers; that is, $f_{-i}(b_i(.))$, where $f_{-i}(.)$ is a correspondence, meaning that i's output is used by several sectors denoted by $-i$.

Having identified the backward and forward linkages of a targeted sector i, we combine these linkages to create a single directed graph (or network) and analyze all the pathways for a given pair of sectors such as (i, j) to find out the ones that promise the highest employment gains. Such a directed network would allow policy makers to carry out ex-ante and ex-post policy impact analysis of an intervention. The method is applied to characterize IO systems of the sample of eight countries, which account for about 60 percent of the world GDP. The characterization suggests that manufacturing sector MA2 is vital for all the countries examined, followed by EST and WHS, and that these three sectors need to be coupled with at least one other sector to main the connectedness of the directed network to capture the external employment effects of the interacting communities (or clusters).

The findings provide critical new information about the backward-forward sectoral dependencies that should be considered in the design of employment strategies to respond to the adverse effects of the COVID-19 pandemic. The analysis should especially shed light on the design of effective sectoral employment policies in light of ILO's youth unemployment projections across sectors.

References

ILO. Ilo monitor: Covid-19 and the world of work. fourth edition updated estimates and analysis. techreport, International Labor Organization, 2020. URL https://www.ilo.org/wcmsp5/groups/public/@dgreports/@dcomm/documents/briefingnote/wcms_745963.pdf.

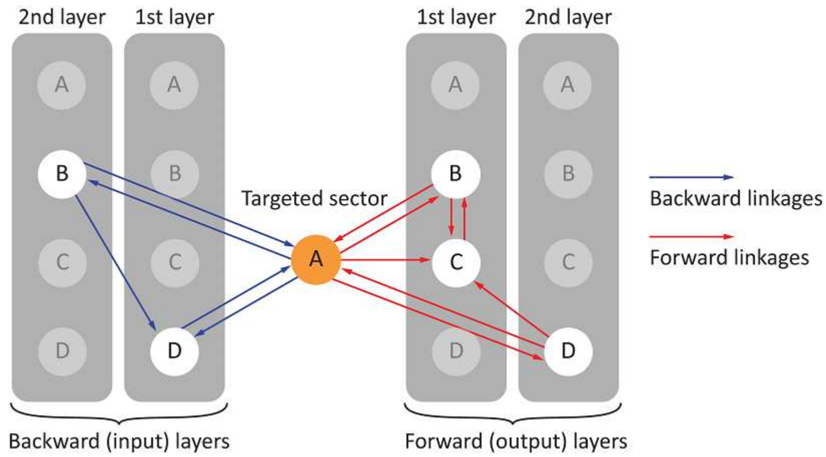
Table 1: Anatomy of targeted sectors across countries

		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

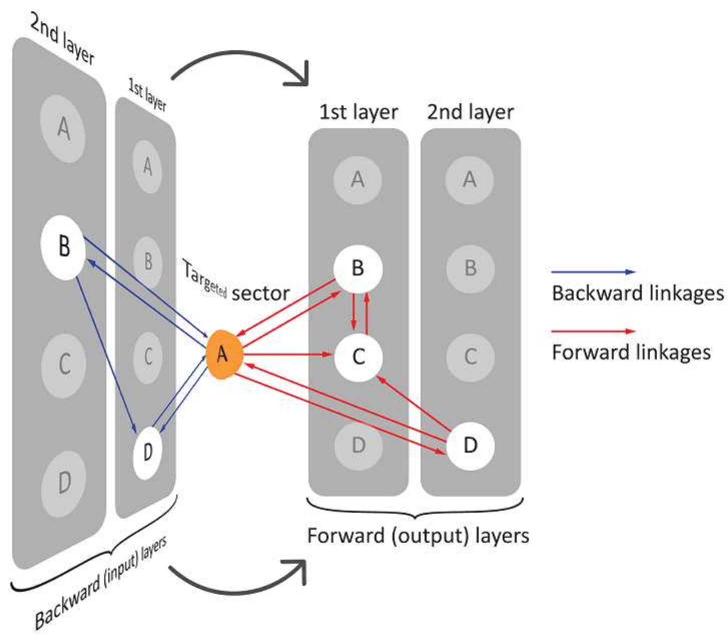
Table 2: Sectoral dependencies implied by targeting and key sectors

	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

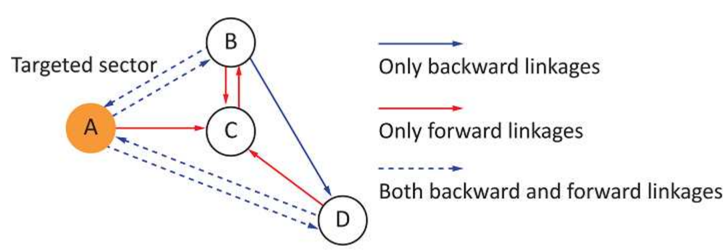
Figure 1: Layers of backward and forward linkages of a targeted sector A



