**A method to identify key sectors and their feedback loops for a certain industry in one economy and its application in the evaluation of the role of real estate industry in Chicago**

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Abstract: This paper explores the possibility of merging into a 'combined' proposal three standard I-O methods identifying key sectors and their sub feedback loops, namely Hypothetical Extraction, Classical Multiplier Method and the Hieratical Feedback Loop Method. The novelty of the formulation allows us to disaggregate the total stimuli of one certain sector or a sub feedback loop into four components: internal effect (IE), net backward linkage (NBL), net forward linkage (NFL) and mixed effect (ME). With Chicago input-output tables, we applied this method to find out key sectors and the first and the second feedback loops in 1995. And singled out the sub feedback loop that connected with real estate industry in Chicago economic system-specifically. Then compared the impacts (composed by IE, NFL, NBL, MX) of key sectors, non-key sectors, feedback loop composed by key sectors and by non-key sectors. The results indicated that when the industrial policy was designed, not only key sectors should be concerned, but also should the sub feedback loop composed by key sectors or non-key sectors be more concerned.

Keywords: Key Sector, Feedback Loop, Hypothetical Extraction, Decomposed Impacts

**1. Introduction**

 In general, the purpose of key sector analysis is to identify the sectors which have the greatest effects on the rest of the economy. The motivation to perform the examination of key sectors is that in case of any group of economies the identification and classification of such influential fields might provide the basis for taxonomy of economies as well as contribute to enriching our understanding of the growth and development processes ([Ćmiel and Gurgul, 2002](http://www.sciencedirect.com/science/article/pii/S0967067X1400083X%22%20%5Cl%20%22bib9)). In case of transition economies, however, such an analysis may also provide crucial information on the structural change of an economy during the process of economic transformation. EU ‘sector-specific’ recommendations and the policy actions of subsequent member states have their roots in sound academic and technical reports that very often rest on the key-sector approach (Hirschman 1958).This approach identifies those production sectors of the economy that contribute most to the cost-effectiveness of particular policy actions. There are several analytical approaches within key-sector analysis but input-output (I-O) methods are probably among the most popular and widely used. The low data requirements and ease of implementation of I-O analysis provide a powerful operational platform for the design of policy strategies.

Using these I-O key sector methods, several studies have already evaluated and quantified the ‘keyness’ of sectors. The studies of Cumberland (1966), Strout (1967) and Blair (1980) are among the earliest works in this field. More recent examples in the academic literature are those carried out by Guerra and Sancho (2010), Alcántara et al. (2010, 2013), Tarancón et al. (2008, 2011), for the case of Spain; Cellura et al. (2011), (2012), (2013a, b), for the case of Italy; Mu et al. (2010), Su and Ang (2012),Wang and Liang (2013) and Chang and Lahr (2016) for China; Lenzen (2003) for Australia, Tarancón et al. (2010) and Henryk and Łukasz (2015) in the context of a group of EU economies.

With the objective of identifying dominant or key sectors, these academic contributions have, in most cases, used two alternative criteria. The first criterion is based on the Classical Multiplier Method (CMM), while the second uses the Hypothetical Extraction Method (HEM). The CMM criterion maximizes sectors’ policy outcomes when controlling for their total industrial interdependencies, i.e. the internal interdependencies that stem from its own intermediate demand plus the external interdependencies that affect the remaining sectors of the economy. Alternatively, the HEM can be used to focus the selection criterion on the intensity of the potential distributive or external industrial linkages alone.

Except key sectors that played an important role in the economic development, economic structure change is another main factor. Thompson (1965) considered that the evolution of the economy structure transformation is logistic, with a slow accumulation of interaction effects characterizing the early period before a take-off into an accelerated period of growth. As the economy reaches maturity, the deepening of the interactions slows down. Jensen et al. (1986, 1988) explored the ways in which development would be accompanied by an essential deepening of the intensity of interaction between sectors. Sonis and Hewings (1988, 1991) developed hierarchical feedback loop analysis method which can be employed to facilitate the identification of economic interactions among sets of different sectors, as well as the change over time in the structural patterns and sectoral composition of this interaction.

