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Identifying key sectors using regional input-output model at sub-national level: The case of Korean economy*

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Abstract Since key sectors have high backward and forward linkages with the rest of the economy, investment in these sectors is expected to maximize economic growth, which is extensively meaningful in underdeveloped or developing countries with limited resources. Besides, identifying key sectors is considerably necessary and helpful for analyzing the long-term structural change and making the strategic policy of economic development, both at the national and regional level. However, the identification of the key sectors is somehow difficult to operate in practice at the regional level due to the absence of regional data at hand. In this study, the traditional backward and forward linkages are employed as indicators to identify the key sectors for sub-national regions where the input-output (IO) tables are unavailable. The regional IO tables are produced by adjusting national ones with several non-survey techniques. To capture the performance of non-survey techniques on recognizing key sectors, the estimated regional backward/forward linkages are computed and compared with the survey based benchmarks through the rank correlation coefficients. A large value of correlation coefficient indicates a high capability of the non-survey techniques on the identification of regional key sectors. At last, an empirical study is given with Korean 2005 national and regional IO tables.

Key words: Regional Input-Output model, Location quotients, Non-survey techniques, Key sectors, Linkage effect

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1. Introduction

Since key sectors have high backward and forward linkages with the rest of the economy, investment in these sectors is expected to maximize the economic growth. This is extensively meaningful in underdeveloped or developing countries with limited resources. Besides, the key sectors are considerably necessary and helpful for analyzing the long-term structural change and the economic development strategic policy, both at the national and regional level. However, the definition and estimation of the so-called key sector has been divided until today. Literatures have mainly focused on reviewing the different concepts or definitions of key sectors to determine what they are or how to estimate them via the theoretical and mathematical processes at the national level. Few of them actually attempted to define and measure the key sectors at the regional level. On the other hand, it is noticed that key sector analysis has been widely studied in developed countries and regions instead of developing or underdeveloped ones. This is probably due to the scarcity of regional data. Indeed, such process requires considerable data collection. Even a basic key sectors analysis demands a regional input-output table, which is only compiled every five years or so by most developing countries. Moreover, many regions are capital scarce and cannot easily support investment in key sectors even if such sectors are identified, making them less interesting from a policy perspective. However, key sector analysis remains a useful tool where the necessary data and funding are available, especially for the balanced growth of the regional economies in a country. This study presents an alternative method to carry out key sector analysis in which the required regional data is retrieved with the Input-Output (IO) model along with non-survey techniques.

The fundamental purpose of the IO framework is to analyze the interdependence of the industries in an economy. In its most basic form, an IO model consists of a system of linear equations, each one of which describes the distribution of an industry's product throughout the economy. The IO models can be useful in providing detailed information about an industry's effect both at the national and regional level. Furthermore, by computing various kinds of multipliers, one can measure the impact of an industry on employment, household income, and the activity level of all industries, which is considerably meaningful for economic development forecasting (Burford and Katz, 1981). Researchers usually prefer building the regional IO tables through adjusting the national ones with non-survey techniques when the regional information is unavailable in order to analyze the impact effects and make growth strategies at the regional level. Examples can be found in Schaffer (1976), Schaffer and Chu (1969), Jensen (1978), Choi (2010), Zhao and Choi (2012), *etc.* On the other hand, the IO model can be used to identify 'key sectors' or 'leading industries' through the backward linkages (BL) and forward linkages (FL). Those sectors with high BL/FL are substantially connected with each other and therefore, in some sense, could be the 'key sectors', which possess high growth potential in the region. However, the adequacy of applying non-survey techniques in the IO models to deduce 'key' sectors for the small regions is still a mystery due to the shortage of regional

information and the shortcomings of the methods themselves.

The method used in this study is to estimate the regional IO tables with non-survey techniques and, hence, to identify the regional key sectors. The estimated multipliers which represent the backward and forward linkages are compared with the survey-based benchmarks through the rank correlation coefficients. The empirical study is given on two objective regions to shed more light on the possibility to identify regional key sectors with non-survey methods. If possible, which one is more appropriate?

The paper is structured as follows. The second section reviews previous studies on the concept of key sectors and its development as well as the non-survey techniques within the IO frameworks. The third section addresses the methodology used in this study. The introduction of the data and empirical test follow in the fourth section. The final section contains the findings and conclusions.

2. Reviews on previous studies

2.1 Reviews on the key sectors

New policy programs have been predicated on the view that there could be economic value in the identification and promotion of sectors that display strong forward and/or backward linkages in a region. The linkage concept is generalized to the observation that ongoing activities ‘induce’ agents to take up new activities. This effect expresses a linkage between the ongoing and the new activity. The backward linkage effects are related to the derived demand, i.e. the provision of the input for a given activity. The forward linkage effects are related to output utilization, i.e. the output from a given activity will induce attempts to use this output as inputs in some new activities (Hirschman, 1958).

In the framework of an IO model, production by a particular sector has two kinds of economic effects on other sectors in the economy. If sector j increases its output, this means there will be increased demands from sector j (as a purchaser) on the sectors whose goods are used as inputs to production in j . This is the direction of causation in the usual demand-side model, and the term *backward linkage* is used to indicate this kind of interconnection of a particular sector with those sectors from which it purchases inputs. On the other hand, increased output in sector j also means that additional amounts of product j are available to be used as inputs to other sectors for their own production – that is, there will be increased supplies from sector j (as a seller) for the sectors that use good j in their production. This is the direction of causation in the supply-side model. The term *forward linkage* is used to indicate this kind of interconnection of a particular sector with those sectors to which it sells its output. If the backward linkage of sector i is larger than that of sector j , one might conclude that a dollar’s worth of expansion of sector i ’s output would be more beneficial to the economy than would an equal expansion in sector j ’s output, in terms of the productive activity throughout the economy that would be generated by it.

Similarly, if the forward linkage of sector r is larger than that of sector s , it could be said that the growth of the sector r is more contributive to the economy. Comparisons of the strengths of the backward/forward linkages for the sectors in a single economy provide one mechanism for identifying the key sectors in that economy (Miller and Blair, 2009, p. 555).

The key sectors refer to specialized sectors or sectoral cluster that have broad market prospects and strong technical progress ability, represent direction or tendency of industrial structural evolution and can spur and promote the entire regional economic development in a certain period of a local economic development. To push forward the development of a region, identification of key sectors is a necessary channel for realizing efficient allocation of regional resources and is the engine to boost rationalization and high-level of regional industrial structure. The question ‘what sector is the most important?’ is not a new one. Rasmussen (1956) is the first one who tried to answer this question and termed such an industry as ‘key industry’. He described that key industries were enjoying high backward linkages while, simultaneously, other industries displaying a low amount of variance in their dependence upon the industry being measured. Statistically, they can be represented by the sums of the columns and the rows of the Leontief inverse matrix L , where $L = (I - A)^{-1}$, which had the advantage of gathering together the direct and indirect effects. The sectors that have above-average effects would be the key sectors.

Hirschman (1958) also proposed using the Leontief inverse to calculate linkages and put forward these concepts as important considerations for developing economies when targeting industries for future investments. This emphasizes a more dynamic view of the key industry than we need. He suggested that the “key industries could be useful to stimulate the development of these countries, in addition to reactivating economies in crisis”. Since Rasmussen’s indexes could measure what Hirschman called the total backward linkages (TBL) and the total forward linkages (TFL), some authors started using the term Rasmussen-Hirschman (R&H) multipliers for the multipliers based on Leontief inverse.

In the middle of the 1970s, a series of improvements on the measurement of key sectors were proposed. Researchers gradually accepted that the concept of the key sector was diverse since it often depended on the objectives that were to be studied and measured. On the other hand, several authors, although accepting the total backward multipliers, criticized that the forward multipliers that estimated by the Leontief inverse were so far from reality due to the strong hypothesis—identical growth of final demand in every sector. (Hazari, 1970; Laumas, 1975, 1976; McGilvray, 1977).

A thought-provoking alternative was raised when Augustinovic (1970), Jones (1976) and Beyers (1976) proposed substituting the FL for the sum of the rows of the inverse $G = (I - B)^{-1}$ of the distribution matrix B , in accordance with the supply model proposed by Ghosh (1958). Jones (1976) criticized that the sum of the row of the Leontief inverse did not provide a measurement of the forward linkages symmetrical with that provided by the sum of column. Augustinovic (1970) proposed his terms *input approach* and *output approach* to define the analysis of the IO table through

their columns or rows, and indicated that both of them presented their advantages. Furthermore, the empirical study on several European countries showed that the allocation coefficients of matrix B was not more unstable than matrix A of technical coefficients.