(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

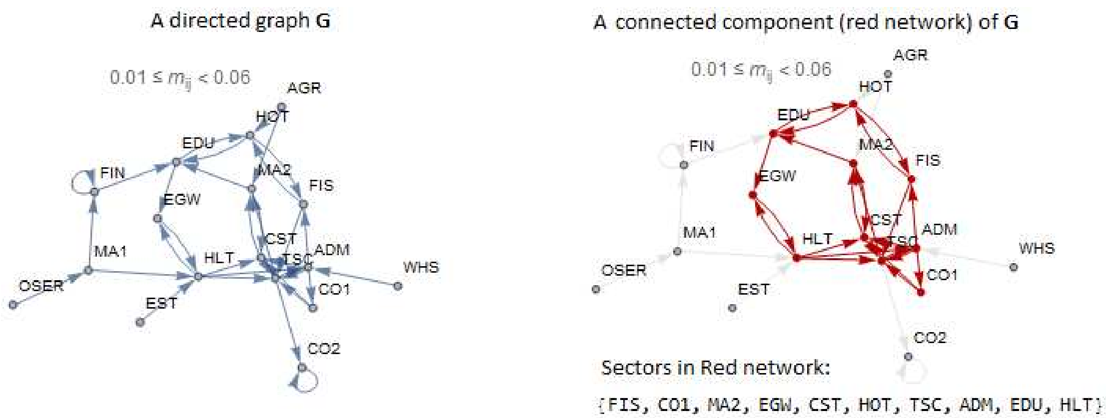


Figure 3: A connected component and its communities

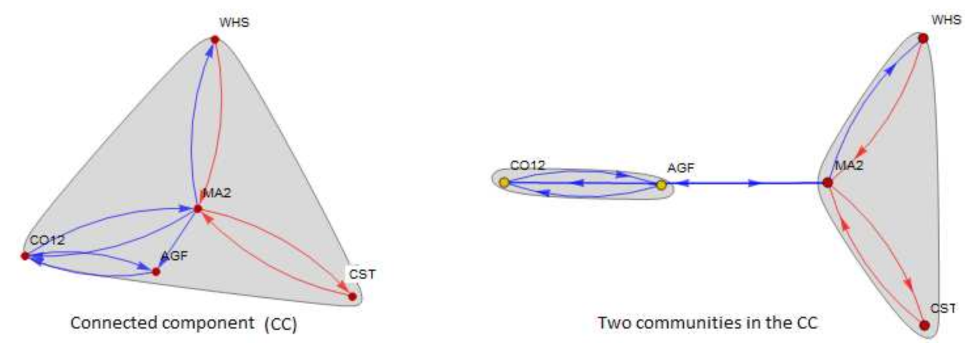


Figure 4: A network of key sectors from both backward and froward linkages

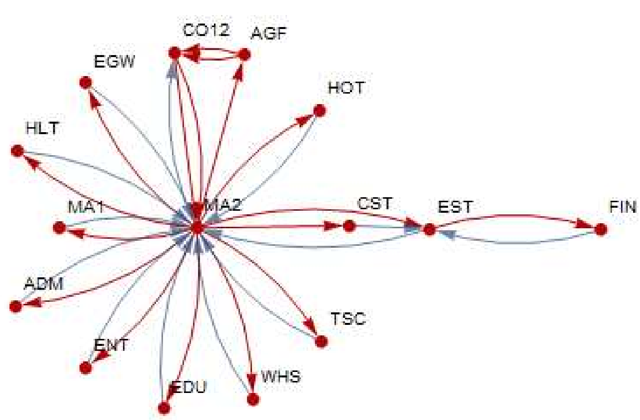


Figure 5: China: Sectors targeted at significance level of 0.15 and key sectors of the economy

