The Asian economy: trade structure interpreted by feedback loop analysis

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1995

The Asian Economy: Trade Structure Interpreted by Feedback Loop Analysis[1]

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Abstract

The recent discussions that focused on the problems of the Uruguay Round of the General Agreement on Tariffs and Trade [GATT] together with the emergence of strengthened and expanded free trade areas [such as NAFTA, European Union and MERCOSUL/MERCOSUR] have created the need for careful analysis of the nature of internal and external dependence among nations and, within any nation, among the constituent regions. The picture that is obtained from inspection of import and export flows is only one (and often the smaller) part of the nature of dependence; there is a need to consider the indirect effects and, in addition, the possible feedbacks that may accrue from expansion of links between any two countries rippling through a broader set of economies and returning to expand activity in the originating economy. However, until recently, a dearth of data precluded the type of analysis conducted here; the development of consistent intercountry input-output tables for Europe enabled the first attempt at an understanding of intercountry dependencies (see Sonis, Oosterhaven and Hewings, 1993). This paper will explore similar perspectives with a set of Asian intercountry input-output tables for 1985.

In this paper, some new perspectives are advanced that provide a more comprehensive view of the interactions between the economies of Asia. The analysis focuses on the potential for uncovering alternative perspectives about the role of linkages and multipliers in input-output systems. The analysis draws on some pioneering work by Miyazawa in the identification of *internal* and *external* multiplier effects. Paths of direct and indirect dependency are revealed as well as the nature and strength of feedback loops. In addition, some potential exists for contibutions to the debate raised by Krugman (1991, 1993) on the role of regionalism versus multilaterialism.

Using these methods, it is possible to provide insights into the way in which these economies are integrated, the strength of the integration and the potential consequences of action in one economy on the rest of the system. The analysis parallels some earlier work on the European economies and will provide the basis for future comparative analysis as updated tables are produced.

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[1] The support provided by FAPESP and by REAL (University of Illinois) to Guilhoto is gratefully acknowledged.

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1. Introduction

The recent discussions that focused on the problems of the Uruguay Round of the General Agreement on Tariffs and Trade [GATT] together with the emergence of strengthened and expanded free trade areas [such as NAFTA, European Union and MERCOSUL/MERCOSUR] have created the need for careful analysis of the nature of internal and external dependence among nations and, within any nation, among the constitutent regions. The picture that is obtained from inspection of import and export flows is only one (and often the smaller) part of the nature of dependence; there is a need to consider the indirect effects and, in addition, the possible feedbacks that may accrue from espansion of links between any two countries rippling through a broader set of economies and returning to expand activity in the originating economy. However, until recently, a dearth of data precluded the type of analysis conducted here; the development of consistent intercountry input-output tables for Europe enabled the first attempt at an understanding of intercountry dependencies (see Sonis, Oosterhaven and Hewings, 1993). This paper will explore similar perspectives with a set of Asian intercountry input-output tables for 1985.

There seems to be general agreement that the processes of economic change are often stimulated by a relatively small number of sectors initially even if the whole economy ends up experiencing change. While this perspective is advanced for an individual economy, can a similar perspective be applied to a set of interacting economies, either nations or regions? In a companion paper (Sonis *et al.* 1994), some alternative perspectives to this debate are offered; these perspectives are drawn from papers by Sonis *et al*. (1994b) and Guilhoto *et al*. (1994) that attempted to intervene in the debate on likages that have continued between Cella (1984), Guccione (1986), Clements and Rossi (1991, 1992) on Cella's decomposition technique.

However, the major contribution of this present paper is to place these debates into a broader context through an examination of the macro-level feedback loops that can be identified from the country-to-country trading patterns. This paper only draws on a small set of these perspectives (see Sonis *et al.*, 1994a for a more comprehensive evaluation) that adopt an hierarchy of micro-, meso- and macro-levels of economic analysis. The feedback loop analysis offers the potential for insights into some of the issues that have been raised by Krugman (1991, 1993) in the debate on regionalism versus multilateralism. It is felt that this perspective will help inform on the nature of economic structure and, most critically, on the ways in which the transmission of structural change penetrates the complex web of interactions that characterize an economy.

The paper is organized as follows; in the next section, a brief review of feedback loop analysis will be provided. The major empirical evaluation will occur in the next section; the analysis will be presented at a very high level of aggregation essentially, one-sector analysis, to enable an appreciation of the major loops in trade interactions. The paper will conclude with an evaluation and interpretation of the findings.

2. Closed Feedback Loops

Consider a system of *n* region and *m* sectors; assume that the transactions between the regions can be presented by an *nm x nm* block matrix *X*, of transactions flows:

$$X = \begin{bmatrix} X_{11} & X_{12} & \cdots & X_{1n} \\ X_{21} & X_{22} & \cdots & X_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ X_{n1} & X_{n2} & \cdots & X_{nn} \end{bmatrix} \quad (1)$$

where each block

$$X_{rs} = \left\| x_{ij}^{rs} \right\| \quad (2)$$

represents the transactions flows from sectors in region *r* to those in region *s*. Define:

$$t_{rs} = \sum_{ij} x_{ij}^{rs} \quad (3)$$

namely, the sum of flows between all sectors within each submatrix, X_{rs}. Hence, an aggregated *nxn* matrix may be defined as:

$$T = \left\| t_{rs} \right\| \quad (4)$$

The major focus of this paper will be the identification of multi-regional feedback loops that reveal the economic self-influence of each region. This self-influence can be represented by a chain of transactions in which the flows leave a region and "journey" through the rest of the regions before returning to the origin. A series of aggregate transactions are specified such that each region is allowed precisely one transaction flow entering it and one flow leaving it. Economically, a series of transactions, of course, represents a chain of bilateral influences which are based on either backward of forward linkages depending on the point of view one takes.