Cella (1984) expressed the *Joint Stability Problem*, which states that the indexes obtained by the Leontief and Ghosh models would not be able to be combined due to the simultaneous inconsistency of the models based on the coefficients A or B. The supposition of a stable matrix A was not compatible with that of a stable matrix B, and vice versa. On the other hand, he expressed his doubts about the adequacy of the forward linkages: “In fact in the Rasmussen index for the sector j FL consists only of commodity j and is therefore completely different from the real nature of FL (which, if correctly evaluated, should be expressed in terms of all commodities)” (Cella, 1984, p. 76).

In the 1990s, a new era of renovation began, Dietzenbacher (1997, 2001 and 2002) debated about the consistency of models. He insisted that what the Ghosh model reveals are the variations in output as a consequence of the variation of the prices of the primary inputs, just as Leontief’s own model of prices does. Therefore what turns out to be accepted today is that the Ghosh model is equivalent to Leontief’s price model

Even so, the problem of the simultaneous use of both multipliers has not yet been solved till today. The search for alternative procedures to determine the key sectors continues. An example is given by Dietzenbacher (1992). He proposed using the elements of the right and left vectors associated with the dominant eigenvalue of matrices B and A, respectively, as indicators of intersectoral relations. In particular, the elements of eigenvector V_d associated with the dominant eigenvalue λ_D of matrix B could be used to measure forward linkages, whereas those of the left eigenvector V_i of matrix A could be used to estimate backward relations. Thus $BV_d = \lambda_D V_d$ and $V_i^t A = \lambda_D V_i^t$. The matrix A and B, which were similar matrices, have the same autovectors and, consequently, the same determinant, given that the latter can be expressed as the product of the former. Likewise, the elements of the dominant vectors were the same in matrix A, A^n and L or in B, B^n and G. He compared traditional multipliers to eigenvalues and found that, after ranking them among sectors, there is a greater difference for forward linkages than for backward linkages.

An alternative way of identifying the key sectors is through so-called important coefficients or ICs. The important coefficients (ICs) are those input coefficients which have the biggest influence in economic activity. Early mathematical work on the notion of the “important coefficients” in an input-output model explored the ways of identifying a_{ij} coefficients that have a particularly strong influence on one or more elements in the model, usually on the associated Leontief inverse matrix for one or more regions. Sonis and Hewings (1989, 1992) have proposed and developed the concept of a “field of influence” associated with each coefficient in an A matrix and they applied it to the economy of Chicago. Given a change in a particular a_{ij} in matrix A, the change on the corresponding Leontief inverse would be

$$\Delta L_{rs(ij)} = L_{rs(ij)}^* - L_{rs} = \frac{l_{ri}l_{js}\Delta a_{ij}}{1-l_{ji}\Delta a_{ij}} = l_{ri}l_{js}k_{(ij)} \quad (1)$$

where $k_{(ij)} = \Delta a_{ij}/(1 - l_{ji}\Delta a_{ij})$, a constant for a given i and j . Finding all the n^2 elements in the $n \times n$ matrix would require $[n^2-(2n-1)]$ operations. In order to simplify, Sonis and Hewings proposed an efficient alternative way. The first order (direct) field of influence of the incremental change Δa_{ij} is defined as

$$F_{i,j} = L_{\cdot i}L_{j \cdot} = \begin{bmatrix} l_{1i} \\ l_{2i} \\ \vdots \\ l_{ni} \end{bmatrix} \begin{bmatrix} l_{j1} & l_{j2} & \dots & l_{jn} \end{bmatrix} = \begin{bmatrix} l_{1i}l_{j1} & l_{1i}l_{j2} & \dots & l_{1i}l_{jn} \\ l_{2i}l_{j1} & l_{2i}l_{j2} & \dots & l_{2i}l_{jn} \\ \vdots & \vdots & \ddots & \vdots \\ l_{ni}l_{j1} & l_{ni}l_{j2} & \dots & l_{ni}l_{jn} \end{bmatrix} \quad (2)$$

Thus, $F_{i,j} = [l_{ri}l_{js}]$ for $r,s=1,\dots,n$. The matrix shows the change in each element of L caused by Δa_{ij} is just $\Delta L_{ij} = F_{i,j} k_{ij}$. Therefore,

$$L_{ij}^* = L + \Delta L_{ij} = L + F_{i,j} k_{ij} \quad (3)$$

Since $k_{(ij)}$ is a constant for a specific Δa_{ij} , corresponding elements of ΔL_{ij} and $F_{i,j}$ are proportional and will have the same ordering or ranking, for example, from largest to smallest. The authors suggest that inverse-important coefficients can be identified by comparing their fields of influence through $F = [f_{ij}]$ or

$F = \max_{ij} f_{ij}$. From the values of F , a hierarchy can be developed of the direct coefficients based on their field of influence, i.e., ranking sectoral relations in terms of their sensitivity to changes, in a sense that they will be responsible for more significant impacts on the economy.

However, some caution should be taken with this perspective. Sectors with the highest levels of inter-industry linkage in a region may not be the same as those that make the largest contributions to local employment and incomes (Midmore *et al.*, 2006). Hewings (1982) revealed that a problem with methods used to assess linkage intensities was that they were not always easily connected to the multifaceted goals of regional or national policy. Consequently, sectors of a regional economy that score highly in terms of local inter-industry linkages might score lower on their ability to create employment, or their ability to generate exports or substitute imports (Clements and Rossi, 1991).

2.2 Reviews on the IO models and non-survey techniques

It is well known that IO analysis is among the most data-ravenous regional economic models. The necessity of collecting an enormous amount of data to undertake such analysis has resulted in the development of non-survey techniques which aim to build subnational input-output tables without having to undertake the traditional survey exercise. However, on theoretical and empirical grounds, a well-designed and

executed survey IO model would be superior to a non-survey one. Nevertheless, the enormous time and budgetary outlays required to complete regional survey applications often favor non-survey approaches of generating regional tables. So far, several alternative non-survey and semi-survey techniques for assembling regional input-output tables have been suggested in the literature. Most of them involve a method of adjusting or regionalizing the national coefficients, since the regional coefficients are known to vary considerably from the national ones. Reviews of these techniques are provided in Miller and Blair (2009), Flegg and Tohmo (2010), Flegg and Webber (1997, 2000), and Bonfiglio (2009), among others. Considering both the advantages and disadvantages of non-survey techniques, analysts have to admit that the regional IO models become a powerful analytical tool when the prime purpose of any regional IO application is essentially to assess the impact of local-oriented policies or of national policies with regionally differentiated impacts (Tzouvelekas and Mattas, 1995).

Unfortunately, the empirical results show that the various non-survey methods always significantly overestimated the regional inter-industry flows, underestimated the exports, and thus overestimated the regional income multipliers. In an effort to address this problem, Flegg *et al.* (1995) proposed a new employment-based location quotient, the Flegg's location quotient (FLQ) formula, to take the regional size explicitly into account. They posited an inverse relationship between the regional size and the propensity to import from other regions. This FLQ formula was subsequently refined by Flegg and Webber (1997). A further refinement, Augmented Flegg's location quotient (AFLQ), was proposed by Flegg and Webber (2000) which aimed to capture the effect of regional specialization on the magnitude of the regional input coefficients. Flegg and Tohmo (2013) examined both input coefficients and type I sectoral output multipliers with 20 survey-based data sets from 1995 which were published by Statistics Finland. The results showed that the FLQ outperformed the conventional LQs. Furthermore, the best single value for estimating multipliers is $\delta = 0.25$ with the minimum mean proportional difference for the most of the regions. On the other hand, it suggested that a $\delta > 0.15$ might be required if the criteria based on the absolute values for both multipliers and coefficients are used. A regression equation was developed to estimate the exponential value of δ with the explanatory variables of the regional size (R) and regional propensity to import from other regions, divided by the mean value of this propensity for all regions (P) and the survey-based average use of intermediate inputs divided by the corresponding national proportion of intermediate inputs (I). However, the value of P and I were naturally difficult to estimate due to the shortage of the regional data. Choi (2010) estimated the regional multipliers with the non-survey based LQs using 2003 Korean data and compared them to the survey-based multipliers. The findings implied that the FLQ and AFLQ perform better than the conventional LQs. The results showed that the best non-survey LQ is FLQ with a $\delta = 0.6$ for the Dae-Gyeong region (Daegu and Gyeongbuk). This conclusion was confirmed by Zhao and Choi (2012), which indicated that the best LQs for Daegu city and Gyeongbuk province were FLQ with $\delta = 0.5$ and $\delta = 0.6$, respectively.

