ANP-based Intra and Inter-industry Analysis for Measuring Spillover Effect of ICT Industries

Yongyoon Suh and Yongtae Park

***Abstract*—**The interaction among information and communication technology (ICT) industries is a recently ubiquitous phenomenon through fixed-mobile integration. To monitor the impact of interaction, previous research has mainly focused on measuring spillover effect among ICT industries using various methods. Among others, inter-industry analysis is one of the useful methods for examining spillover effect between industries. However, more complex ICT industries become, more important the impact within an industry is. Inter-industry analysis is limited in mirroring intra-relationships within an industry. Thus, this study applies the analytic network process (ANP) to measure the spillover effect, capturing all of the intra and inter-relationships. Using ANP-based intra and inter-industry analysis, the spillover effect is effectively measured, mirroring the complex structure of ICT industries. A main ICT industry and its linkages are also explored to show the current structure of ICT industries. The proposed approach is expected to allow policy makers to understand interactions of ICT industries and their impact.

***Keywords*—**ANP, intra and inter-industry analysis, spillover effect

I. Introduction

RECENTLY, the interaction of information and communication technology (ICT) industries is not a trend, but a ubiquitous phenomenon [1]. One of the key drivers for this phenomenon has been the fixed-mobile integration in a telecommunication sector. A new business environment for fixed-mobile telecommunication has emerged dealing with various players such as manufacturers and service providers [2]. Traditionally, ICTs have been mainly developed for the fixed telecommunication services, but those services are being extended into mobile telecommunication. In response to the extension from fixed to mobile, the manufacturers try to develop the advanced devices as well. As a result, ICT industries in the telecommunications sector have become more complex and resources are being shared across those industries. New ICT industries and new relations have been even created and influenced competency of the other industries. Also, the traditional distribution of power of ICT industries is shifting substantially [3]. Thus, exploring the interactions of ICT industries and their spillover effect needs to be made.

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Several attempts have been made to explore the interactions of ICT industries at both micro-level and macro-level. Many studies have been conducted to understand environment of ICTs and its nature [4]-[6]. Among these, the relationships between ICTs or ICT firms were analyzed by network analysis using several indexes [3][7]. Some studies have focused on identifying the relationships between ICTs and their impact based on citation analysis using patents [7][8]. However, these studies have still focused on micro-level analysis of interactions among ICTs or ICT firms. It is difficult for the micro-level analysis to explain the whole structure of interactions among industries.

As for the macro-level analysis, the inter-industry analysis has been widely employed to measure the interactions of industries [1][9][10]. The input-output table of inter-industry analysis is useful for exploring inflows and outflows of the economic resource between ICT industries. By exploring the interactions of resources among industries, spillover effect can be measured. However, the inter-industry analysis can measure spillover effect between industries only, not within an individual industry. As fixed telecommunication services combine with mobile telecommunication services, ICT industries become more huge and complex. Sub-industries within an individual industry are also complicatedly linked. Thus, both intra and inter-industry analyses can be more appropriate for measuring the spillover effect of modern ICT industries.

The major tenet of this paper is that analytic network process (ANP) can be used for considering intra-industry relationships. The ANP proposed by Saaty [11] is one of the most widely used multiple criteria decision-making (MCDM) methods that models a system as a network. In general, the ANP has been widely adapted for selection and prioritization of alternatives. However, this study attempts to apply ANP into inter-industry analysis for considering the relationships of sub-industries within an individual industry. The ANP can be well employed in that the inter-industry analysis is also formed as network structure. The ANP-based intra and inter-industry analysis has the following advantages with respect to the limitation of inter-industry analysis above. First and foremost, the ANP is capable of measuring the spillover effect of ICT industries by capturing all of the indirect interactions between and within ICT industries. Thus, interactions can be effectively examined, combining the inter-industry spillover effect with the intra-industry spillover effect. Second, based on the ANP, the input-output table of inter-industry analysis can be also easily transformed as a network. Accordingly, the ANP enable us to understand the complex network of ICT industries, including industries and sub-industries.

The remainder of this paper is organized as follows. Section II deals with the research background based on the inter-industry analysis and the ANP. Section III proposes the ANP-based intra and inter-industry analysis. Finally, Section IV concludes the paper with future research.

II. Research Background

A. *Inter-industry analysis*

The inter-industry analysis is widely and usefully applied in the various fields [10]. The main purpose of the inter-industry analysis is to examine the spillover effect throughout the economy. Prior to the outset of inter-industry analysis, the input-output table is first considered. The input-output table includes the basic information on inter-industrial transactions in a national or regional economy during a certain period. The input-output tables are constructed based on the system of national accounting that is most commonly used around the world today [1]. Based on the input-output table, the relationships can be represented in terms of inputs and outputs across a range of industries. The advantage of inter-industry analysis is twofold. First, the inter-industry analysis boasts of a high quality and internationally comparable database. Second, as a branch of empirical economics, the inter-industry analysis has been more and more mature. Many studies have demonstrated that this approach has provided a powerful tool adaptable to empirical investigation and analysis of a variety of economic issues.