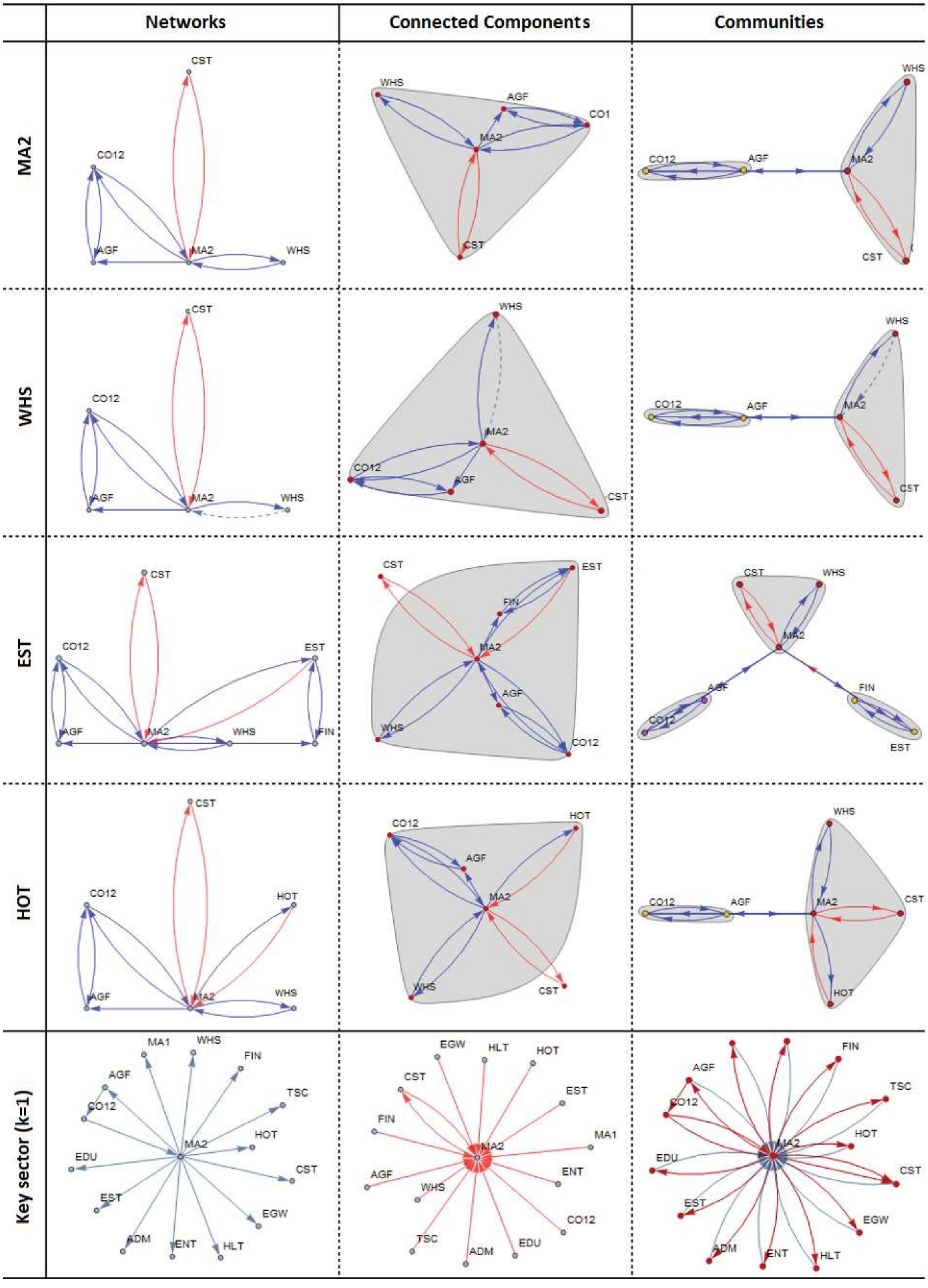


Figure 6: Japan: Sectors targeted at significance level of 0.15 and key sectors of the economy