The present analysis departs from such common practice to offer a modified methodology that merges the three aforementioned standard I-O key-sector methods and, consequently, their criteria as well. This ‘combined’ approach allows a more detailed analysis of the structure and nature of the production chains that emanate from the stimuli of a certain sector or a feedback loop. By making use of this approach, we connect the role played by each sector and its feedback loop within these production interdependencies with the composition and intensity of their own backward, forward linkage internal effects and mixed effects in the economy.

Via an empirical application to the Chicago economy, we show that this combined approach yields useful information that can be employed to develop a more balanced and cost-effective design for some policies in general.

The reminder of this paper is organized as follows. Section 2 and section 3 introduce the basic elements of the hierarchical feedback loop approach and modified hypothetical extraction method. Section 4 briefly describes the derivation of Chicago input-output tables using the Chicago Region Econometric Input-Output Model (CREIM). Section 5 presents application results. The sixth section concludes with some summary remarks.

**2. Hierarchical Feedback Loop Approach[[1]](#footnote-1)**

A series of transactions, in which each sector appears only once with one incoming flow and one outgoing flow, may indeed be called a feedback loop, because each sector in such a loop affects itself at the end of the loop (assuming one starts the loop with the sector in question).[[2]](#footnote-2) A feedback loop is complete if it includes all the sectors. The economic interpretation of a feedback loop is straightforward; it indicates how strongly (at each hierarchical level) each sector is tied to all other sectors included in that loop. In the analysis to be performed, attention will be directed only to complete loops, primarily for presentation reasons. By focusing on complete loops, one can evaluate the place and position of each sector relative to all other sectors of Chicago.

Considering only complete feedback loops is technically possible, as each non-complete feedback loop can be extended to become a complete loop through the addition of loops including the sectors outside the non-complete loop. Moreover, an hierarchical analysis of the set of all complete loops is simpler than an hierarchical analysis of the set of all possible loops. For a set of *n* sectors, the number of complete feedback loops is already equal to *n*!

A complete feedback loop is either closed or can be decomposed into a set of closed sub-loops. If the entering flow and the leaving flow for the same sector are identical, we have the smallest closed sub-loop possible, i.e., the effect that a sector exerts directly on itself – the self-effect. It is important to note that the matrix form of a complete feedback loop can be represented with the help of a sub-matrix of flows extracted from the matrix $T=\left|t\_{ij}\right|$ of all the aggregated transaction flows. Such a sub-matrix  represents a complete feedback loop if it includes in each row and in each column only one non-zero entry from the matrix *T* and contains zeros elsewhere. One can define the ‘flow intensity,’  of a complete feedback loop as the sum of all the transaction flows of the corresponding sub-matrix, .

If all the non-zero entries of are replaced by 1s (thus converting the matrix into a Boolean form), the result is the so-called permutation matrix . This Boolean matrix corresponds to some permutation of the sequence of numbers 1, 2,…, *n*. Such a permutation (of sectors) represents the structure of the corresponding complete feedback loops. The sub-matrices, are referred to as ‘quasi-permutation matrices.’

The hierarchy of all complete feedback loops is defined as the sequence of quasi-permutation sub-matrices, , chosen according to the rank size of their flow intensities. This means that on the top of the hierarchy, one finds the complete feedback loop with the maximal flow intensity. The problem of the determination of the quasi-permutation sub-matrix with the maximal flow intensity is mathematically equivalent to the solution of the optimal personnel assignment of *n* persons (here rows) between *n* jobs (here columns), in such a way that one person will have one job, while profit is maximized (see Danzig, 1963). Here, “profit” is defined by the size of the transaction flows in matrix *T*. Further details of the procedure can be found in Sonis and Hewings (1988, 1991). In this paper, a MATLAB program was compiled to find the quasi-permutation sub-matrices .