Midmore *et al.* (2006) evaluated several alternative methods of assessing inter-industry linkages using IO tables to identify the industries with potential. In particular, it used the financial information from Welsh IO tables of 1995 to derive a measurement giving specific insights into regional industry interdependency and the presence of relatively self-contained groups of activity. This was the first time that this more complex measure had been applied to a regional transactions table in the UK, with the method shown to be of direct relevance to a smaller open economy. The results revealed the differences in rankings of the ‘key’ sectors compared with more conventional approaches. Furthermore, the conclusions discussed the importance of assessing industry interdependencies for the regional strategic planning process and the problems associated with using the IO frameworks for such assessment.

The latest creative research on the non-survey IO models might be Kowalewski (2013). An extended formula, called the industry-specific FLQ (SFLQ), was proposed and compared with the conventional LQs with various criteria in terms of both input coefficients and multipliers. The conclusions demonstrated the superiority of SFLQ, and indicated that a value of $0.11 \leq \delta \leq 0.17$ would produce the most accurate regional tables for B-W (Baden-Wuerttemberg of German Federal State) regions. The author also carried out a regression model to determine the δ value. The statistics presented that the only variable that had a significant impact on the value of δ is the coefficient of localization with $R^2=0.67$.

3. Methodology

3.1 Regional IO modeling: Non-survey techniques

Since regional information, such as GRDP, income, and value-added data, are not available at hand, the regional IO tables have to be deduced from national IO tables with LQs. This is one popular way that non-survey techniques are widely used in the process of constructing IO tables recently. All the non-survey techniques are aimed at estimating the regional input coefficients assuming that the regional and the national technologies are identical except for the product mix approach (Miller and Blair, 2009). The regional input coefficient is estimated accordingly: $r_{ij} = q_{ij}a_{ij}$, where r_{ij} is the estimated regional input coefficient, a_{ij} is the national technical coefficient, and q_{ij} represents the degree of modification of the national coefficient which must be less than or equal to unity. If $q_{ij} > 1$, we set: $r_{ij} = a_{ij}$. In other words:

$$r_{ij} = \begin{cases} q_{ij}a_{ij} & \text{if } q_{ij} \leq 1 \\ a_{ij} & \text{if } q_{ij} > 1 \end{cases} \quad (4)$$

Non-survey techniques can be considered as different ways of estimating q_{ij} , which includes the Simple Location Quotient (SLQ), the Cross-Industry Location Quotient (CIQ), the Semi-logarithmic Location Quotient (RLQ), nine versions of the FLQ, and nine versions of the AFLQ. The choice of these methods depends on the fact that some of them appear frequently in the literature whereas the others (i.e. the FLQ and,

in particular, the AFLQ) are relatively recent and therefore they have not been discussed extensively.

The SLQ is defined as

$$SLQ_i = \frac{E_i^R E^R}{E_i^N E^N} = \frac{E_i^R E_i^N}{E^R E^N} \quad (5)$$

where i represents a given sector, E is employment, and R and N indicate the region and the nation, respectively. As a result of the limitation of the data at the local level, the employment data are often replaced with the output, value-added data, and so on. The constraint $SLQ_i = 1$ is imposed when $SLQ_i > 1$. Round (1978) mentioned that the size of the regional input coefficients can be expressed as a function that depends on: (a) the relative size of the regional selling sector compared with that of the nation, (b) the relative size of the regional purchasing sector, (c) the relative size of the region, and (d) the additional unspecified factors. From the formula, it is easy to note that the SLQ incorporates the first and third property. Actually, contrary to expectations, as the relative size of a region decreases, the SLQ increases, and the adjustment of the national coefficients for the regional imports diminishes (Bonfiglio and Chelli, 2008).

The CIQ takes the form as following:

$$CIQ_{ij} = \frac{E_i^R E_i^N}{E_j^R E_j^N} = \frac{SLQ_i}{SLQ_j} \quad (6)$$

The CIQ compares the proportion of the employment (or the national output) of the selling industry i in the region to that of the purchasing industry j . From the formula, it can be easily noted that the CIQ neglects the relative size of the region. As we discussed above, the size of the regional input coefficients can be expressed as a function that depends on three properties: the relative size of the supplying sector, the purchasing sector, and the relative size of the region. Round (1978) pointed out that SLQ incorporates the first and third of these variables, whereas CIQ embodies the first two, but not the third, which can be demonstrated easily with the formulas above. In order to capture all three desirable properties simultaneously, he postulated the following semi-logarithmic adjustment formula:

$$RLQ_{ij} = \frac{SLQ_i}{\log_2 1 + SLQ_j} = \frac{E_i^R E^R}{E_i^N E^N} / \left[\log_2 1 + \frac{E_j^R}{E_j^N} * \frac{E^N}{E^R} \right] \quad (7)$$

It should be noted that the factor $\frac{E^N}{E^R}$ does not cancel out in the expression above – the same as it is in the CIQ, which indicates the relative importance of the region. Also, via the inclusion of both SLQ_i and SLQ_j , it incorporates the relative size of both sectors. As same as the others, the RLQ should not be more than a unit.

The FLQ method is established by Flegg (1995) which combined the merits of the RLQ and CIQ, while avoiding their short-comings. The FLQ takes the following form:

$$FLQ_{ij} = \begin{cases} CIQ_{ij} * \lambda & \text{for } i \neq j \\ SLQ_i * \lambda & \text{for } i = j \end{cases} \quad (8)$$

where $\lambda = [\log_2(1 + E^R E^N)]^\delta$, $0 \leq \delta < 1$, $0 \leq \lambda \leq 1$. The application of the SLQ along the main diagonal of the national table is to eliminate the problem of overestimation of the intra-sectoral coefficients. The FLQ was proposed to incorporate the advantages of the CIQ and SLQ and avoid the relevant shortcomings. The relative size of the selling and purchasing sectors is taken into account through the inclusion of CIQ, whereas the relative size of the region appears in terms of λ . The inclusion of the exponent δ introduces an element of flexibility by altering the convexity of the function λ . A higher value of δ would lower the value of λ and thus greater adjustments of the regional imports are made. However, the choice of the value of δ is considered to be an empirical matter. The principal advantage of the FLQ may well be that it offers a way of handling the problem – inherent in other LQ-based approaches – of underestimating regional imports and hence overstating regional multipliers (Flegg and Webber, 2000). On the basis of the studies concerning Peterborough's economy in 1968 (Morrison and Smith, 1974) and Scotland in 1989, Flegg and Webber (1997) found that an approximate value of δ with 0.3 allows the derivation of the closer multipliers to those obtained by the surveys than multipliers obtained by the conventional cross-industry LQs. However, the authors suggested that more empirical studies are needed to confirm the value of δ .

The AFLQ formula is a variant of the FLQ, which was conceived to incorporate a measure of regional specialization (Flegg and Webber, 2000). It takes the following form:

$$AFLQ_{ij} = \begin{cases} FLQ_{ij} * \log_2 1 + SLQ_j & \text{for } SLQ_j > 1 \\ FLQ_{ij} & \text{for } SLQ_j \leq 1 \end{cases} \quad (9)$$

where $\log_2 1 + SLQ_j$ has been included to allow for the effects of regional specialization. If $SLQ_j > 1$ and $FLQ_{ij} > 1$, the national coefficients are scaled upwards. Therefore, the constraint $FLQ_{ij} \leq 1$ is imposed to avoid the upwards scaling.

Kowalewski (2013) proposed the SFLQ which is also an extension of the FLQ, with the equation of:

$$SFLQ_{ij} = CIQ_{ij} \cdot [\log_2(1 + E^R E^N)]^{\delta_j} \quad (10)$$

Unlike the FLQ and AFLQ, which are subject to the strong assumption that the value of the exponent δ is equal for all industries, the SFLQ allows for a variation in δ_j across the industries. The empirical study on the region of B-W in Germany examined the relative success of SFLQ on the estimation of the multipliers and the input

coefficients with various criterions. The results show that the use of SLFQ enhanced the accuracy of the estimation no matter which criterion was applied. However, as same as the FLQ and AFLQ, the main shortcoming of SFLQ is how to determine the δ value before updating or constructing the regional IO tables with it.