Such a series of transactions, in which each region appears only once with one incoming flow and one outgoing flow, may indeed be called a feedback loop because each and every region in such a loop influences itself at the end of the loop (assuming one starts the loop with the region at hand). A feedback loop is complete if it includes all regions.

The economic interpretation of a feedback loop is straightforward. It indicates how strongly (at each hierarchical level) each region is tied to all other regions included in that loop. By focusing on complete loops, one can evaluate the place and position of each and every region *vis à vis* **all** other regions. Considering only complete feedback loops is technically possible as each non-complete feedback loop can be extended to a complete one through the addition of loops that include the regions outside the non-complete loop. Moreover, a hierarchical analysis of the set of all complete loops is simpler than a hierarchical analysis of the set of all possible loops. For a set of n regions the amount of all complete feedback loops is already equal to $n!$ A complete feedback loop is either closed or can be decomposed into a set of closed subloops. If the entering flow and the leaving flow for the same region are identical, the smallest closed sub-loop possible has been identified, i.e. the influence that a region directly exerts on itself, the domestic self-influence.

In the case of two regions, with the transactions matrix:

$$X = \left[\begin{array}{c|c} X_{11} & X_{12} \\ \hline X_{21} & X_{22} \end{array}\right] \tag{5}$$

the *aggregated transactions* matrix:

$$T = \begin{bmatrix} t_{11} & t_{12} \\ t_{21} & t_{22} \end{bmatrix} \tag{6}$$

includes only two feedback loops:

$$T_1 = \begin{bmatrix} t_{11} & 0 \\ 0 & t_{22} \end{bmatrix}, \quad T_2 = \begin{bmatrix} 0 & t_{12} \\ t_{21} & 0 \end{bmatrix} \tag{7}$$

This provides the basis for the following decompositions of X and T into a sum of its feedback loops:

$$T = \begin{bmatrix} t_{11} & t_{12} \\ t_{21} & t_{22} \end{bmatrix} = \begin{bmatrix} t_{11} & 0 \\ 0 & t_{22} \end{bmatrix} + \begin{bmatrix} 0 & t_{12} \\ t_{21} & 0 \end{bmatrix} = T_1 + T_2 \tag{8}$$

and

$$X = \left[\begin{array}{c|c} X_{11} & X_{12} \\ \hline X_{21} & X_{22} \end{array}\right] = \left[\begin{array}{c|c} X_{11} & 0 \\ \hline 0 & X_{22} \end{array}\right] + \left[\begin{array}{c|c} 0 & X_{12} \\ \hline X_{21} & 0 \end{array}\right] = X_1 + X_2 \tag{9}$$

With a three-region system:

$$X = \left[\begin{array}{c|c|c} X_{11} & X_{12} & X_{13} \\ \hline X_{21} & X_{22} & X_{23} \\ \hline X_{31} & X_{32} & X_{33} \end{array}\right] \quad T = \begin{bmatrix} t_{11} & t_{12} & t_{13} \\ t_{21} & t_{22} & t_{23} \\ t_{31} & t_{32} & t_{33} \end{bmatrix} \tag{10}$$

there are six feedback loops:

$$T_1 = \begin{bmatrix} t_{11} & 0 & 0 \\ 0 & t_{22} & 0 \\ 0 & 0 & t_{33} \end{bmatrix} \; T_2 = \begin{bmatrix} 0 & 0 & t_{13} \\ t_{21} & 0 & 0 \\ 0 & t_{32} & 0 \end{bmatrix} \; T_3 = \begin{bmatrix} 0 & t_{12} & 0 \\ 0 & 0 & t_{23} \\ t_{31} & 0 & 0 \end{bmatrix}$$

$$T_4 = \begin{bmatrix} t_{11} & 0 & 0 \\ 0 & 0 & t_{13} \\ 0 & t_{32} & 0 \end{bmatrix} \; T_5 = \begin{bmatrix} 0 & t_{12} & 0 \\ t_{21} & 0 & 0 \\ 0 & 0 & t_{33} \end{bmatrix} \; T_6 = \begin{bmatrix} 0 & 0 & t_{13} \\ 0 & t_{22} & 0 \\ t_{31} & 0 & 0 \end{bmatrix} \tag{11}$$

A similar structure would characterize the decompositions of X. A more complete interpretation of the notion of self-influence may be provided by considering the matrix, T_2, presented in stylized form with unit entries replacing the non-zero components. Thus, the following permutation matrix may be developed:

$$P_2 = \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \tag{12}$$

This matrix implies the following chain, with the first region sending to the third, the third to the second and the second back to the first.

$$\begin{array}{ccccc} r_1 & & \rightarrow & & r_3 \\ \nwarrow & & & & \swarrow \\ & \leftarrow & r_2 & \leftarrow & \end{array} \tag{13}$$

This scheme provides a translation or permutation of the series (1, 2, 3) into (3, 1, 2) and so on until the original series is replaced. This is shown in (14) below:

$$\begin{array}{ccc} 1 & 2 & 3 \\ \downarrow & \downarrow & \downarrow \\ 3 & 1 & 2 \\ \downarrow & \downarrow & \downarrow \\ 2 & 3 & 1 \\ \downarrow & \downarrow & \downarrow \\ 1 & 2 & 3 \end{array} \tag{14}$$

This also implies that:

$$P_2^3 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \tag{15}$$

and:

$$T_2^3 = \begin{bmatrix} t_{13}t_{32}t_{21} & 0 & 0 \\ 0 & t_{21}t_{13}t_{32} & 0 \\ 0 & 0 & t_{32}t_{21}t_{13} \end{bmatrix} \tag{16}$$

are diagonal matrices, where the products $t_{13}t_{32}t_{21}$, $t_{21}t_{13}t_{32}$ and $t_{32}t_{21}t_{13}$ are the indices from the first, second and third columns of (14).