**3. Modified Hypothetical Extraction Method**

HEM was first used by Schultz (1977) to analyze the economic impact of a sector’s activity change. The original idea of HEM is to measure the effect of a sector i on the economy by comparing the production of the economy with that of a hypothetical economy in which the sector I is extracted. Based on the comparison, the effect of sector I on the economy can be distinguished, allowing us to detect key sectors in the economy. HEM was later reformulated by Cella(1984) and Duarte et al. (2002) in greater details as described below.

Fs represents a series of target sectors in the economy, it can be one sub-feedback loop, while F-s represents the remaining blocks. With HEM method, the change in production, which reflects the impact of the block, can then be expressed as follows,

$$x^{0}-x^{1}=\left(\begin{matrix}x\_{s}^{0}-x\_{s}^{1}\\x\_{-s}^{0}-x\_{-s}^{1}\end{matrix}\right)=\left(\begin{matrix}∆\_{s,s}-\left(I-A\_{s,s}\right)^{-1}&∆\_{s,-s}\\∆\_{-s,s}&∆\_{-s,-s}-\left(I-A\_{-s,-s}\right)^{-1}\end{matrix}\right)\left(\begin{matrix}y\_{s}\\y\_{-s}\end{matrix}\right)$$

**=**$\left(\begin{matrix}C\_{s,s}&C\_{s,-s}\\C\_{-s,s}&C\_{-s,-s}\end{matrix}\right)^{}\left(\begin{matrix}y\_{s}\\y\_{-s}\end{matrix}\right)$ (1)

Where $x^{0},x^{1} $is the vector of total output before and after the block was extracted, y is the vector of final demand, A= $\left(\begin{matrix}A\_{s,s}&A\_{s,-s}\\A\_{-s,s}&A\_{-s,-s}\end{matrix}\right)$is the matrix of technical coefficients, and $(I-A)^{-1}=\left(\begin{matrix}∆\_{s,s}&∆\_{s,-s}\\∆\_{-s,s}&∆\_{-s,-s}\end{matrix}\right)$ is the Leontief inverse matrix.

Accordingly, the change of total output has four components as we defined as follows.

Internal effects (IE):

$IE=C\_{s,s}\*y\_{s}$ (2)

Net forward linkage (NFL):

$NFL=C\_{s,-s}\*y\_{-s}$ (3)

Net backward linkage (NBL):

$NBL=C\_{-s,s}\*y\_{s}$ (4)

Mixed effects (ME):

$ME=C\_{-s,-s}\*y\_{-s}$ (5)

IE represents the change embodied in the goods produced, sold, and purchased exclusively inside the block Fs. By contract, ME is the part of x change that is associated with the participation of both Fs and F-s. NBL reflects the real or net ‘imports’ made by Fs to obtain its own demand. NFL is the real or net ‘export’ made by Fs, that is to say, the part of Fs used by F-s to produce y-s.

**4. Data**

In order to analyze structural changes in the Chicago economy, 36-sector input-output tables[[3]](#footnote-3) were extracted from the Chicago Region Econometric Input-Output Model (CREIM for the period of 1995-2011(see Israilevich *et al*., 1997 for more details). This system of 250 equations includes both exogenous and endogenous variables. Endogenous coefficient change serves as the mechanism to clear markets in a quantity-adjustment process. The input-output coefficient matrix is not observed directly; however, it is possible to derive analytically the estimated direct coefficient matrix. An important assumption here is that the error terms in the derived input-output coefficients from the CREIM are normally distributed, and are independent and identically distributed; thus, the coefficients, while not “real” observations, can be treated as such, since they are derived by a quantity adjustment general equilibrium process. With the estimated direct coefficient matrix and the total output by 36 industrial sectors, the annual intermediate flow matrix can be calculated from 1995 to 2010.