3.2 . Linkage measurement

A measure of the strength of the backward linkage of sector j is given by the sum of the elements in the j th column of the direct input coefficients in matrix A , namely

$$BL\ d = \sum_{i=1}^n a_{ij} \quad (11)^\dagger$$

Since the coefficients in A are measures of the direct effects only, this is called the *direct backward linkage*. To capture both direct and indirect linkages in an economy, the sums of the columns of the Leontief inverse matrix, $L = [l_{ij}]$, were proposed as a *total backward linkage* measurement, namely,

$$BL\ t = \sum_{i=1}^n l_{ij} \quad (12)^\ddagger$$

A measure of the *direct forward linkage* was also proposed, based on A and L , as the row sum of Ai , along with an associated *total forward linkage measure*, the sums of the rows of Li . Symmetrically, the forward linkages are measured as:

$$FL\ d = \sum_{j=1}^n a_{ij} \quad (13)^\S$$

$$FL\ t = \sum_{j=1}^n l_{ij} \quad (14)$$

where $A = [a_{ij}]$ is the input coefficient matrix and $L = [l_{ij}]$ is the Leontief inverse matrix (Miller and Blair, 2009). As mentioned before, the effectiveness assigned to forward linkages was a matter of controversy. Many authors criticized the lack of a real practical basis for forward multipliers even though they accepted total backward multipliers. Consequently, consideration will be put on the backward multipliers in this study.

In order to examine the performance of SFLQ on identifying the key sectors, it is necessary to compare the rank of the estimated backward linkages with the survey-based ones. A highly consistent rank between them indicates that the estimated backward linkages could be regarded as an indicator to identify the key sectors since they are capable of representing the importance of certain sectors among all the industries. The rank correlation analysis is employed to measure the rank similarity of the estimated backward linkages with the survey-based ones. The Spearman's rank correlation coefficient, denoted by ρ , is a method of calculating the correlation coefficient for a set of bivariate data by ranking that data.

$$\rho = 1 - \frac{6 \sum d_i^2}{n(n-1)} \quad (15)^{**}$$

[†] The definition was first proposed by Chenery and Watanabe (1958).

[‡] The definition was first proposed by Rasmussen (1957).

[§] The definition was also first proposed by Chenery and Watanabe (1958).

^{**} Myers JL, Well AD (2003) Research design and statistical analysis (2nd ed.). Lawrence Erlbaum. P 508.

where d is the difference in ranks and n is the amount of pairs of the data.

The Kendall rank correlation coefficient, commonly referred to as Kendall's τ coefficient, is used to measure the association between the two measured quantities. Specifically, it is a measure of the rank correlation, i.e., the similarity of the orderings of the data when ranked by each of the quantities. It is named after Maurice Kendall, who developed it in 1938 and defined it as:

$$\tau = \frac{n_c - n_d}{(n_0 - n_1)(n_0 - n_2)} \quad (16)^{\dagger\dagger}$$

where

$$n_0 = \frac{n(n-1)}{2}$$

$$n_1 = \sum_i t_i(t_i - 1)/2$$

$$n_2 = \sum_j u_j(u_j - 1)/2$$

n_c is the Number of concordant pairs.

n_d is the Number of discordant pairs.

t_i is the Number of tied values in the i^{th} group of ties for the first quantity.

u_j is the Number of tied values in the j^{th} group of ties for the second quantity.

4. Empirical analysis

4.1 The data

The data employed here is the 2005 national input coefficient tables issued by the Bank of Korea (BOK) based on the surveys as well as the employment data of 2005 issued by the Statistics Korea (KOSTAT). A brief description of two regions is listed as following.

TABLE 1. The characteristics of Daegu City and Gyeongbuk Province in 2005 (out of nation)

Region	Population (%)	Output (%)	Employment (%)
Daegu	5.22	2.9	4.72
Gyeongbuk	5.52	8.4	5.44

*Source: Bank of Korea (2008) and National Statistical Office of Korea (2006)

^{††} Agresti A (2010) Analysis of ordinal categorical data (2nd ed.). John Wiley & Sons. New York.

<Table 1> and <Table 2> reveal some marked differences in the characteristics of two regions, most notably in terms of their relative size. Regional size can be measured in several different ways and it is expressed with the employment data since we have to use the employment as a proxy for the regional output data, which are not normally available.

TABLE 2. The relative size of the industries in Daegu City and Gyeongbuk Province base on employment data

Code	Sections	Nation	Percentage (%)	Daegu	Percentage (%)	Gyeongbuk	Percentage (%)
1	Agriculture, forestry and fishing	32,294	0.2132	306	0.0428	3,098	0.3762
2	Mining and quarrying	19,372	0.1279	131	0.0183	1,393	0.1692
3	Food, beverages and tobacco products	300,663	1.9849	9,522	1.3323	23,266	2.8253
4	Textile and apparel	378,108	2.4962	37,891	5.3016	23,541	2.8587
5	Wood and paper products	109,157	0.7206	4,739	0.6631	6,687	0.8120
6	Printing and reproduction of recorded media	137,877	0.9102	4,567	0.6390	3,085	0.3746
7	Petroleum and coal products	103,26	0.0682	8	0.0011	202	0.0245
8	Chemicals, drugs and medicines	387,908	2.5609	10,876	1.5218	29,130	3.5373
9	Non-metallic mineral products	107,162	0.7075	2,209	0.3091	13,512	1.6408
10	Basic metal products	126,871	0.8376	4,174	0.5840	26,517	3.2200
11	Fabricated metal products except machinery and furniture	325,472	2.1487	27,248	3.8125	20,301	2.4652
12	General machinery and equipment	362,961	2.3962	17,991	2.5173	15,155	1.8403
13	Electronic and electrical equipment	617,864	4.0790	12,308	1.7221	74,488	9.0453
14	Precision instruments	71,683	0.4732	3,887	0.5439	3,960	0.4809
15	Transportation equipment	372,425	2.4587	16,011	2.2402	19,260	2.3388
16	Furniture and other manufactured products	142,416	0.9402	4,053	0.5671	5,909	0.7175
17	Electricity, gas, steam and water supply	66,370	0.4382	2,419	0.3385	6,245	0.7583
18	Construction	779,864	5.1485	30,666	4.2907	41,123	4.9937
19	Wholesale and retail trade	2,440,701	16.1129	131,073	18.3395	105,070	12.7590
20	Accommodation and food services	1,696,133	11.1975	81,161	11.3559	97,122	11.7938
21	Transportation	881,104	5.8168	40,463	5.6615	37,368	4.5377
22	Communications and broadcasting	138,577	0.9149	5,786	0.8096	5,802	0.7046
23	Finance and insurance	591,969	3.9080	29,293	4.0986	25,954	3.1517
24	Real estate and business services	1,470,397	9.7072	56,735	7.9383	37,237	4.5218
25	Public administration and defense	539,085	3.5589	23,333	3.2647	36,177	4.3931
26	Education, health and social work	1,841,109	12.1546	96,743	13.5361	100,651	12.2223
27	Other services	1,199,603	7.9195	61,110	8.5504	61,247	7.4374
Total		15,147,471	100	714,703	100	823,500	100

4.2 Empirical results

The concerns on the output multipliers are motivated by their importance in the regional analysis, along with the fact that many earlier studies have attempted to derive satisfactory estimates of such multipliers. The multipliers which are calculated with the LQs have been ranked by the size (see <table 9> and <table 10> in appendix). By attempting to find the key sectors with non-survey methods, the ranks of backward and forward linkages generated by the LQs are compared with the benchmark which is issued by the BOK. Take the backward linkages as an example. <Table 3> and <Table 4> describe the distribution of key sectors for Daegu City and Gyeongbuk province, respectively. With the suggestions of Rasmussen-Hirschman, the sectors that have an above-average value of multipliers are considered as the key sectors, which are indicated with gray cells in both tables. At first sight, the key sectors defined by the benchmark and the LQs are severely inconsistent with each other. First of all, it is worthy to notice that the number of key sectors identified by each method is different. In this case, 14 key sectors are identified with the backward linkage in the

survey method, 12 by SLQ and RLQ, 11 by CIQ and SFLQ and 8 by FLQ. Compare the number identified by the FLQ to one by the benchmark, almost half of the key sectors are lost by the FLQ. In addition, it is also inconsistent on which cells are considered as the key sectors in each method. As indicated in <Table 3>, among the LQs, SFLQ produces the most identical result from the survey method, in which three sectors are mismatched, namely, *Printing and reproduction of recorded media*, *Petroleum and coal products* and *Fabricated metal products except machinery and furniture*.