For the case of *n* regions, the situation is more complicated. It is possible to prove that for *n* regions, the number of decompositions is equal to:

$$N = (n-1)!(n-2)!\ldots 3!2! \tag{17}$$

One natural method for dealing with such a large amount of complete feedback loops is of course the derivation of some hierarchical structure. Essentially, the proposed Hierarchical Feedback Loop Approach attempts to extract complete feedback loops that successively account for the most "explanation" in each stage of the selection process.

The procedure continues until all transaction flows have been included. It is important to note that the matrix form of a complete feedback loop can be presented with the help of a submatrix T_X of flows extracted from the matrix $T = \|t_{ij}\|$ of all aggregated transaction flows. Such a submatrix T_X 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 zeros elsewhere. One can define the *flow intensity* of a complete feedback loop as the sum of all transaction flows of the corresponding submatrix T_x.

Further, if all non-zero entries of T_x are replaced by units, a so-called *permutation matrix* P_x is obtained. This zero-one matrix corresponds to some permutation of the sequence of numbers 1,2,...,n. Such a permutation (of regions) represents the structure of the corresponding complete feedback loop. The submatrices T_x are referred to as *quasi-permutation matrices*.

It is important to note that for each permutation matrix P_x there is an integer k such that P^k is the unit matrix I. For that k, the corresponding quasi-permutation matrix T_x has the property that T_x^k is a diagonal matrix, implying that the corresponding feedback loop indeed represents the notion of *self-influence*.

The hierarchy of all complete feedback loops is defined as the sequence of quasi-permutation submatrices T_x 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 submatrix 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.

The procedure can be summarized formally in the following steps:[5]

Step 1: For the matrix $T = \left\| t_{ij} \right\|$ of all aggregate transactions flows, find an optimal solution of the Linear Programming Personnel Assignment problem, the solution of which is equivalent to the

[5] The section draws on Sonis, Oosterhaven and Hewings (1993)

standard transportation problem of linear programming. The solution determines the quasi-permutation submatrix T_1 and the corresponding permutation matrix P_1 associated with the complete feedback loop with maximal flow intensity. This loop stands on top of the hierarchy[6].

Step 2: Replace in T the flows from T_1 by arbitrary large (in absolute terms) negative numbers, -M, and find for this new matrix $T^{/}$ an optimal solution of corresponding Personnel Assignment problem. This solution gives the next complete feedback loop, represented by the corresponding quasi-permutation sub-matrix T_2, the permutation matrix P_2, and the corresponding permutation sequence of regions.

Step 3 through n-1. Repeat the Step 2 for the matrix $T^{/}$.

After *n-1* steps, one obtains a sequence of *n* complete feedback loops, ordered according to the decreasing size of their flow intensities. Moreover, this hierarchical sequence corresponds to the sequence of quasi-permutation submatrices with the property:

$$T = T_1 + T_2 + \ldots + T_n \tag{18}$$

3. The Nested Hierarchy of Feedback Loops Interpreted by the Matrioshka Principle

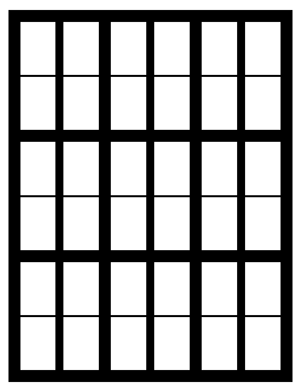
It is necessary and possible to combine the interregional and intersectoral interdependencies. To this aim, the aggregated table needs to be replaced by the detailed table describing the interplay between the intersectoral and inter-country interdependencies. It is important to stress that the flexible form of the spatio-economic feedback loop analysis employed in this paper allows an easy extension to the spatio-sectoral level. In such an extension, the analysis will relate to sectors per country. Thus, the hierarchy of the feedback loops will reflect the intersectoral

[6] The procedure in Step 1 has a simple economic meaning. It is possible to replace it by other procedures with more convoluted economic interpretations. For example, instead of the maximization of the total flow, one can demand the choice of the submatrix T_1 corresponding to $\max\min t_{ij}$, which means that one aims to select feedback loops whose weakest chain is as strong as possible.

interdependencies intertwined spatially, enabling one to distinguish the spatial extent of multi-country industrial complexes. The procedure operates as successive levels on the system, but the approach at each stage is similar. This 'top-down' decomposition may be considered analogously to the exfoliation process in the removal of layers of an onion or, more appropriately, to the construction of 'Matrioshka' dolls in which successively smaller dolls of exactly the same shape and style are nested within the larger dolls. Hence, the *Matrioshka* approach examines the intra- and inter-regional transactions in terms of the hierarchical structure of feedback effects.