The basic structure of the input-output table is formed as a matrix in which an input is enumerated in the column of each industry and its output is aligned in its corresponding row as shown in Table I. In the table, x_{ij} denotes the inter-industry supply from industry *i* to industry *j*. To measure the spillover effect, the input coefficient, which divided each inter-sectoral transaction x_{ij} by total inputs x_j, should be first obtained. Then, we calculate the spillover effect by multiplying infinitely an input coefficient itself.

TABLE I
THE DOMESTIC INPUT-OUTPUT TABLE

		Intermediate demand				Final demand	Total outputs
		1	2	…	N		
Intermediate inputs	1	x_{11}	x_{12}	…	x_{1n}	Y_1	X_1
	2	x_{21}	x_{22}	…	x_{2n}	Y_2	X_2
	…	…	…	…	…	…	…
	n	x_{n1}	x_{n2}	…	x_{nn}	Y_n	X_n
Value added		V_1	V_2	…	V_n		
Total inputs		X_1	X_2	…	X_n		

However, with only the input-output analysis framework, it is impossible to simultaneously exploring the intra-industry supply in industry *i*. Although the input-output analysis provides the inflows and outflows among industries based on various levels (macro-level industry, meso-level industry, and micro-level industry, etc.), the integrated approach to intra and inter-industry has been not proposed. Since sub-industries within an individual industry have influences on each other, intra-relationships should be considered.

B. *ANP*

The ANP is a generalization of the AHP which is one of the most widely used multi-criteria decision making (MCDM) methods. The ANP is capable of considering the dependence and feedback, whereas, the AHP deals with the independent problems. The ANP allows for complex interdependencies among decision elements by structuring a network model [12]. Recent years, therefore, have found a huge increase in the use of the ANP in the various fields, such as decision making, product design, and network problem (add refer here). The process of the ANP consists of four principle steps [11]-[13]. The ANP is employed through four steps: model construction, pairwise comparisons and extraction of local priority vectors, supermatrix formation and transformation, and extraction of final priorities. These steps are described in more detail with proposed model in next section. This paper only focuses on the ANP processes with inter-industry analysis, but if you need more detailed information, please refer the Saaty [11].

III. ANP-based Intra and Inter-industry Analysis

This section proposed the ANP-based intra and inter-industry analysis through four steps.

Step 1: model construction

The Fig. 2 shows an illustration of the network model for intra and inter-industry using ANP. The network in the proposed approach is made on the basis of the input-output table. A cluster in the ANP network corresponds to an industry, and elements in a cluster are matched with the sub-industries in an industry. Finally, an arrow represents the relationships between industries or sub-industries.

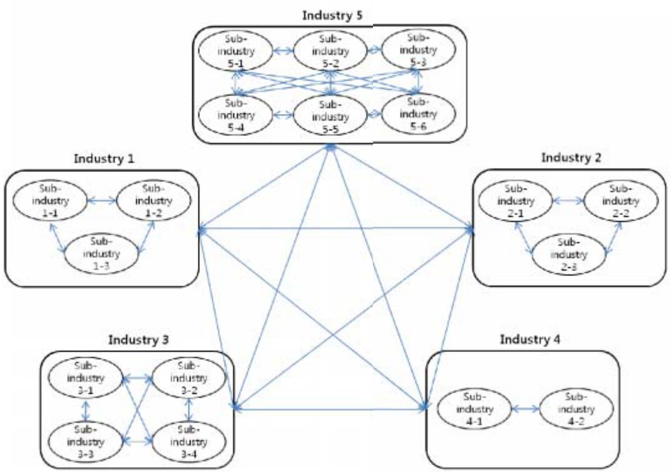

Fig. 1 Example of intra and inter-industry network for ANP

Every industry has influences on each other, and includes a feedback loop that indicates the resource flows in the industry itself. The relationships between industries are identified by the inter-industry analysis, whereas the relationships between sub-industries are explored for the intra-industry analysis. Previously, the traditional inter-industry analysis can be used for only one case between both analyses. To overcome this limitation, the ANP is capable of both intra and inter-industry analyses, constructing the network model including industries and sub-industries. The ANP-based intra and inter-industry network enables us to find the core industry and its linkages with other industries, combining the inter-industry effect with intra-industry effect.

Step 2: pairwise comparisons and local priority vectors

The elements of each cluster are compared pairwisely with respect to their impacts on other elements in the cluster. This is the intra-relationships among elements. Next, pairwise comparisons are also conducted for including interdependency among elements outside clusters. Finally, clusters are then compared pairwisely with respect to their impacts on other clusters. Both comparisons are conducted for reflecting the inter-relationships among elements and clusters. The way of conducting pairwise comparisons and calculating local priority vectors is the same as in the case of AHP. The local priority vectors for each pairwise comparison matrix can be obtained by employing the eigenvector method.