TABLE 3. The distribution of key sectors of Daegu City

Codes	Sectors	Benchmark		SLQ		CIQ		RLQ		FLQ		SFLQ
		BL	FL	BL	FL	BL	FL	BL	FL	BL	FL	BL
1	Agriculture, forestry and fishing	1.2060	1.1195	1.1841	1.8022	1.7841	1.4329	1.7037	1.3809	1.3573	1.1043	1.1878
2	Mining and quarrying	1.2872	1.0315	1.2156	1.6232	1.6927	1.8710	1.6726	1.8281	1.4414	1.6370	1.2720
3	Food, beverages and tobacco products	1.2320	1.2269	1.7285	2.0742	1.8515	2.0987	1.7783	2.0571	1.1765	1.4120	1.2350
4	Textile and apparel	1.2913	1.1661	2.4431	1.7170	1.8929	1.8374	1.9803	1.8287	1.3041	1.4075	1.3041
5	Wood and paper products	1.3180	1.3288	2.3538	2.1341	2.3370	2.4832	2.2781	2.4410	1.2243	1.3232	1.2976
6	Printing and reproduction of recorded media	1.2875	1.1442	1.8373	1.2575	2.1975	1.3106	2.1229	1.2899	1.2522	1.0679	1.2522
7	Petroleum and coal products	1.1509	1.0070	1.0223	2.1889	2.2141	1.0981	2.1751	1.0764	1.9438	1.0125	1.6544
8	Chemicals, drugs and medicines	1.1903	1.3314	1.7873	3.2555	2.4659	4.1745	2.2437	3.7481	1.2057	1.4771	1.2057
9	Non-metallic mineral products	1.2506	1.0732	1.5117	1.3283	2.0835	1.4758	1.9723	1.3951	1.2773	1.0680	1.2773
10	Basic metal products	1.1638	1.2290	2.1245	3.7143	3.1055	4.7104	2.7383	4.2323	1.2009	1.3208	1.1517
11	Fabricated metal products except machinery and furniture	1.2444	1.2802	2.4421	1.7273	1.8818	1.9397	1.9443	1.9217	1.1858	1.3748	1.2402
12	General machinery and equipment	1.2815	1.1704	2.5666	1.7886	2.3920	1.9917	2.3399	1.9770	1.2325	1.2304	1.3103
13	Electronic and electrical equipment	1.2318	1.2061	1.5497	2.0435	2.8903	2.3255	2.5288	2.0708	1.2803	1.1414	1.2118
14	Precision instruments	1.2440	1.0211	2.3346	1.2942	2.0476	1.3483	2.0238	1.3412	1.1900	1.0901	1.2510
15	Transportation equipment	1.2640	1.1749	2.5975	1.7965	2.7385	1.9759	2.6153	1.9460	1.2352	1.1885	1.2352
16	Furniture and other manufactured products	1.2399	1.0368	1.8715	1.1893	2.5053	1.2054	2.3922	1.1918	1.3836	1.0619	1.2183
17	Electricity, gas, steam and water supply	1.1512	1.1722	1.6554	1.7892	1.5227	2.0252	1.4865	1.9739	1.1024	1.2051	1.1344
18	Construction	1.2146	1.0916	1.8666	1.1469	1.9380	1.1878	1.8760	1.1804	1.1980	1.0297	1.1980
19	Wholesale and retail trade	1.2767	1.2854	1.7200	2.2726	1.5681	2.6322	1.5759	2.6086	1.1630	1.5042	1.3086
20	Accommodation and food services	1.1904	1.4148	1.9822	2.0056	1.7076	2.0515	1.6912	2.0401	1.1368	1.8744	1.1827
21	Transportation	1.1624	1.5966	1.9067	2.1323	1.6764	2.6969	1.6607	2.6609	1.1416	1.4866	1.1813
22	Communications and broadcasting	1.3315	1.4326	1.7928	1.6536	1.8545	1.7480	1.8170	1.7340	1.1888	1.1599	1.3128
23	Finance and insurance	1.4244	1.7923	1.6303	2.1235	1.5743	2.4162	1.5721	2.4014	1.1420	1.2941	1.4140
24	Real estate and business services	1.1618	1.8565	1.4838	3.1246	1.5563	3.4445	1.5328	3.3775	1.1563	1.4889	1.1563
25	Public administration and defense	1.2535	1.0411	1.6364	1.0457	1.6283	1.0526	1.6100	1.0517	1.2327	1.0281	1.2631
26	Education, health and social work	1.1743	1.1154	1.5870	1.1536	1.4734	1.1967	1.4665	1.1942	1.1494	1.0490	1.1729
27	Other services	1.3324	1.1433	1.9809	1.3691	1.8291	1.4333	1.8207	1.4291	1.2464	1.1760	1.3513
Number of key sectors		14	9	12	11	11	10	12	11	8	12	11

* FLQ is estimated with $\delta=0.5$.

TABLE 4. The distribution of key sectors of Gyeongbuk Province

Codes	Sectors	Benchmark		SLQ		CIQ		RLQ		FLQ		SFLQ
		BL	FL	BL	FL	BL	FL	BL	FL	BL	FL	BL
1	Agriculture, forestry and fishing	1.2359	1.6666	1.9552	2.3609	1.6319	2.3350	1.7433	2.3606	1.1256	1.2834	1.26851
2	Mining and quarrying	1.2834	1.0439	1.8665	2.7938	1.5857	2.7208	1.6207	2.9718	1.1573	1.5975	1.27202
3	Food, beverages and tobacco products	1.5124	1.3801	2.4971	2.5067	2.1805	2.4275	2.2565	2.4859	1.2103	1.4277	1.51066
4	Textile and apparel	1.3413	1.2046	2.7017	1.8143	2.4417	1.8292	2.4702	1.8432	1.2278	1.1693	1.29694
5	Wood and paper products	1.2886	1.2217	2.7664	2.3147	2.5020	2.4766	2.5333	2.5022	1.2311	1.3326	1.30550
6	Printing and reproduction of recorded media	1.2772	1.1684	1.5835	1.2211	2.3189	1.2590	2.2576	1.2252	1.3508	1.0430	1.27570
7	Petroleum and coal products	1.0868	1.1184	1.4778	3.1080	2.1588	1.7104	2.1683	1.7508	1.6035	1.0785	1.27049
8	Chemicals, drugs and medicines	1.2127	1.7048	2.8684	5.2165	2.4282	5.1229	2.4823	5.3352	1.2405	1.6620	1.24046
9	Non-metallic mineral products	1.2724	1.1842	2.4641	1.6356	1.7909	1.6231	1.9597	1.6540	1.2057	1.2169	1.27021
10	Basic metal products	1.7252	2.5646	3.4881	5.8448	2.7728	6.0142	2.9677	6.0623	2.0094	3.3535	1.64723
11	Fabricated metal products except machinery and furniture	1.5989	1.2883	3.0257	1.9164	2.6288	1.8822	2.7130	1.9248	1.5959	1.1740	1.59592
12	General machinery and equipment	1.4588	1.1432	2.4862	1.9269	2.7794	1.7966	2.7701	1.8013	1.5210	1.1004	1.52100
13	Electronic and electrical equipment	1.2472	1.3405	3.0435	2.8831	2.4052	2.9733	2.5616	2.9959	1.3451	1.6061	1.24979
14	Precision instruments	1.3275	1.0301	2.8395	1.3461	2.4943	1.3151	2.5442	1.3285	1.3232	1.0581	1.32324
15	Transportation equipment	1.4457	1.1782	3.1436	1.9495	2.9888	1.9556	3.0144	1.9702	1.3941	1.1266	1.39412
16	Furniture and other manufactured products	1.3688	1.0398	2.3830	1.2181	2.6223	1.2228	2.6297	1.2164	1.3940	1.0623	1.39398
17	Electricity, gas, steam and water supply	1.2056	1.3388	2.1573	2.2046	1.7506	2.1326	1.8708	2.2357	1.1446	1.2512	1.19127
18	Construction	1.3602	1.1044	2.3336	1.1397	2.1028	1.1414	2.1440	1.1486	1.3144	1.0274	1.31445
19	Wholesale and retail trade	1.2693	1.1703	1.6089	2.6997	1.6720	2.2826	1.6438	2.3485	1.1648	1.2799	1.24359
20	Accommodation and food services	1.3245	1.3949	2.2860	2.0944	2.0618	2.0596	2.0967	2.0705	1.1894	1.8667	1.34402
21	Transportation	1.1436	1.4856	1.8217	2.7664	1.9246	2.3247	1.8808	2.4023	1.1546	1.1674	1.15457
22	Communications and broadcasting	1.3155	1.3610	1.7380	1.6366	1.8660	1.6809	1.8308	1.6628	1.1814	1.1226	1.30094

23	Finance and insurance	1.3110	1.5292	1.5020	2.2168	1.5787	2.1497	1.5456	2.1641	1.1141	1.1522	1.37182
24	Real estate and business services	1.1785	1.6608	1.3508	3.5901	1.6227	2.3653	1.6073	2.3719	1.2088	1.1801	1.17167
25	Public administration and defense	1.2177	1.0348	1.7466	1.0516	1.5743	1.0511	1.5987	1.0526	1.2114	1.0270	1.21138
26	Education, health and social work	1.1748	1.1035	1.7221	1.1982	1.5997	1.1734	1.6087	1.1857	1.1664	1.0291	1.16642
27	Other services	1.3480	1.1186	2.0450	1.3834	1.9317	1.3957	1.9337	1.4031	1.2488	1.1553	1.35661
Number of key sectors		12	11	14	11	13	10	13	11	8	7	10

* FLQ is estimated with $\delta=0.6$.