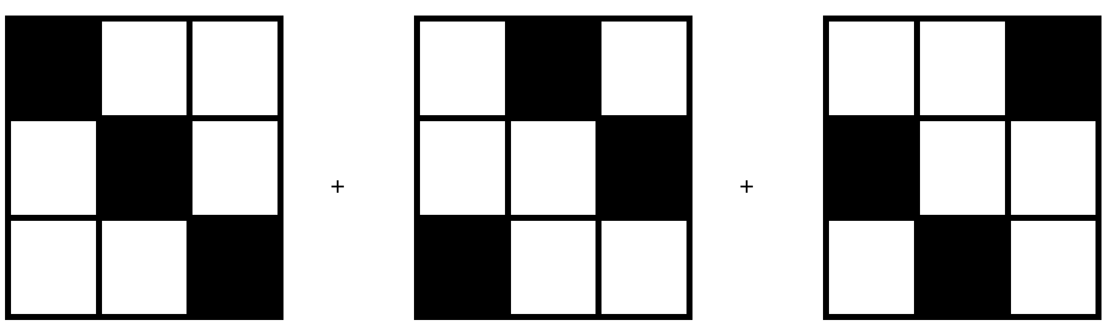
Consider, as an example, the three-country/two-sector input-output table of the following form:

$X =$

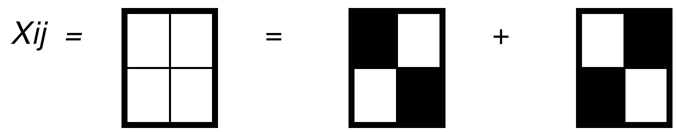


At the country spatial scale (i.e., where interest is merely focused on the aggregate flows rather than the intersectoral flows), the following hierarchical feedback loop structure can be identified:

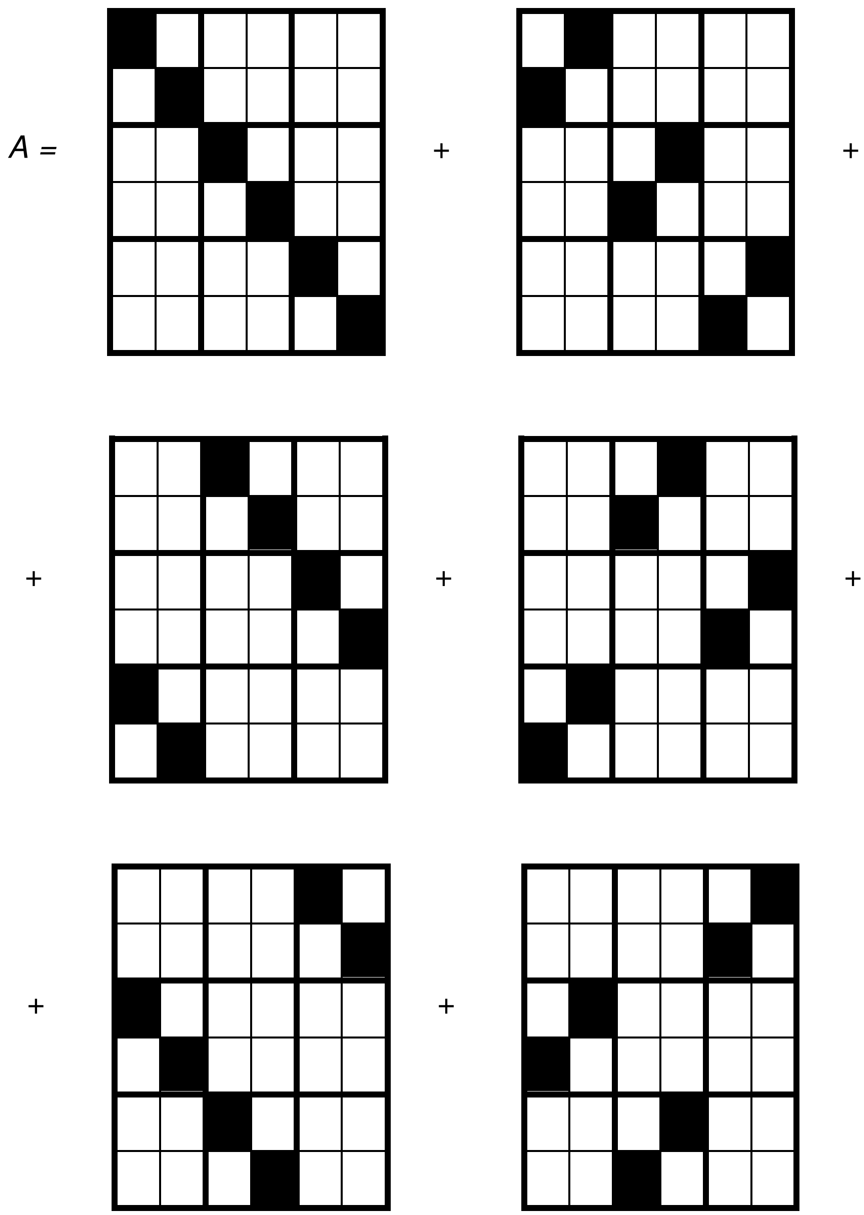
$X =$



At the sectoral level, the simple decomposition holds:



Therefore, the following nested hierarchical decomposition satisfies the rules of the Matrioshka principle:



4. The Asian International Input-output Tables, 1985

The data used in this analysis were derived from a set of international input-output tables prepared by the Institute of Developing Economies (1992). The tables provide information not only on intra-country flows but flows between ten countries. These flows are sector specific, in that the flow is shown from a sector in one country to a sector in another country. All data are reported in the producers' prices of the the producing country; these prices were then converted to US dollars.[7] Since the tables were expressly constructed as key tools in the analysis of interdependency, the use to which they are being put in this paper is appropriate. In the next section, some of the major findings at the one-sector and three-sector levels of aggregation will be reported.