**Table 1. Sector Definitions for Chicago IO tables**

|  |  |  |  |
| --- | --- | --- | --- |
| ***Sector Description*** | ***Sector Number*** | ***Sector Description*** | ***Sector Number*** |
| Livestock, Agric. products | 1 | Non Electrical Machinery | 19 |
| Forestry, Fisheries, Agric. Serv. | 2 | Electrical Mach. & Electronic | 20 |
| Mining | 3 | Transportation Equip. | 21 |
| Construction | 4 | Instruments | 22 |
| Food and Kindred products | 5 | Miscellaneous Manufac. | 23 |
| Tobacco | 6 | Transportation | 24 |
| Apparel and Textiles | 7 | Communications | 25 |
| Lumber and Wood products | 8 | Utilities | 26 |
| Furniture and Fixtures | 9 | Trade | 27 |
| Paper and Allied products | 10 | Finance, Insurance | 28 |
| Printing and Publishing | 11 | Real Estate | 29 |
| Chemicals and Allied products | 12 | Hotels, Repair Services | 30 |
| Petroleum | 13 | Eating & Drinking Places | 31 |
| Rubber and Plastics | 14 | Auto Repair & Services | 32 |
| Leather | 15 | Amusements & Recreation | 33 |
| Stone, Clay and Glass | 16 | Health & Nonprofit | 34 |
| Primary Metals | 17 | Federal Govt. Enterprises | 35 |
| Fabricated Metals | 18 | State & Local Gov. Enterpr. | 36 |

CREIM, defined in real 1982 dollars, forecasts output, employment, and income for 36 roughly two-digit SIC sectors, as well as many other final demand and demographic variables up to 25 years into the future.

**5. Application**

As Carter (1970) noted, structural change is a moving average process that often reveals noticeable changes over longer time spans. Although input-output tables were obtained for each year for the period 1995 to 2010, the hierarchical feedback loops were only extracted for the years 1995 and 2010. It would be impossible to effectively summarize all the changes for all the feedback loops so, by way of illustration, attention is focused on the first two feedback loops that accounted for the largest proportion of the total intermediate flow. The components of the first two feedback loops in 1995 and 2010 are shown in Table 2 (Liu and Hewings, 2014).

**Table 2. The components of the first 2 feedback loops in 1995 to 2010**

|  |  |  |
| --- | --- | --- |
| **Year** | **T1** | **T2** |
| **1995** | (1)18-31-28-27-30-4-18 (12689.0, 45.4%)(2)11-3-13-36-10-11 (1448.5, 5.2%) (3)35-9-35 (13.3, 0.05%)(4)Sectors1,2,5,6,7,8,12,14,15,16,17,19,20,21,22,23,24,25,26,29,32,33,34 are self-dependent sub-loops (13807.8,49.4%) | (1)27-4-27 (5983.2, 28.4%) (2)30-30 (4020, 19.1%) (3) 11-6-15-7-35-13-24-12-14-22-11 (3218.6, 15.3%) (4)34-28-29-34 (3075.4, 14.6%) (5) 2-1-8-9-3-16-5-31-33-25-23-17-20-21-32-2 (3055.9, 14.5%)(6)19-18-19 (871.8, 4.1%)(7)10-10 (498.8, 2.4%) (8)36-26-36 (361.2, 1.7%) |
| **2010** | (1)9-3-13-36-16-4-30-27-28-31-18-32-10-11-35-9(23152.4, 57.2%)(2)Sectors 1,2,5,6,7,8,12,14,15,17,19,20, 21, 22, 23, 24,25, 26, 29, 33, 34 are self-dependent sub-loops(17303.0, 42.8%) | (1)27-4-27 (9932.5, 31.4%) (2)11-3-16-5-31-35-13-24-12-14-22-11(8236.4, 26.1%) (3)30-30 (6293.1, 19.9%) (4)34-28-29-34 (4577.1, 14.5%) (5)19-18-19 (904.2, 2.9%) (6)2-1-6-8-9-23-17-20-25-33-15-7-21-32-2 (688.3, 2.2%) (7)10-10 (637.0, 2.0%) (8)36-26-36 (327.5, 1.0%) |

With CMM method, we can identify five key sectors of Chicago economy in 1995, they were sector 30, 3, 27, 9, 35. Their total output multiplier were (274.5, 273.5, 177.9, 136.2, 134.6) which ranked the top five in the 36 sectors.