In order to capture the difference of rankings between benchmarks and estimated multipliers more deeply, the rank correlation coefficients are employed to expose this chaos. <Table 5> and <Table 6> show the rank correlation of forward and backward linkages on Daegu city. The values of correlation coefficient on the forward linkages may indicate that the ranking orders of the estimated multipliers are mostly consist with the benchmarks. The poorest estimation is from the SLQ with the smallest value of coefficients both on Spearman's ρ and Kendall's τ . On the contrary, the best estimation is based on RLQ with a coefficient of 0.823 of Spearman's ρ and 0.635 of Kendall's τ . However, even with the highest coefficients, the errors associated within the estimation could produce severe consequences during the process of identifying a small cluster of the key sectors. In the meanwhile, the rank correlation coefficients of the backward linkages tell us a different story from <Table 6>. The coefficients show that the backward linkages' behavior is mostly irrelevant with benchmarks and themselves, except the coefficient with SFLQ. As high as the coefficient value of 0.978, it suggests that the SFLQ produces nearly identical key sectors as the survey method. At last, there is a high correlation between CIQ and RLQ, which is represented by the value of 0.943 on Kendall's τ and 0.991 on Spearman's ρ . As a matter of fact, it is not surprising that CIQ and RLQ produce the similar output since their formulas show clearly that RLQ is an extensive version of CIQ.

The discussion so far has focused on the statistics of Daegu city, so it might be necessary to take a look at the results on the Gyeongbuk province and see whether it generates comparable results. <Table 4> provides the distribution of the key sectors with each LQ. <Table 7> and <Table 8> describe the rank correlation coefficients of Gyeongbuk province. Despite the fact that Gyeongbuk province is bigger than Daegu city geographically, it gives only slightly better results. The significant values of the forward linkages indicate that there are certain connections between the survey method and non-survey methods, approximately 0.573 of Kendall's τ and 0.722 of Spearman's ρ between the benchmark and the CIQ, as well as the equivalent amount between the benchmark and the others. However, they are not as plausible as expected. The best estimation suggested by the calculations on the backward linkages is based on SFLQ with a 0.936 of Spearman's ρ and 0.823 of Kendall's τ . Meanwhile, it is worthy of noticing that the FLQ, which is mostly discussed and considered as the best non-survey method by many researchers recently, does not produce satisfactory answers as well. In the case of the backward linkages, the coefficient produced by FLQ is even insignificant in Daegu city. Although it is significant at the 0.05 level in Gyeongbuk province, the FLQ is proven the worst one out of total of 5 non-survey methods. On the other hand, the forward linkages indicate that the FLQ is slightly better than SLQ and worse than CIQ and RLQ in both regions.

Under this circumstances, it appears that the non-survey methods may not be a

suitable proxy to determine the key sectors at the sub-national level except for SFLQ. Furthermore, the results from the rank correlation indicate that conventional LQs might have distorted the regional industrial structures from the beginning, as well as FLQ. A larger amount of previous studies explored the performance and capability of the LQs on constructing regional input-output tables as well as estimation of the regional inter- and intra-industrial impact effects in the last decades. Examples can be found in Bonfiglio (2009), Dietzenbacher and Miller (2009), Flegg and Webber (1997, 2000), Lahr (1993), Miller and Blair (2009) and so on. However, few of them have focused on the ability of the LQs to reflect the industrial structure. Indeed, the non-survey methods offer a cost-effective way of building the foundations of a hybrid model, argued by *Flegg et al.* (1997, 2000, 2013b), and LQ-generated coefficients can be used as the initial values in the application of the RAS iterative procedure. From this study, however, the traditional non-survey methods obviously fail to produce proper regional IO tables for identifying the key sectors since the information on the industrial structure is estimated improperly, especially for Daegu city. Moreover, it is not the first time this problem appeared. Examples can be found in other references as well, such as Flegg and Webber (1997, 2000), Flegg and Tohmo (2010, 2013), *etc.* One of the explanations might be the failure of LQs to capture the regional specialization. Besides, the accuracy of the survey data also requires special scrutiny since this is the second time that BOK issued the regional survey data and first time issued the survey data for 16 regions (The BOK issued 2003 regional survey data for 6 regions and 2005 data for 16 regions).

TABLE 5. The rank correlation of forward linkages, Daegu^{‡‡}

Spearman's ρ						Kendall's τ					
Correlation coefficient	BK	SLQ	CIQ	RLQ	FLQ	Correlation coefficient	BK	SLQ	CIQ	RLQ	FLQ
BK	1.000					BK	1.000				
SLQ	.648**	1.000				SLQ	.499**	1.000			
CIQ	.813**	.824**	1.000			CIQ	.624**	.783**	1.000		
RLQ	.823**	.825**	.998**	1.000		RLQ	.635**	.783**	.977**	1.000	
FLQ	.666**	.601**	.804**	.803**	1.000	FLQ	.533**	.476**	.647**	.647**	1.000

** Correlation is significant at the 0.01 level (2-tailed).

*** FLQ is estimated with $\delta=0.5$.

TABLE 6. The rank correlation of backward linkages, Daegu

Spearman's ρ							Kendall's τ						
Correlation	BK	SLQ	CIQ	RLQ	FLQ5	SFLQ	Correlation	BK	SLQ	CIQ	RLQ	FLQ5	SFLQ

^{‡‡} The *SFLQ* might be unfit for estimating forward linkages since the optimal δ values of *SFLQ* are derived with backward multipliers themselves.

coefficient						coefficient							
BK	1.000					BK	1.000						
SLQ	.315	1.000				SLQ	.219	1.000					
CIQ	.073	.407*	1.000			CIQ	.043	.299*	1.000				
RLQ	.114	.476*	.991**	1.000		RLQ	.077	.356**	.943**	1.000			
FLQ5	.240	-.139	.559**	.572**	1.000	FLQ5	.162	-.071	.390**	.413**	1.000		
SFLQ	.987**	.303	.014	.059	.197	1.000	SFLQ	.937**	.202	-.009	.037	.123	1.000

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

*** FLQ is estimated with $\delta=0.5$.

**** BK means Benchmark

TABLE 7. The rank correlation of forward linkages, Gyeongbuk

Spearman's ρ						Kendall's τ					
Correlation coefficient	BK	SLQ	CIQ	RLQ	FLQ	Correlation coefficient	BK	SLQ	CIQ	RLQ	FLQ
BK	1.000					BK	1.000				
SLQ	.656**	1.000				SLQ	.516**	1.000			
CIQ	.722**	.911**	1.000			CIQ	.573**	.840**	1.000		
RLQ	.716**	.910**	.998**	1.000		RLQ	.556**	.835**	.983**	1.000	
FLQ	.676**	.752**	.883**	.881**	1.000	FLQ	.527**	.613**	.761**	.755**	1.000

** Correlation is significant at the 0.01 level (2-tailed).

*** FLQ is estimated with $\delta=0.6$.

TABLE 8. The rank correlation of backward linkages, Gyeongbuk

Spearman's ρ							Kendall's τ						
Correlation coefficient	BK	SLQ	CIQ	RLQ	FLQ6	SFLQ	Correlation coefficient	BK	SLQ	CIQ	RLQ	FLQ6	SFLQ
BK	1.000						BK	1.000					
SLQ	.590**	1.000					SLQ	.436**	1.000				
CIQ	.623**	.761**	1.000				CIQ	.453**	.573**	1.000			
RLQ	.602**	.813**	.984**	1.000			RLQ	.430**	.664**	.909**	1.000		
FLQ6	.484*	.505**	.808**	.819**	1.000		FLQ6	.390**	.407**	.607**	.630**	1.000	
SFLQ	.936**	.495**	.634**	.611**	.542**	1.000	SFLQ	.823**	.350*	.459**	.447**	.419**	1.000