5. Feedback Loop Analysis of Asia Trade, 1985

At the first level of analysis, all transactions were aggregated into one sector to reveal the macro-level structure of the feedback loops. Table 1 shows the structure of the flows; the dominance of the intra-country flows is readily apparent. However, without a detailed inspection of the table, it would be difficult to understand the dominant inter-country linkages. This is done in Table 2. Note that the inter-country transactions account for only 2.6% of total transactions, although for some countries, the percentages are often much higher.

Table 1

The Asian Input-Output Table, 1985

	INDON	MALAY	PHIL	SING	THAIL	CHINA	TAIWAN	KOREA	JAPAN	USA	
	1	2	3	4	5	6	7	8	9	10	Total
1	52721.32	101.81	113.46	961.35	47.27	291.77	361.81	745.74	9369.14	4095.40	68809.07
2	42.61	20620.17	232.44	1766.99	470.93	144.54	377.57	1045.64	3678.82	1571.58	29951.29
3	17.76	90.13	21661.10	88.14	31.00	73.21	81.50	90.77	836.66	1102.05	24072.32
4	568.63	1457.12	42.17	13935.74	480.93	116.18	210.70	195.75	1332.69	1632.97	19972.88

7 For more detail on the table construction, see Institute of Developing Economies (1992).

5	38.64	254.94	29.56	158.42	30105.53	198.72	83.38	130.43	834.10	705.58	32539.30
6	172.60	171.85	225.61	1639.63	155.56	319404.30	0.00	0.00	5316.12	1589.44	328675.11
7	205.41	187.59	96.52	370.53	172.71	492.42	67603.18	304.79	1980.48	5521.56	76935.19
8	160.08	178.85	113.52	175.75	128.90	0.00	106.92	94001.03	2646.29	3612.79	101124.13
9	1813.39	1756.96	286.40	1582.11	1106.24	6028.28	3546.14	5116.59	1313103.41	22540.20	1356879.72
10	1138.35	821.02	690.08	1323.42	459.37	2266.39	3159.66	4551.10	18404.88	3196351.30	3229165.57
T	56878.79	25640.44	23490.86	22002.08	33158.44	329015.81	75530.86	106181.84	1357502.59	3238722.87	5268124.58

Source: Institute of Developing Economies (1992).

Nine feedback loops are presented in Table 2; these are arranged hierarchically to enable an appreciation of their dominance in the trading system. Not suprisingly, the Japan-USA sub-loop dominates accounting for over 88% of the first feedback loop. This total feedback loop accounts for one-third of the inter-country transactions. The second most important loop involves Japan and China (53.9%) and Taiwan and the USA (35.3%) together with the remaining countries. Taken together, the first two feedback loops account for over 53% of the inter-country transactions. Thereafter, a slow decline in the importance of the transactions may be observed with the dominant position of Japan revealed very clearly. In the fourth feedback loop, there are two interesting subloops, one centered on Japan and one centered on the USA.

Table 2

Decomposition of One-Sector Transactions Flows into Feedback Loops

Domestic Transactions 97.30%	Inter-country Transactions 2.60%	% of inter-country transactions	Cumulative %
	I (JAP USA) (CHI SIN MAL KOR IND TAI) (PHI THA)	33.3	33.3
	II (JAP CHI PHI TAI USA KOR THA MAL SIN IND)	20.6	53.9
	III (JAP KOR MAL PHI IND USA TAI SIN THA CHI)	13.8	67.7
	IV (JAP TAI PHI MAL) (USA CHI THA IND SIN KOR)	10.5	78.2
	V (JAP MAL THA TAI KOR) (USA SIN) (CHI IND PHI)	6.2	84.4
	VI (JAP IND THA SIN CHI USA MAL TAI) (KOR PHI)	5.1	89.5

	VII (JAP SIN PHI) (USA IND CHI MAL) (KOR TAI THA)	4.3	93.8
	VIII (JAP THA USA PHI SIN) (CHI TAI MAL IND KOR)	3.5	97.3
	IX (JAP PHI USA THA) (CHI KOR SIN TAI IND MAL)	2.7	100

Table 3

Hierarchical Decomposition of the First Aggregate Feedback Loop

From Table 2 into 3 Sectoral/Inter-country Feedback Loops

(JAP USA):

1. $(M_{JAP} S_{USA} S_{JAP} P_{USA})(P_{JAP} M_{USA})$ (54.8%)
   (99.1%) (0.9%)
2. $(P_{JAP} P_{USA} S_{JAP} S_{USA})(M_{JAP} M_{USA})$ (36.9%)
   (99.2%) (0.8%)
3. $(P_{JAP} S_{USA} M_{JAP} P_{USA})(S_{JAP} M_{USA})$ (8.3%)
   (65.9%) (34.1%)

(CHI SIN MAL KOR IND TAI):