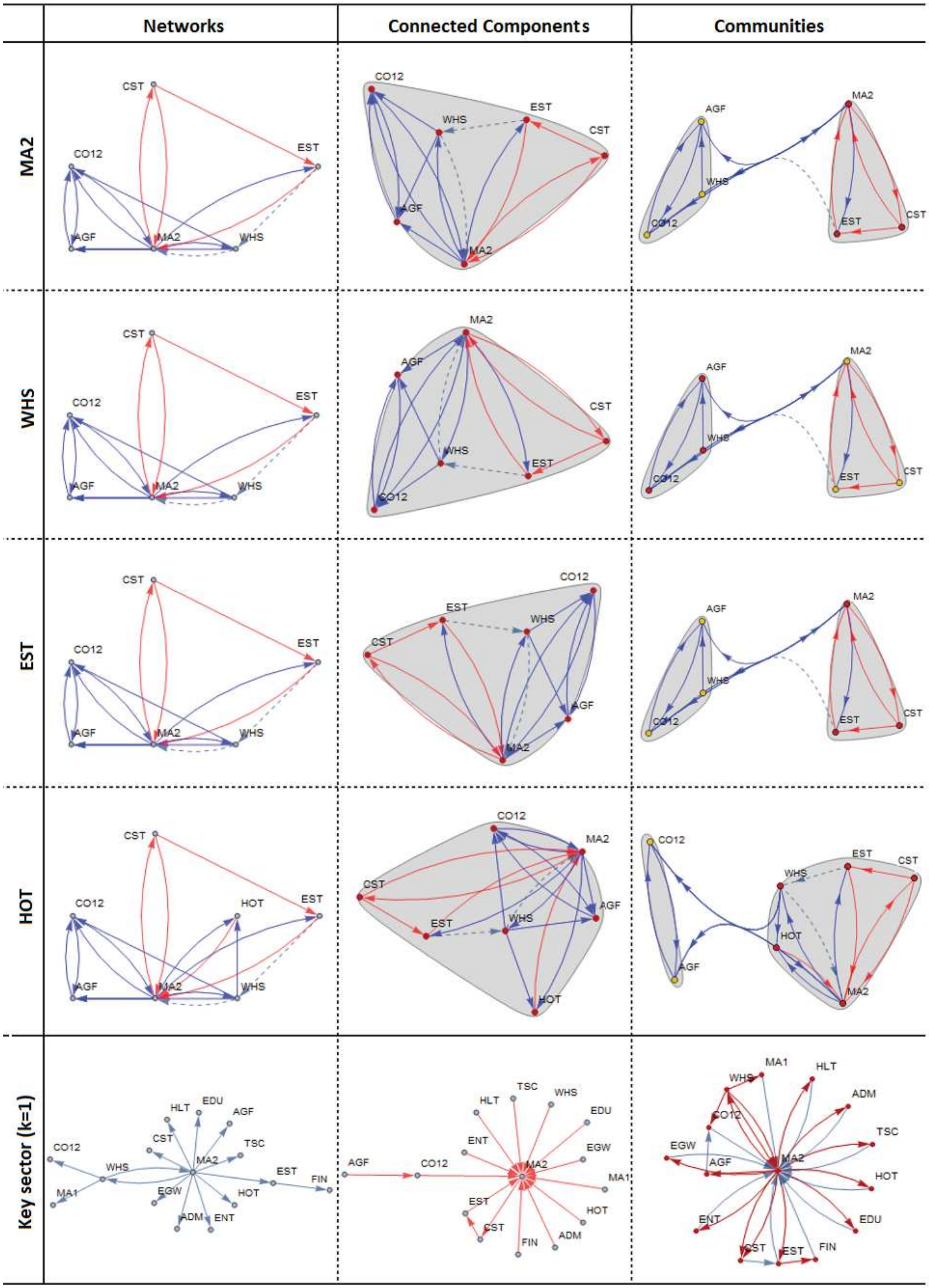


Figure 7: India: Sectors targeted at significance level of 0.15 and key sectors of the economy

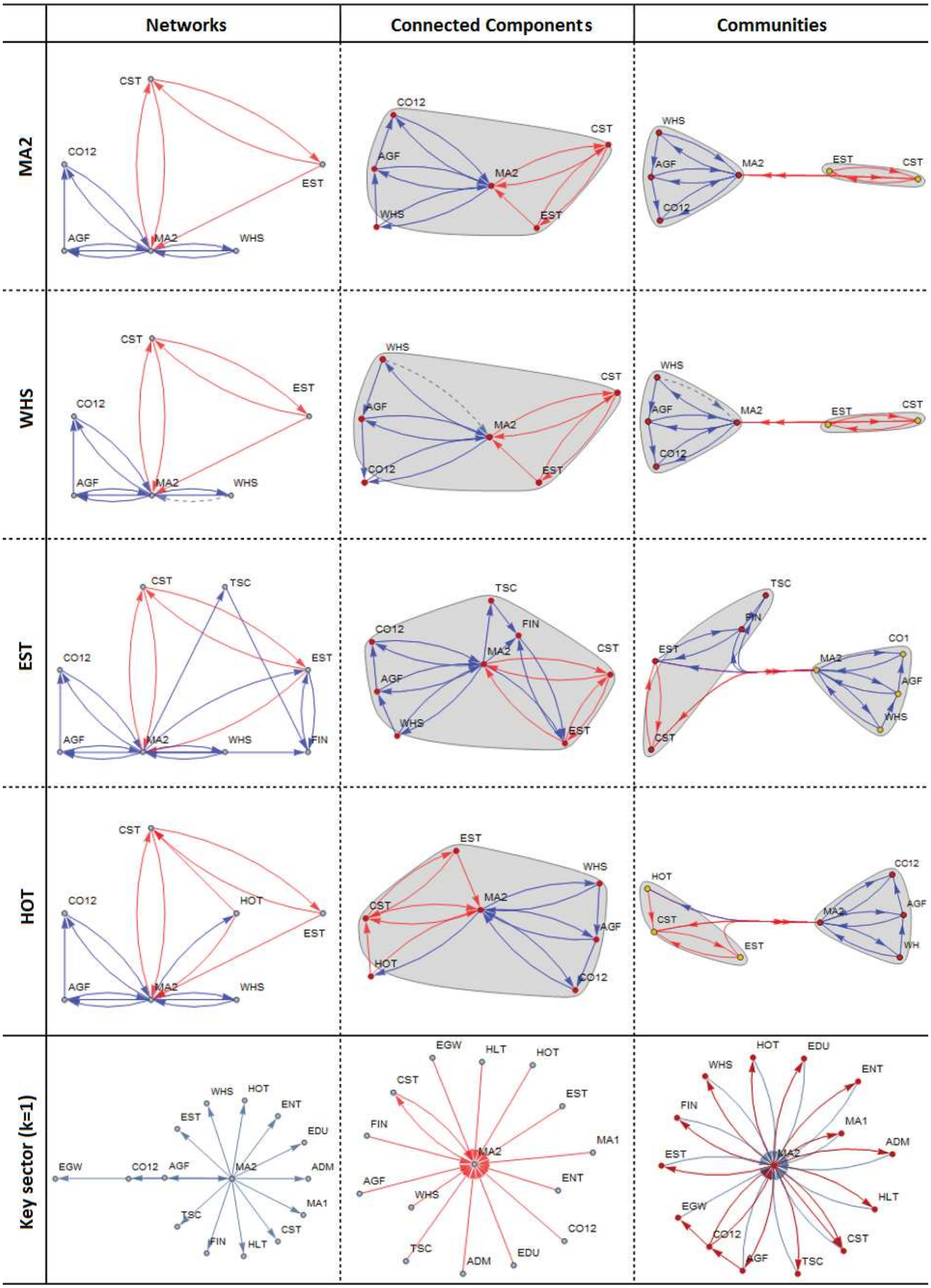


Figure 8: Russia: Sectors targeted at significance level of 0.15 and key sectors of the economy