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

*** FLQ is estimated with $\delta=0.6$.

5. Summary and conclusions

There is a wildly growing belief that regional economic development has to be considered as a strictly integrated process involving not only one particular sector but a whole range of economic activities. Several sectors, closely interconnected, can be expanded to provide an impulse to the regional economic engine. Various studies suggest that identification and promotion of the key sectors that display strong forward and/or backward linkages in a region could contribute to the analysis of the regional economic development. Furthermore, it helps with new regional strategic policy programs. The IO models have proven to be useful in providing detailed information about an industry's effect both at the national level and the regional level. By computing various kinds of multipliers, one can measure the impact of an industry on employment, household income, and the activity level of all industries, which is considerably meaningful for economic development forecasting. Researchers usually prefer to build regional IO tables through adjusting the national ones with non-survey techniques to analyze the impact effects and make growth strategies when such information is unavailable at hand. On the other hand, the IO model can be used to identify the key sectors through linkage effects. The backward and forward linkages for the sectors in a single economy provide a mechanism for identifying the key sectors in the economy. However, the key sector analysis has been hardly applied at the regional level due to the shortage of regional information. In this study, the regional key sectors are identified from the regional IO tables along with non-survey techniques. At first, the traditional backward linkages are estimated and ranked in descending order. Then, those ranks are compared with benchmarks through the rank correlation coefficients. The empirical study is given on two objective regions, Daegu and Gyeongbuk, to figure out if it is possible to identify the regional key sectors through non-survey methods? If possible, which one is more appropriate?

Based on the empirical test, it appears, unfortunately, that the non-survey techniques, except for the SFLQ, may distort the information of the regional industrial structure and be incapable of identifying key sectors. Given by the statistics, the low-rank correlation coefficients between the benchmarks and the estimated backward and forward linkages indicate that all the conventional non-survey techniques may not be a suitable proxy to identify the 'key' sectors, since the industrial structure could not be reflected correctly. Especially, it is worth noticing that the FLQ, which is widely discussed and considered as a superior non-survey method by many researchers recently, does not produce satisfactory answers either. Its failure on reflecting regional industrial structure precisely may need more concern and discussion. On the other hand, the SFLQ outperforms all the conventional LQs and produces not only a more accurate estimation of the multipliers, but also a consistent rank of them with the survey method. Given the high rank coefficients between the SFLQ and the benchmark, it is highly recommended that the SFLQ should be a suitable agent to

identify the regional key sectors in terms of capturing the regional specialization and industrial structure.

Despite of the fact that few demonstrations have been provided to illustrate whether the non-survey techniques can reflect the industrial structure properly, it has been well admitted that the non-survey techniques have been a powerful tool to analyze the regional impact effects, since they offer a low cost and time-saving options to construct regional IO tables or build the initial foundations for the hybrid IO models. Above all, it is highly suggested that more caution is needed while using the LQs to identify the regional key sectors or construct the regional IO tables.

A more comprehensive and insightful analysis, together with the non-survey IO model, is expected to examine the perspectives of the key sectors at the sub-national level in the future research. Furthermore, a multi-sectoral qualitative analysis of the growth sectors may be necessary to provide various information about industries together with an analysis of the characteristics of the objective region. Such studies are expected to reveal perspectives on regional and industrial core competencies, risk and linkage possibilities, which should be meaningful on policy-making. In the meantime, more indicators may be helpful in identifying the key sectors rather than only backward and forward linkage. At last, some caution should be taken with the key sectors. Sectors with the highest levels of inter-industry linkage in a region may not be the same as those that make the largest contributions to the local employment and incomes (Midmore *et al.*, 2006).

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TABLE 9. The multipliers and ranking of Daegu City

Codes	Sectors	Benchmark				SLQ				CIQ				RLQ				FLQ				SFLQ	
		BL	Rank	FL	Rank	BL	Rank	FL	Rank	BL	Rank	FL	Rank	BL	Rank	FL	Rank	BL	Rank	FL	Rank	BL	Rank
1	Agriculture, forestry and fishing	1.2060	19	1.1195	19	1.1841	26	1.8022	12	1.7641	18	1.4329	20	1.7037	18	1.3809	20	1.3573	4	1.1043	19	1.1878 (0.8)	19
2	Mining and quarrying	1.2872	7	1.0315	25	1.2156	25	1.6232	19	1.6927	20	1.8710	15	1.6726	20	1.8281	16	1.4414	2	1.6370	2	1.272 (0.9)	6
3	Food, beverages and tobacco products	1.2320	16	1.2269	11	1.7285	16	2.0742	9	1.8515	16	2.0987	9	1.7783	17	2.0571	9	1.1765	20	1.4120	7	1.2289 (0.4)	14
4	Textile and apparel	1.2913	5	1.1661	16	2.4431	3	1.7170	17	1.8929	13	1.8374	16	1.9803	11	1.8287	15	1.3041	5	1.4075	8	1.2785 (0.5)	5
5	Wood and paper products	1.3180	4	1.3288	7	2.3538	5	2.1341	6	2.3370	7	2.4832	6	2.2781	6	2.4410	6	1.2243	13	1.3232	10	1.2976 (0.4)	4
6	Printing and reproduction of recorded media	1.2875	6	1.1442	17	1.8373	13	1.2575	23	2.1975	9	1.3106	22	2.1229	9	1.2899	22	1.2522	8	1.0679	22	1.2522 (0.5)	8
7	Petroleum and coal products	1.1509	27	1.0070	27	1.0223	27	2.1889	5	2.2141	8	1.0981	26	2.1751	8	1.0764	26	1.9438	1	1.0125	27	0.6474 (0.9)	27
8	Chemicals, drugs and medicines	1.1903	21	1.3314	6	1.7873	15	3.2555	2	2.4659	5	4.1745	2	2.2437	7	3.7481	2	1.2057	14	1.4771	6	1.1749 (0.5)	21
9	Non-metallic mineral products	1.2506	12	1.0732	22	1.5117	23	1.3283	21	2.0835	10	1.4758	18	1.9723	12	1.3951	19	1.2773	7	1.0680	21	1.2238 (0.5)	15
10	Basic metal products	1.1638	23	1.2290	10	2.1245	7	3.7143	1	3.1055	1	4.7104	1	2.7383	1	4.2323	1	1.2009	15	1.3208	11	1.1517 (0.6)	24
11	Fabricated metal products except machinery and furniture	1.2444	13	1.2802	9	2.4421	4	1.7273	16	1.8818	14	1.9397	14	1.9443	13	1.9217	14	1.1858	19	1.3748	9	1.2402 (0.4)	11
12	General machinery and equipment	1.2815	8	1.1704	15	2.5666	2	1.7886	15	2.3920	6	1.9917	12	2.3399	5	1.9770	11	1.2325	12	1.2304	13	1.2527 (0.4)	7
13	Electronic and electrical equipment	1.2318	17	1.2061	12	1.5497	22	2.0435	10	2.8903	2	2.3255	8	2.5288	3	2.0708	8	1.2803	6	1.1414	18	1.2118 (0.6)	17
14	Precision instruments	1.2440	14	1.0211	26	2.3346	6	1.2942	22	2.0476	11	1.3483	21	2.0238	10	1.3412	21	1.1900	17	1.0901	20	1.237 (0.4)	12
15	Transportation equipment	1.2640	10	1.1749	13	2.5975	1	1.7965	13	2.7385	3	1.9759	13	2.6153	2	1.9460	13	1.2352	10	1.1885	15	1.2352 (0.5)	13
16	Furniture and other manufactured products	1.2399	15	1.0368	24	1.8715	11	1.1893	24	2.5053	4	1.2054	23	2.3922	4	1.1918	24	1.3836	3	1.0619	23	1.2183 (0.7)	16
17	Electricity, gas, steam and water supply	1.1512	26	1.1722	14	1.6554	18	1.7892	14	1.5227	26	2.0252	11	1.4865	26	1.9739	12	1.1024	27	1.2051	14	1.1344 (0.4)	26
18	Construction	1.2146	18	1.0916	21	1.8666	12	1.1469	26	1.9380	12	1.1878	25	1.8760	14	1.1804	25	1.1960	16	1.0297	25	1.196 (0.5)	18
19	Wholesale and retail trade	1.2767	9	1.2854	8	1.7200	17	2.2726	4	1.5681	24	2.6322	5	1.5759	23	2.6086	5	1.1630	21	1.5042	3	1.2448 (0.2)	9
20	Accommodation and food services	1.1904	20	1.4148	5	1.9822	8	2.0056	11	1.7076	19	2.0515	10	1.6912	19	2.0401	10	1.1368	26	1.8744	1	1.1827 (0.4)	20
21	Transportation	1.1624	24	1.5966	3	1.9067	10	2.1323	7	1.6764	21	2.6969	4	1.6607	21	2.6609	4	1.1416	25	1.4866	5	1.1436 (0.4)	25
22	Communications and broadcasting	1.3315	3	1.4326	4	1.7928	14	1.6536	18	1.8545	15	1.7480	17	1.8170	16	1.7340	17	1.1888	18	1.1599	17	1.3128 (0.3)	3
23	Finance and insurance	1.4244	1	1.7923	2	1.6303	20	2.1235	8	1.5743	23	2.4162	7	1.5721	24	2.4014	7	1.1420	24	1.2941	12	1.414 (0.1)	1
24	Real estate and business services	1.1618	25	1.8565	1	1.4838	24	3.1246	3	1.5563	25	3.4445	3	1.5328	25	3.3775	3	1.1563	22	1.4889	4	1.1563 (0.5)	23
25	Public administration and defense	1.2535	11	1.0411	23	1.6364	19	1.0457	27	1.6283	22	1.0526	27	1.6100	22	1.0517	27	1.2327	11	1.0281	26	1.244 (0.4)	10
26	Education, health and social work	1.1743	22	1.1154	20	1.5870	21	1.1536	25	1.4734	27	1.1967	24	1.4665	27	1.1942	23	1.1494	23	1.0490	24	1.1729 (0.4)	22
27	Other services	1.3324	2	1.1433	18	1.9809	9	1.3691	20	1.8291	17	1.4333	19	1.8207	15	1.4291	18	1.2464	9	1.1760	16	1.3136 (0.3)	2