1. $\left\{ (M_{CHI} M_{SIN} M_{MAL} M_{KOR} M_{IND} M_{TAI}) \; (P_{CHI} P_{SIN} P_{MAL} S_{KOR} P_{IND} S_{TAI} S_{CHI} S_{SIN} S_{MAL} P_{KOR} S_{IND} P_{TAI}) \right\}$ (72.5%)
   (92.3%) / (7.7%)
2. $\left\{ (P_{CHI} S_{SIN} P_{MAL} P_{KOR} P_{IND} P_{TAI} S_{CHI} M_{SIN} S_{MAL} M_{KOR} S_{IND} M_{TAI}) \; (M_{CHI} P_{SIN} M_{MAL} S_{KOR} M_{IND} S_{TAI}) \right\}$ (22.0%)
   (95.6%) / (5.4%)
3. $(P_{CHI} M_{SIN} M_{MAL} P_{KOR} M_{IND} P_{TAI} M_{CHI} S_{SIN} P_{MAL} M_{KOR} P_{IND} M_{TAI} S_{CHI} P_{SIN} S_{MAL} S_{KOR} S_{IND} S_{TAI})$ (5.5%)

(PHI THA):

1. $(M_{PHI} P_{THA})(P_{PHI} S_{THA} S_{PHI} M_{THA})$ (44.3%)
   (85.2%) (36.4%)
2. $(P_{PHI} M_{THA} M_{PHI} S_{THA})(S_{PHI} P_{THA})$ (36.0%)
   (63.6%) (36.4%)
3. $(M_{PHI} M_{THA} S_{PHI} S_{THA})(P_{PHI} P_{THA})$ (19.7%)
   (99.9%) (0.1%)

However, an inspection of the loops in Table 3 does not lead to a straightforward appreciation of the nature of the feedbcak loops that have been identified. Attention is now drwan to a set of five figures that present these feedback loops graphically. Figure 1 shows the decompsoition of the aggregate-level feedback loops; the spatial nature of the loop is readily apparent. Note also that the sub-loops are rather simple. Figure 2 prsents the second and third loops; the pattern of interaction is now decidedly more complex with the loops involving a larger number of the individual countries.

Figure 1

Decomposition of the First Inter-Country Feedback Loop

into Partial Feedback Loops

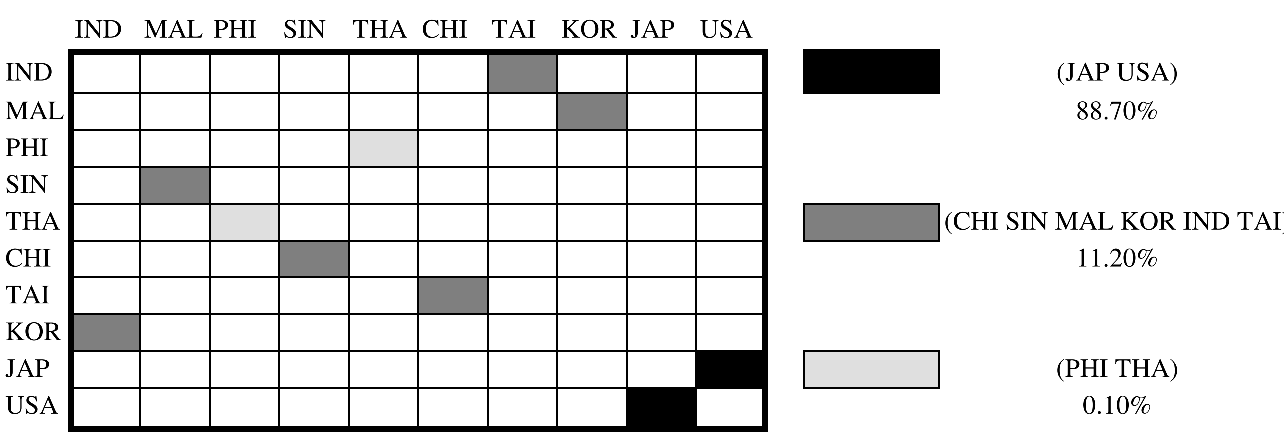
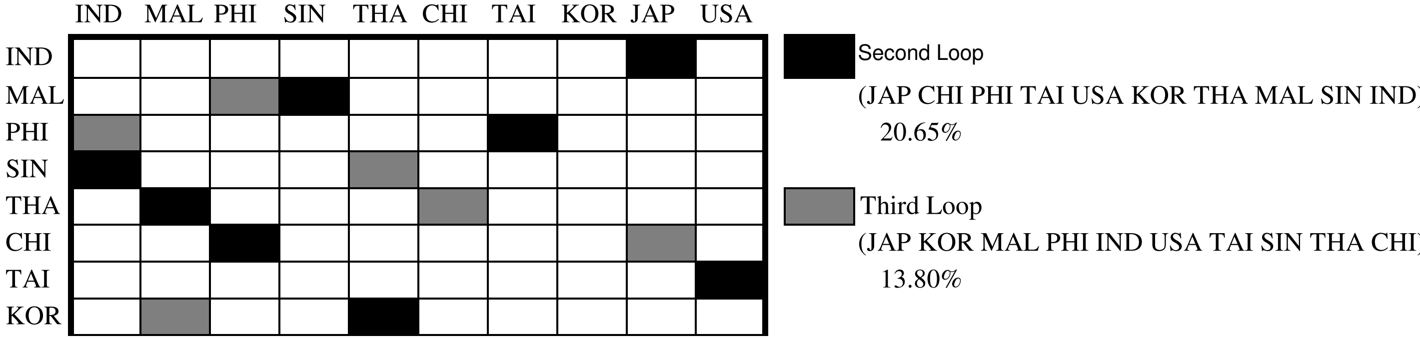
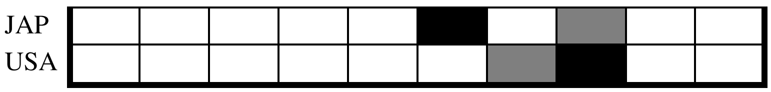