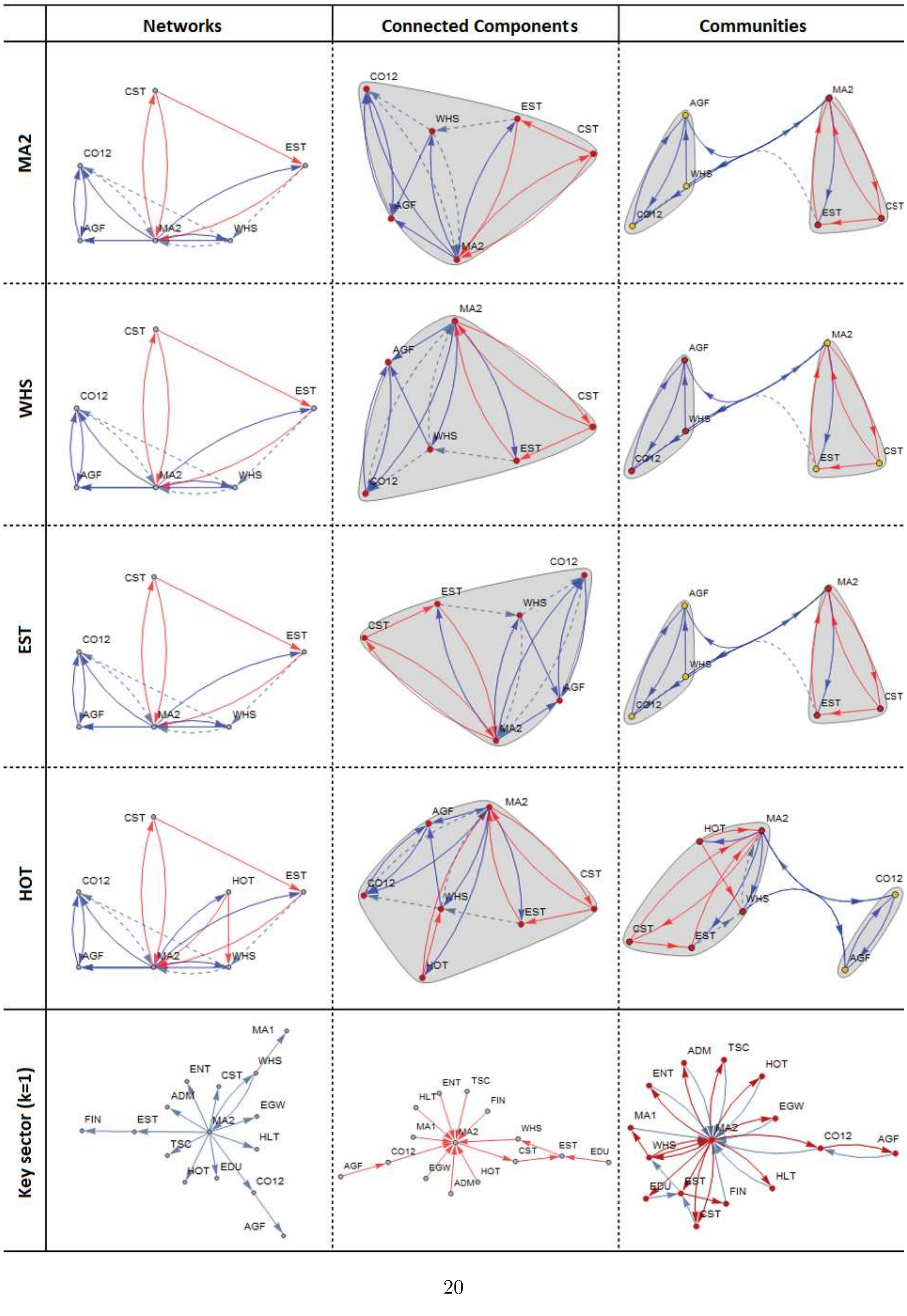


Figure 9: Germany: Sectors targeted at significance level of 0.15 and key sectors of the economy