*FLQ is estimated with $\delta=0.5$.

TABLE 10. The multipliers and ranking of Gyeongbuk province

Code	Sectors	Benchmark				SLQ				CIQ				RLQ				FLQ				SFLQ	
		BL	Rank	FL	Rank	BL	Rank	FL	Rank	BL	Rank	FL	Rank	BL	Rank	FL	Rank	BL	Rank	FL	Rank	BL	Rank
1	Agriculture, forestry and fishing	1.2359	20	1.6666	3	1.9552	17	2.3609	10	1.6319	22	2.3350	8	1.7433	21	2.3606	9	1.1256	26	1.2834	8	1.2685 (0.3)	19
2	Mining and quarrying	1.2834	15	1.0439	24	1.8665	18	2.7938	6	1.5857	25	2.7208	4	1.6207	23	2.9718	4	1.1573	23	1.5975	5	1.272 (0.3)	16
3	Food, beverages and tobacco products	1.5124	3	1.3801	8	2.4971	9	2.5067	9	2.1805	12	2.4275	6	2.2565	12	2.4859	6	1.2103	16	1.4277	6	1.5107 (0.3)	4
4	Textile and apparel	1.3413	9	1.2046	14	2.7017	8	1.8143	18	2.4417	8	1.8292	16	2.4702	10	1.8432	16	1.2278	14	1.1693	14	1.2969 (0.5)	14
5	Wood and paper products	1.2886	14	1.2217	13	2.7664	7	2.3147	11	2.5020	6	2.4766	5	2.5333	8	2.5022	5	1.2311	13	1.3326	7	1.3055 (0.5)	12
6	Printing and reproduction of recorded media	1.2772	16	1.1684	18	1.5835	24	1.2211	23	2.3189	11	1.2590	23	2.2576	11	1.2252	23	1.3508	7	1.0430	24	1.2757 (0.7)	15
7	Petroleum and coal products	1.0868	27	1.1184	21	1.4778	26	3.1080	4	2.1588	13	1.7104	18	2.1683	13	1.7508	18	1.6035	2	1.0785	21	1.2705 (0.9)	17
8	Chemicals, drugs and medicines	1.2127	22	1.7048	2	2.8684	5	5.2165	2	2.4282	9	5.1229	2	2.4823	9	5.3352	2	1.2405	12	1.6620	3	1.2405 (0.6)	22
9	Non-metallic mineral products	1.2724	17	1.1842	15	2.4641	11	1.6356	20	1.7909	19	1.6231	20	1.9597	16	1.6540	20	1.2057	18	1.2169	11	1.2702 (0.5)	18
10	Basic metal products	1.7252	1	2.5646	1	3.4881	1	5.8448	1	2.7728	3	6.0142	1	2.9677	2	6.0623	1	2.0094	1	3.3535	1	1.6472 (0.7)	1
11	Fabricated metal products except machinery and furniture	1.5989	2	1.2883	12	3.0257	4	1.9164	17	2.6288	4	1.8822	15	2.7130	4	1.9248	15	1.5959	3	1.1740	13	1.5959 (0.6)	2
12	General machinery and equipment	1.4588	4	1.1432	19	2.4862	10	1.9269	16	2.7794	2	1.7966	17	2.7701	3	1.8013	17	1.5210	4	1.1004	20	1.521 (0.6)	3
13	Electronic and electrical equipment	1.2472	19	1.3405	10	3.0435	3	2.8831	5	2.4052	10	2.9733	3	2.5616	6	2.9959	3	1.3451	8	1.6061	4	1.2498 (0.7)	20
14	Precision instruments	1.3275	10	1.0301	27	2.8395	6	1.3461	22	2.4943	7	1.3151	22	2.5442	7	1.3285	22	1.3232	9	1.0581	23	1.3232 (0.6)	10
15	Transportation equipment	1.4457	5	1.1782	16	3.1436	2	1.9495	15	2.9888	1	1.9556	14	3.0144	1	1.9702	14	1.3941	5	1.1266	18	1.3941 (0.6)	5
16	Furniture and other manufactured products	1.3688	6	1.0398	25	2.3830	12	1.2181	24	2.6223	5	1.2228	24	2.6297	5	1.2164	24	1.3940	6	1.0623	22	1.394 (0.6)	6
17	Electricity, gas, steam and water supply	1.2056	23	1.3388	11	2.1573	15	2.2046	13	1.7506	20	2.1326	12	1.8708	19	2.2357	11	1.1446	25	1.2512	10	1.1913 (0.5)	24
18	Construction	1.3602	7	1.1044	22	2.3336	13	1.1397	26	2.1028	14	1.1414	26	2.1440	14	1.1486	26	1.3144	10	1.0274	26	1.3144 (0.6)	11
19	Wholesale and retail trade	1.2693	18	1.1703	17	1.6089	23	2.6997	8	1.6720	21	2.2826	10	1.6438	22	2.3485	10	1.1648	22	1.2799	9	1.2436 (0.4)	21
20	Accommodation and food services	1.3245	11	1.3949	7	2.2860	14	2.0944	14	2.0618	15	2.0596	13	2.0967	15	2.0705	13	1.1894	19	1.8667	2	1.344 (0.4)	9
21	Transportation	1.1436	26	1.4856	6	1.8217	19	2.7664	7	1.9246	17	2.3247	9	1.8808	18	2.4023	7	1.1546	24	1.1674	15	1.1546 (0.6)	27
22	Communications and broadcasting	1.3155	12	1.3610	9	1.7380	21	1.6366	19	1.8660	18	1.6809	19	1.8308	20	1.6628	19	1.1814	24	1.1226	19	1.3009 (0.4)	13
23	Finance and insurance	1.3110	13	1.5292	5	1.5020	25	2.2168	12	1.5787	26	2.1497	11	1.5456	27	2.1641	12	1.1141	27	1.1522	17	1.3718 (0.2)	7
24	Real estate and business services	1.1785	24	1.6608	4	1.3508	27	3.5901	3	1.6227	23	2.3653	7	1.6073	25	2.3719	8	1.2088	17	1.1801	12	1.1717 (0.7)	25
25	Public administration and defense	1.2177	21	1.0348	26	1.7466	20	1.0516	27	1.5743	27	1.0511	27	1.5987	26	1.0526	27	1.2114	15	1.0270	27	1.2114 (0.6)	23
26	Education, health and social work	1.1748	25	1.1035	23	1.7221	22	1.1982	25	1.5997	24	1.1734	25	1.6087	24	1.1857	25	1.1664	21	1.0291	25	1.1664 (0.6)	26
27	Other services	1.3480	8	1.1186	20	2.0450	16	1.3834	21	1.9317	16	1.3957	21	1.9337	17	1.4031	21	1.2488	11	1.1553	16	1.3566 (0.4)	8

* FLQ is estimated with $\delta=0.6$.