Figure 2

Second and Third Inter-Country Feedback Loops





When attention is directed to the more detailed sectoral analysis, the need for graphical interpretation becomes even more pressing. Figure 3 shows the first inter/intrasectoral transactions loop that is nested within the aggregate loop shown in Figure 1. The dyadic nature of the Japan-USA exchange is in sharp contrast to the nature of the second sub-loop that involves China, Singapore, Malaysia, Korea, Indonesia and Taiwan. The third sub-loop involves exchange between the Philippines and Thailand; this exchange accounts for a very small (0.1%) of the transactions accounted for by this whole feedback loop.

An examination of the sectoral interactions revals different patterns for each subloop. In the case of the Japan-USA exchange, all sectors are involved with the exception of manufacturing in the USA for the first of the transaction sets. When this sector does become involved, it accounts for a very small percentage of the flows. In contracts, over 92% of the second subloop flows between the remaining countries inolves linkages between the manufacturing sectors; the other smaller subloop charts a more complex pattern of sectoral and country interdepndency but it is encompasses a relatively small set of flows. The exchanges between the Philippines and Thailand provides a pattern that is not dissimilar to the one exhibited for Japan-USA.

The second of the major subloops is shown in Figure 4. The compelxity of the transactions begins to assert itself with rather extensive loops embracing in types of sectors in the China-Singapore-Malaysia-Korea-Indonesia-Taiwan loop. This pattern is reinforced in Figure 5 where the third of the major subloops is portrayed. In this case, the loop involves all sectors in all of the six countries. However, it accounts for only 5.5% of this whole loop which itself only 11% of the interregional flows.

6. Evaluation

One of the major problems with an evaluation of international trade has been the ability to probe into the nature and strength of the interdependencies so revealed. Feedback loop analysis is offered as one technique that may be able to highlight these complex patterns of flows by focusing on the nature of the path of dependencies. How can this analysis be linked with some of the recent debates that have centered on some findings, admitedly promulgated under rather severe assumptions, by Krugman? In making some preliminary evaluation, attention will also be drwan to some earlier findings reported for Europe by Sonis *et al*. (1993b). In the European case, over 90% of the flows were accounted for by intra-country transactions in 1980; in contrast, the case presented here revealed that this category accounted for close to 97% of the flows. In the European case, it was noted that domestic transactions had, in fact, decreased over time, while inter-country flows had increased. What was not clear was the degree to which this represented trade creation rather than trade diversion (see Krugman, 1991). In the Asian case, use of the earlier (1980) tables has not been completed so that an answer to this question will have to await further study.

In the European application, the first major subloop accounted for 40% of the overall intercountry flows; in Asia, the first subloop accounted for 33%. However, with the emergence of the expanded European Union, the dominance of a core (German, France, the Netherlands and Belgium) began to dissolve over the period 1970 through 1980. The dominant position of Japan-USA trade in the first subloop (88% of the flows) raises the question as to whether this hegemonic position will be eroded over time. Here is where Krugman's ideas become important; in his analysis, it is assumed, initially, that each country operates in a noncollusive manner in order to maximize welfare. Given his findings that overall welfare decreases to a pessimum when the number of world trading blocs is three, thereafter to rise again, how can the results of the feedback loop analysis be incoporated in further consideration of this finding? While Japan's trade with the USA has captured a great deal of attention, Japan also plays an important role in the other feedback loops (see Table 2).

REFERENCES

Baer, W., M.A.R. Fonseca, J.J.M. Guilhoto (1987). "Structural Changes in Brazil's Industrial Economy, 1960-80," *World Development*. 14:275-286.

Bullard, C.W. and A.R. Sebald (1977). "The Effects of Parametric Uncertainty and Technological Change on Input-Output Models," *Review of Economics and Statistics*, 59:75-81

Bullard, C.W. and A.R. Sebald (1988). "Monte Carlo Sensitivity Analysis of Input-Output Models," *Review of Economics and Statistics*, 70:705-712

Cella, G. (1984). "The Input-Output Measurement of Interindustry Linkages," *Oxford Bulletin of Economics and Statistics*. 46:73-84.

Clements, B.J. (1990). "On the Decomposition and Normalization of Interindustry Linkages," *Economics Letters*, 33:337-340.

Clements, B.J. and J.W. Rossi (1991). "Interindustry Linkages and Economic Development: The Case of Brazil Reconsidered," *The Developing Economies*, 29:166-187.

Clements, B.J. and J.W. Rossi (1992). "Ligações Interindustriais e Setores-Chave na Economia Brasileira," *Pesquisa e Planejamento Econômico*. 22:101-124.

Diamond, (1976). "Key sectors in some underdeveloped countries: a comment," *Kyklos* 4:672-74

Evans, W.D. (1954) "The Effects of Structural Matrix Errors on Interindustry Relations Estimates," *Econometrica* 22:461-480

Fonseca, M.A.R. and J.J.M. Guilhoto (1987). "Uma Análise dos Efeitos Econômicos de Estratégias Setoriais." *Revista Brasileiro de Econometrica* 1:293-310

Guilhoto, J.J.M. (1992). "Mudanças Estruturais e Setores Chaves na Economia Brasileira, 1960 - 1990," *Anais do XIV Encontro Brasileiro de Econometria* 1:293-310.