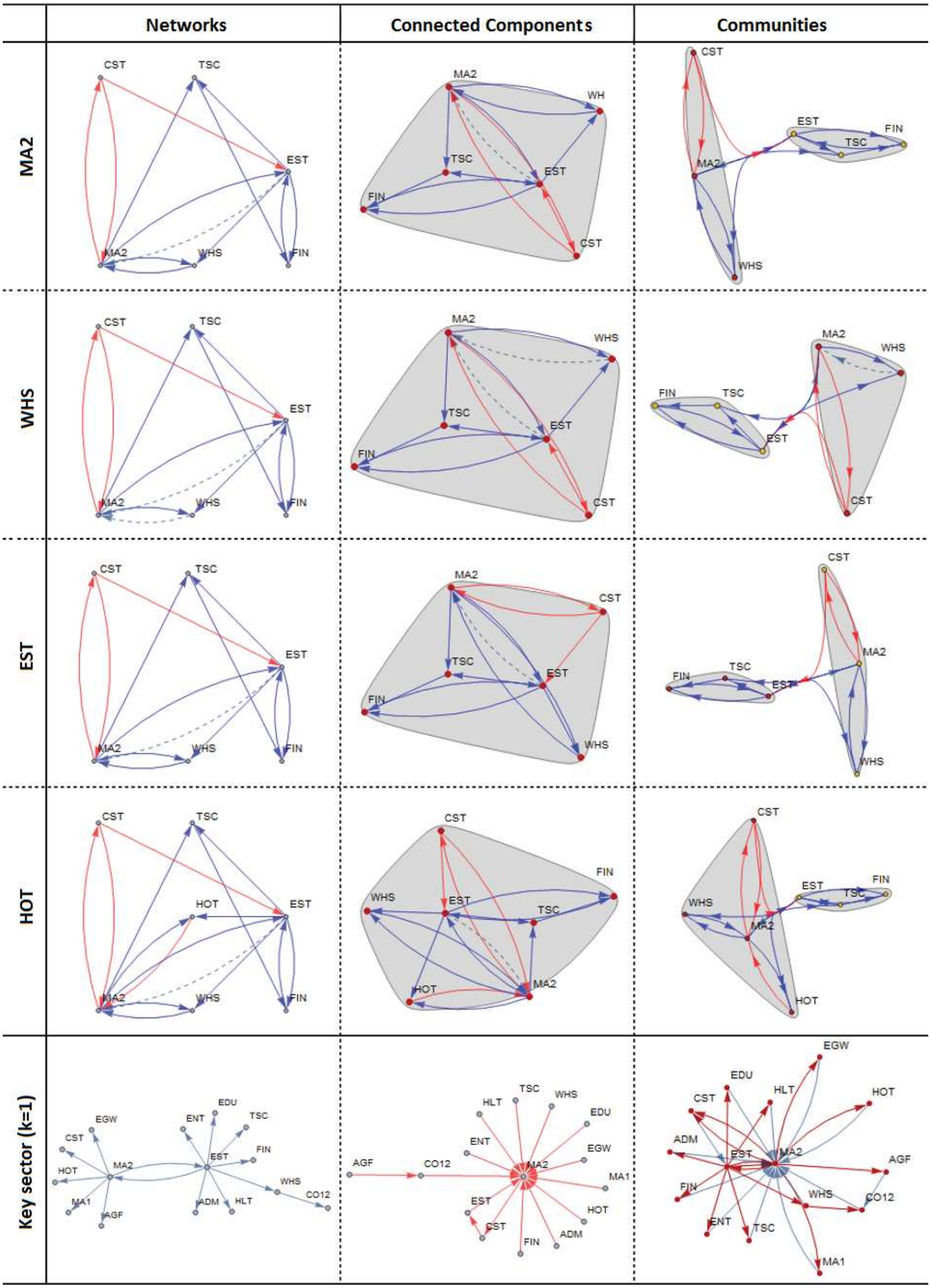


Figure 10: UK: Sectors targeted at significance level of 0.15 and key sectors of the economy