In this case, by using the inflows and outflows between industry clusters, pairwise comparisons should be conducted and industry cluster weights can be extracted. The industry cluster weights are same as the input coefficient in input-output analysis. Also, local priority vectors for mainline sub-industries are obtained. It is conducted based on the resource flows between sub-industries.

Step 3: supermatrix formation and transformation

As a third step, a supermatrix with local priority vectors is constructed and multiplied by the industry cluster weights for making weighted supermatrix. This step is very important in that both inter-relationship (industry cluster weights) and intra-relationship (local priority vectors) can be considered. Finally, the limit supermatrix is derived by raising the weighted supermatrix to powers. The supermatrix of a system of N clusters is denoted as follows:

$$
\begin{array}{cc} & \begin{array}{ccccc} C_1 & \cdots & C_k & \cdots & C_N \\ e_{11}\cdots e_{1n_1} & \cdots & e_{k1}\cdots e_{kn_k} & \cdots & e_{N1}\cdots e_{Nn_N} \end{array} \\ W = \begin{array}{c} C_1 \; \begin{array}{c} e_{11} \\ \vdots \\ e_{1n_1} \end{array} \\ \vdots \\ C_k \; \begin{array}{c} e_{11} \\ \vdots \\ e_{1n_1} \end{array} \\ \vdots \\ C_N \; \begin{array}{c} e_{11} \\ \vdots \\ e_{1n_1} \end{array} \end{array} & \begin{pmatrix} W_{11} & \cdots & W_{1k} & \cdots & W_{1N} \\ \vdots & \ddots & \vdots & & \vdots \\ W_{k1} & \cdots & W_{kk} & \cdots & W_{kN} \\ \vdots & & \vdots & \ddots & \vdots \\ W_{N1} & \cdots & W_{Nk} & \cdots & W_{NN} \end{pmatrix} \end{array}
$$

C_k: *k*th cluster; e_{kn_k}: n_k elements in cluster *k*; W_{ij}: matrix segment representing between *i*th and *j*th clusters

The local priority vectors of each pair are entered into each column of a supermatrix, which consists of partitioned matrices. Each segment divided in the matrix represents a relationship among clusters. Each column of W_{ij} is the local priority vector obtained from the corresponding pairwise comparison, representing the importance of the elements in the *i*th cluster to an element in the *j*th cluster. Formulating the supermatrix, we then transform the supermatrix into the weighted supermatrix. The weighted supermatrix can be obtained from a cluster priority vector for each cluster and a local priority vector for each element. In other words, each matrix segment of the supermatrix W_{ij} is multiplied by the corresponding cluster weights. Finally, the weighted supermatrix is transformed into the limit supermatrix by raising it to powers. The reason why the weighted supermatrix infinitely multiplies itself is to capture the transmission of influence along all direct and indirect paths. Being raised to the power $2k+1$, where k is an arbitrarily large number, the supermatrix converges. Convergence means that the row values converge to the same value for each column of the matrix. The resulting matrix is called the limit supermatrix, which produces limit priorities capturing all of the indirect impact on every other element.

Step 4: final priorities

When the supermatrix covers the whole network, the final priorities of elements are found in the corresponding columns in the limit supermatrix. The final priority (limit centrality) of the limit supermatrix is limit spillover effect of each industry, including intra and inter-relationships. However, the total spillover effect is defined as the sum of all these effect in the inter-industry analysis. Thus, we should modify final steps including summation from the first-order spillover effect to the limit spillover effect.

IV. Conclusions and Future Research

The proposed approach aims at measuring the spillover effect of ICT industries, including the intra and inter-relationships. As going towards fixed-mobile integration, the ICT industries are complex and have influence on each other. Rather than the micro-level analysis, this paper concentrates on the macro-level analysis for measuring spillover effect of each ICT industry.

The main contribution is to reflect the impact of intra-relationships as well as that of inter-relationships. For this, the ANP is employed in the inter-industry analysis. Since ANP captures all of the direct and indirect interactions, the limit centrality measures the spillover effect. To be specific, the impact of both inter-relationships (industry cluster weights) and intra-relationships (local priority vectors) is simultaneously considered. The higher spillover effect an industry has, the more impact the industry has. Therefore, industries and sub-industries should be managed in different ways according to the spillover effect. What can be done with the intra and inter-industry analysis is to manage the whole industries. It is expected that the policy makers can survey the interactions among industries as well as sub-industries. Also, the complex network structure of ICT industries can be easily identified. The future study will focus on application of proposed approach into a case study in practical ICT industries.

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