Guilhoto, J.J.M. (1994) “Using input-output to measure interindustry linkages: a new perspective,” *Discussion Paper* 94-P-2, Regional Economics Applications Laboratory, University of Illinois, Urbana.

Guccione, A. (1986) "The Input-Output Measurement of Interindustry Linkages: A Comment," *Oxford Bulletin of Economics and Statistics*, 48:373-377

Hewings, G.J.D. (1982) "The Empirical Identification of Key Sectors in an Economy: A Regional Perspective" *The Developing Economies*, 20:173-195

Hewings, G.J.D., M. Fonseca, J.J.M. Guilhoto, M. Sonis (1989). "Key Sectors and Structural Change in the Brazilian Economy: A Comparison of Alternative Approaches and Their Policy Implications," *Journal of Policy Modeling*, 11:67-90.

Hirschman, A.O. (1958). *The Strategy of Economic Development*. New Haven: Yale University Press.

IBGE (1979). *Matriz de Relações Intersetoriais Brasil - 1970*. Versão Final. Rio de Janeiro: IBGE.

IBGE (1987). *Matriz de Relações Intersetoriais Brasil - 1975*. Rio de Janeiro: IBGE.

IBGE (1989). *Matriz de Insumo-Produto Brasil - 1980*. Série Relatórios Metodológicos. Vol. 7. Rio de Janeiro: IBGE.

Krugman, P. (1991) "Is bilateralism bad," in E. Helpman and A. Razin (eds.) *International Trade and Trade Policy*. Cambridge, MIT Press, pp. 9-23.

Krugman, P. (1993) "Regionalism versus multilaterialism: analytical notes," in J. De melo and A. Panagariya (eds.) *New Dimensions in Regional Integration*. Cambridge, University Press, pp. 58-79.

McGilvray, J. (1977) Linkages, Key sectors and Development Strategy. In W. Leontief (ed.) *Structure, System and Economic Policy*. Cambridge, University Press, pp. 49-56.

Park, S. (1974). "On Input-Output Multipliers with Errors in Input-Output Coefficients." *Journal of Economic Theory* 6:399-403.

Rasmussen, P. (1956). *Studies in Intersectoral Relations*. Amsterdam: North Holland.

Rijckeghem, W. (1969). An Intersectoral Consistency Model for Economic Planning in Brazil. In Ellis, H.S. (ed.) (1969). *The Economy of Brazil*. Berkeley and Los Angeles: University of California Press.

Sherman, J. and W. Morrison (1949). "Adjustment of an Inverse Matrix to Changes in the Elements of a Given Column or a Given Row in the Original Matrix." *Annals of Mathematical Statistics*, 20:621

Sherman, J. and W. Morrison (1950). "Adjustment of an Inverse Matrix Corresponding to a Change in One Element of a Given Matrix." *Annals of Mathematical Statistics*, 21:124-127

Simonovits, A. (1975). "A Note on the Underestimation and Overestimation of the Leontief Inverse." *Econometrica*, 43:493-498

Sonis, M. and G.J.D. Hewings (1989). "Error and Sensitivity Input-Output Analysis: a New Approach." In R.E. Miller, K.R. Polenske and A.Z. Rose (eds.) *Frontiers of Input-Output Analysis*. New York, Oxford University Press.

Sonis, M. and G.J.D. Hewings (1993). "Hierarchies of Regional Sub-Structures and Their Multipliers Within Input-Output Systems: Miyazawa Revisited," *Hitotsubashi Journal of Economics*. 34:33-44.

Sonis, M., G.J.D. Hewings and J. Guo (1993a) "Sources of Structural Change in Input-Output Systems: a Field of Influence Approach," *Discussion Paper 93-T-12* Regional Economics Applications Laboratory, University of Illinois, Urbana.

Sonis, M., J. Oosterhaven and G.J.D. Hewings (1993b) “Spatial economic structure and structural changes in the EC: Feedback loop input-output analysis,” *Economic Systems Research* 5:173-184

Sonis, M., G.J.D. Hewings and J.K. Lee (1994a). "Spatial economic structure and spatial multipliers: three perspectives," *Geographical Analysis* 26:124-151

Sonis, M., J.J.M. Guilhoto, G.J.D. Hewings and E.B. Martins, (1994b) “Linkages, key sectors and structural change: some new perspectives,” *Discussion Paper* 94-P-1, Regional Economics Applications Laboratory, Urbana, Illinois.

Sonis, M., J.J.M. Guilhoto and G.J.D. Hewings (1994c) “The Asian economy: linkages, key sectors and feedbacks,” *Discussion Paper* 94-P-2, Regional Economics Applications Laboratory, Urbana, Illinois.

Sonis, M. and G.J.D. Hewings (1994) *Fields of Influence in Input-Output Systems*, unpublished manuscript, Regional Economics Applications Laboratory, Urbana, Illinois

Van der Linden, J., J. Oosterhaven, F. Cuello, G.J.D. Hewings and M. Sonis. (1993) "Fields of Influence of Technological Change in EC Intercountry Input-Output Tables 1970-1980" *Working Paper 93-T-13* Regional Economics Applications Laboratory, University of Illinois, Urbana.