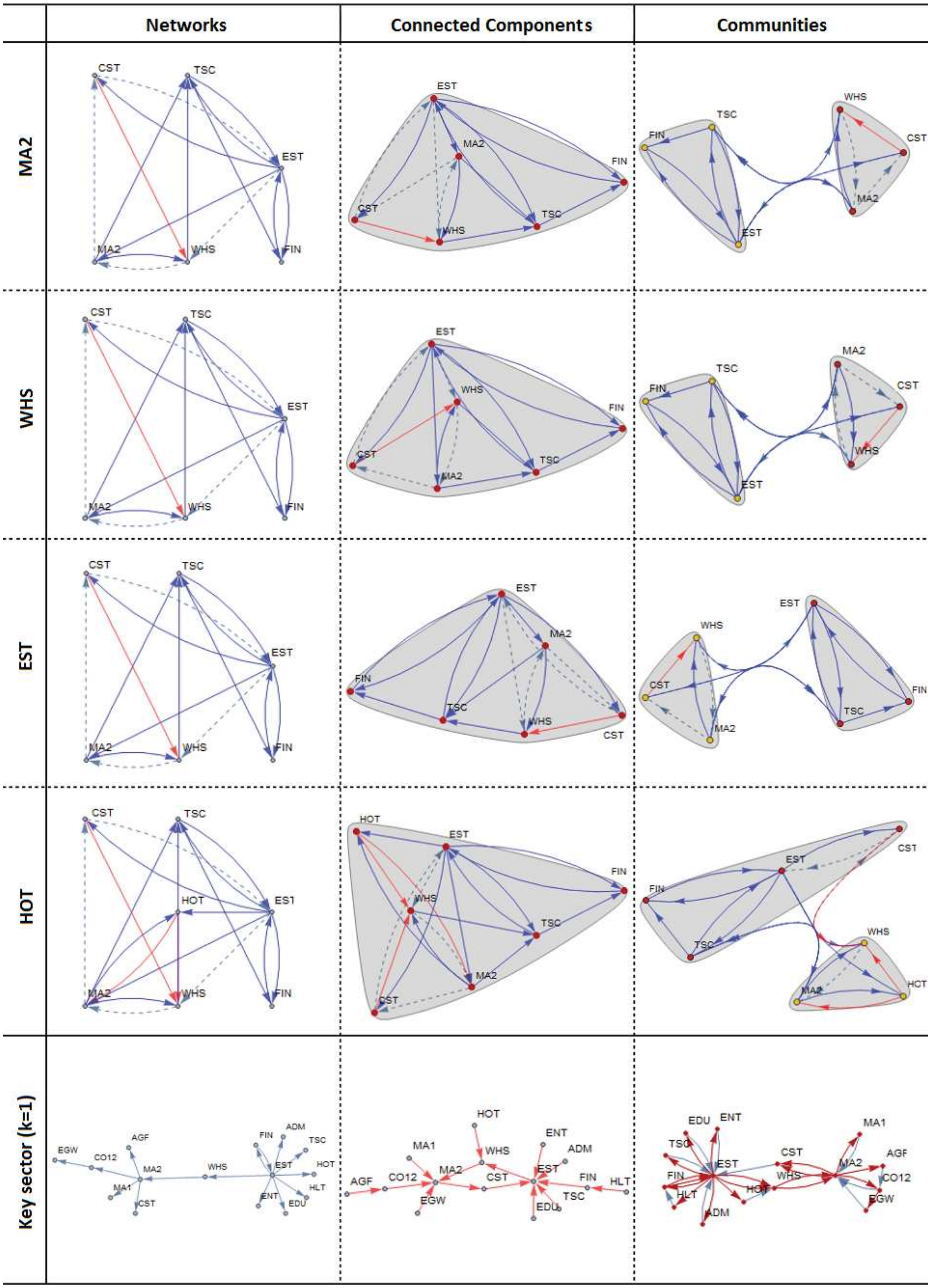


Figure 11: Turkey: Sectors targeted at significance level of 0.15 and key sectors of the economy