In Table 2, all these key sectors were not self-dependent sectors in the first feedback loop in 1995. There were strong connections between sector 30 and sector 27, between sector 35 and sector 9 in 1995 T1.

Especially, to sector 29 which we were concerned with, it was not key sector in Chicago economy in 1995. It was self-dependent in 1995 T1, there had a sub loop (SL) 34-28-29-34 in 1995 T2. We wanted to find which is more important in Chicago economy, key sector or sub-feedback loop? When key sector 30, sector 29, sector 28, sector 34, sub feedback loop 34-28-29-34 and sub feedback loop 9-35 which were composed by key sectors were extracted from Chicago IO table in 1995, their total impacts on the total output were evaluated with the modified HEM method. Results see Table 3.

**Table 3. Results with modified HEM (E10+4)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Components of Impacts | S30 | S29 | S28 | S34 | S (29+28+34) | SL34-28-29-34 | SL 9-35 |
| IE | 58.3 | -12.6 | 8 | -100.9 | -105.5 | 34.6 | 40 |
| NBL | 268.8 | 21.9 | 44.2 | 14.8 | 80.9 | 61.3 | 1759.5 |
| NFL | -65.8 | 2.3 | -0.5 | -140.5 | -138.7 | 27.8 | 213.7 |
| ME | -182.6 | 13 | -18.4 | -32.2 | -37.6 | 2306.2 | 492.4 |
| Absolute Sum (AS) | 575.5 | 49.8 | 71.1 | 288.4 | 362.7 | 2429.9 | 2505.6 |

Table 3 showed us that to key sector 30, its AS value which indicated the total impact on the Chicago economy was bigger than any AS value of non-key sector 29, 28 or 34, and even bigger than the sum of the three sectors’ separate impacts. But its AS value was much smaller than that of FBL 34-28-29-34 and FBL 9-35. The AS value of FBL 9-35 which were composed by key sectors was bigger than that of FBL 34-28-29-34 which were composed by non-key sectors. To the other components of impacts, there had no obvious rule that the value of key sector or feedback loop was definitely bigger than that of non-key sector.

**6. Summary**

The paper applied CMM and FBL method to identify key sectors of one economy and the feedback loop related with key sectors and non-key sectors. Then compared the impacts (composed by IE, NFL, NBL, MX) of key sectors, non-key sectors, feedback loop composed by key sectors and by non-key sectors. The results showed that the total impact of key sector was bigger than that of non-key sector and even bigger than the sum of non-key sectors’ separate impacts. But its AS value was much smaller than that of FBL composed by these non-key sectors and also by key sectors. The total impact of FBL composed by key sectors was bigger than that of FBL composed by non-key sectors. To the components of the total impact, there had no obvious rule that the value of key sector or feedback loop was definitely bigger than that of non-key sector. The results indicated that when the industrial policy was designed, not only key sectors should be concerned, but also should the sub feedback loop composed by key sectors or non-key sectors be more concerned. Much more detailed analysis would be made to the role of real estate industry in Chicago economy. From this analysis, the sectors that impact the intensity of the backward, forward effects of the real estate industry and their feedback loops can be identified, thereby providing a more comprehensive set of perspectives for the evaluation of the role of real estate industry in the economy.

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1. This section draws on Sonis *et al*. (1995) [↑](#footnote-ref-1)
2. In other papers, Sonis et al. (2002) have described feedback loops as spatial production cycles since they highlight the circularity in production systems. [↑](#footnote-ref-2)
3. See Table 1 for a description of the sectors. [↑](#footnote-ref-3)