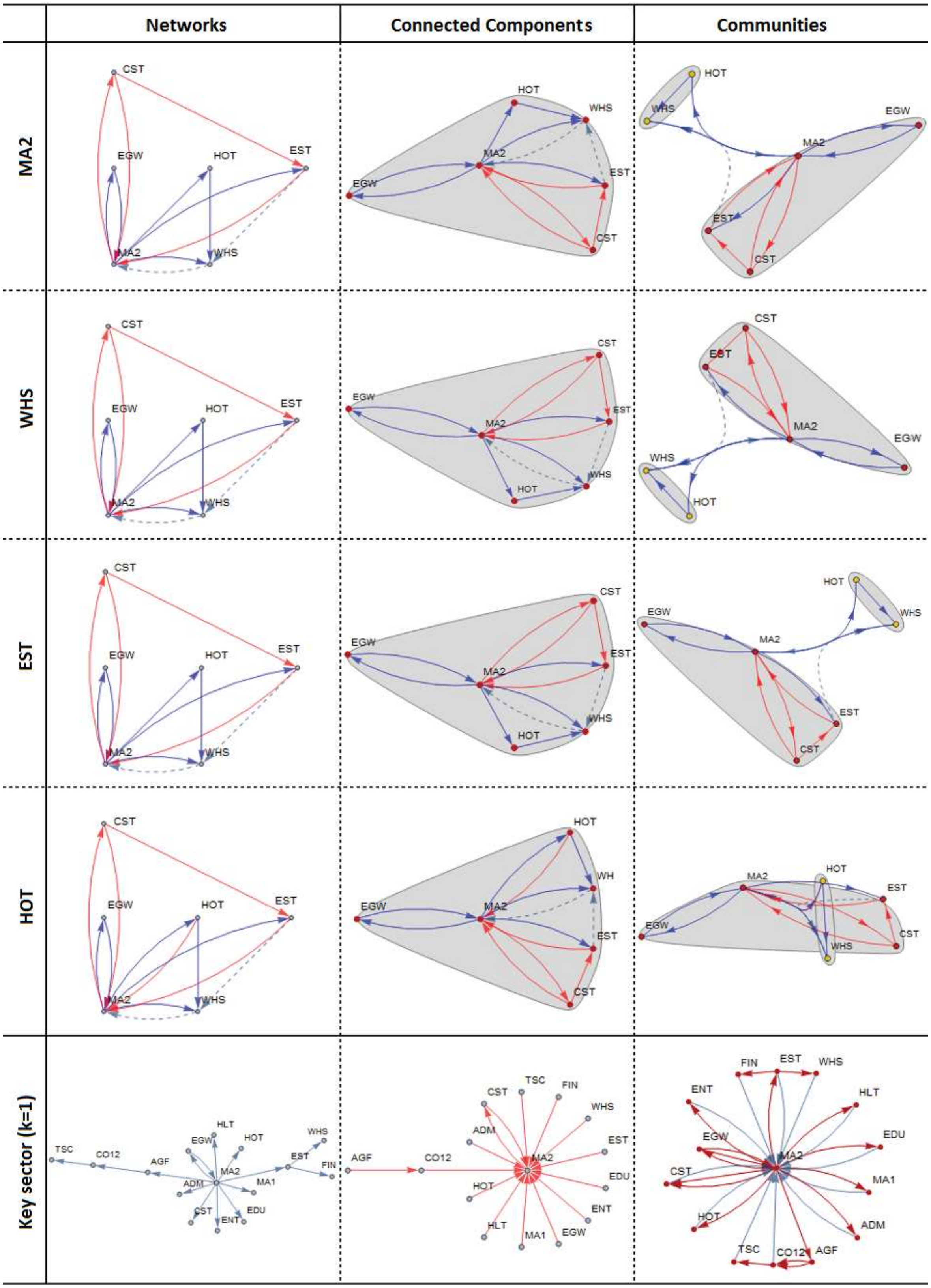


Figure 12: USA: Sectors targeted at significance level of 0.15 and key sectors of the economy

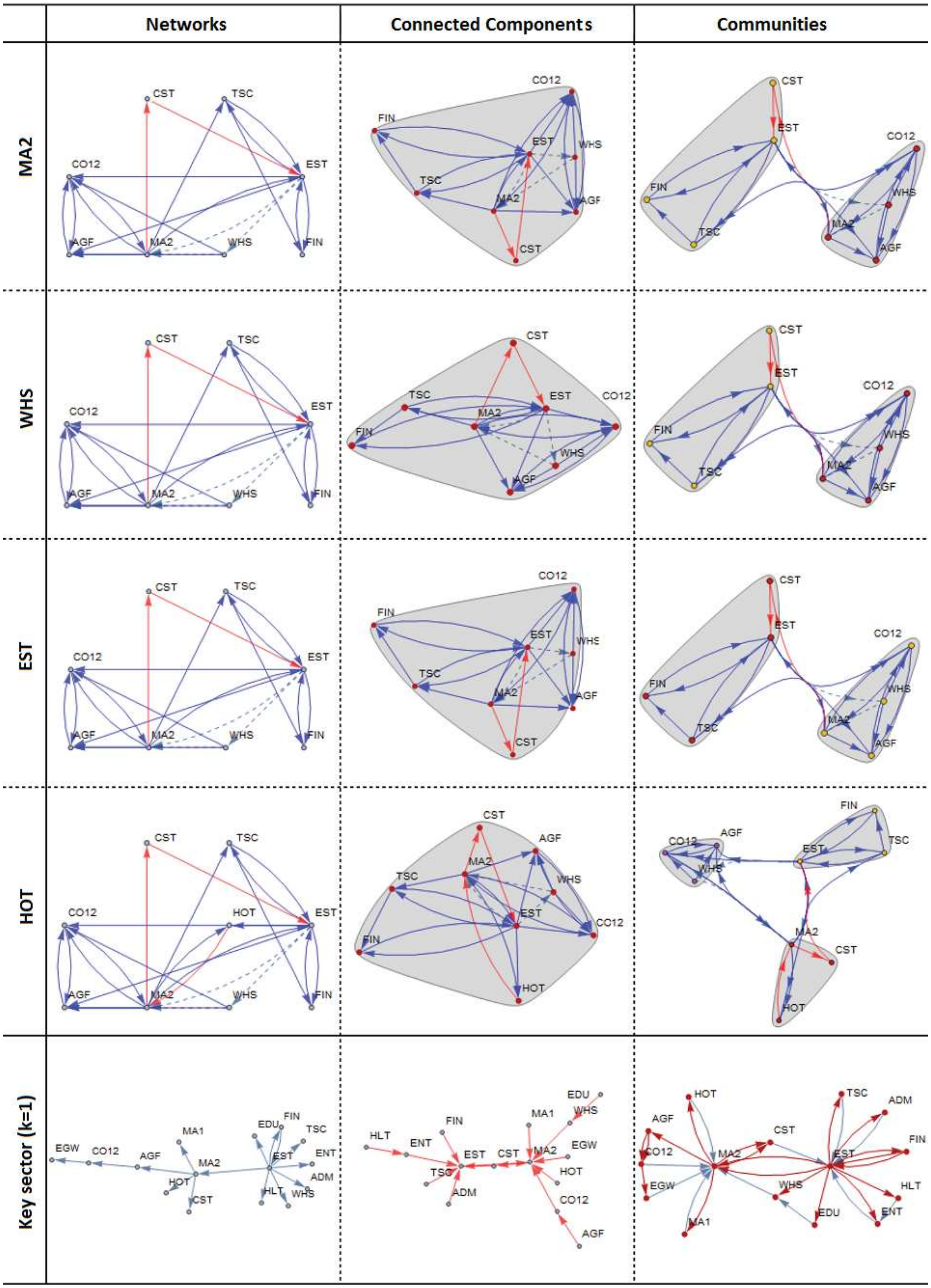


Figure 13: Binary sectoral links ensuring the connectedness of different communities