FEEDBACK LOOPS ANALYSIS OF JAPANESE INTERREGIONAL TRADE: 1980-85-90

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Feedback Loops Analysis of Japanese Interregional Trade, 1980-85-90.[1]

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Abstract. This paper examines the hierarchy of intra- and inter-regional trade flows within the Japanese economy over the period 1980-85-90. The methodology provides an opportunity to explore links between feedback loops analysis and the extraction of an hierarchy of flows using ideas from superposition principles. The resulting analysis of trade feedbacks may be seen to reflect the economic phenomena of horizontal and vertical trade specifications. While the process is explored analytically, the results are presented using visualization to help identify the different permutation matrices presenting the hierarchy of trade feedback loops.

1. Introduction

The rediscovery of the conceptual duality (first articulated by Isard in 1959) in the relationship between trade/transportation and location by trade theorists has generated a need for analytical tools that can embrace traditional trade perspectives with those directed to an understanding of spatial structure. Since developing and regional economies share a common characteristic, namely their dependence on trade, several complementary approaches have been proposed to address issues surrounding the impacts generated by external trade. One approach, exploring feedback effects, draws on the Mezlerian matrix (see Haddad *et al*., 1999 for an exposition and recent application) to examine relationships between countries in terms of trade dependence. A similar approach conisdered the role that these feedback effects might have in further enhancing the growth stimuli provided by exports (see Sonis and Hewings, 2001 for a review). In these applications, the main focus of attention has been centered on the *magnitude* of feedback effects. A complementary approach, that forms the focus of the present paper, examines the role of feedbacks through the introduction of two additional notions - feedback loops and interregional hierarchies. To place this issue in the current perspective, it has been shown (Hitomi *et al*.,

[1] The comments of Jacques Thisse on an earlier draft are gratefully appreciated.

2001) that interregional trade is playing an increasing role in generating growth in the regional economies of Japan; feedback loop analysis offers additional information by presenting the paths of interaction between two regions. As such, it complements rather than replaces more traditional multiplier-based interpretations of the importance of trade.

This paper presents a further elaboration of trade feedback loop analysis, a method that had been employed in several trade-related papers at the international and regional spatial scales (see Sonis *at al.* 1993, 1995a,b, 1997). In this paper, attention will be directed to inter-regional and intra-regional flows within the Japanese economy; trade feedbacks are promoted on the basis of their representing the spatial and functional rank-size hierarchy of intra- and inter-regional trade flows and, as such, contribute towards the understanding of the global process of regionalization at the world economy spatial scale (*cf.* Frankel, 1998). However, the structure of trade flows appears – interpreted both analytically and visually – to have commanded scant attention in the literature and yet considerable attention has been directed towards issues of bilateral and multilateral trade and their role in the emergence, evolution and sustainability of inter-regional trade blocks at the level of nation states. Following the discussion in Frankel *et al.* (1998), it is clamed that the rank-size network hierarchy of feedback loops may be taken to present the existence of natural and supernatural (using Frankel's terminology) trade blocks. In particular, this interpretation would imply that within the evolution of this rank-size hierarchy, monitoring the spatial temporal and structurally stable parts of the trade system would provide important insights into development of the system of trade blocks. Further, the approach complements a parallel analyses that explored the role of interregional trade in changing the structure of the Japanese regional economies and the phenomenon of hollowing out that seems to be characterizing many regional economies (see Hitomir *et al*, 2001; Hewings, *et al*., 1998)

In the next section of the paper, the ideas of feedback loops analysis will be introduced and linked to phenomena of horizontal and vertical specializations within intra- and inter-regional trade; this integration will be presented within the context of a need to explore the structure of trade in new ways. Section 3 will describe the multi-regional feedback loop approach based on the Koopmans-Beckman (1957) assignment problem algorithm; sections 4 and 5 will examine

the structure of Japanese intra- and inter-regional trade for the period 1980-85-90, focusing on both horizontal and vertical specializations. The paper concludes with some further reflections on the emerging challenges for trade theory.

2. Feedback loops, hierarchies and trade: initial explorations

In this paper, the aggregation/disaggregation view on the intra- and inter-regional trade flow is presented so that the interregional feedback loops of intermediate input flows are decomposed into feedback loops of intermediate input flows between economic activities and then further decomposed into the loops of flows at the scale of individual industries. The aggregation/disaggregation scaling of trade flows is generated by the hierarchy of economic subsystems in the form of so-called *Matrioshka* principle (*cf.* Sonis and Hewings, 1990).[2]

The justification for considering a set of feedback loops of interregional trade flows is based on an important phenomenon of vertical specialization that describes the use of imported inputs for producing goods that are exported (see, Bruelhart and Hine, 1999). While Balassa (1967, p.97) coined the term of vertical specialization, subsequent work, such as Hummels *et al*, (1998), has proposed alternative definitions of vertical specialization: "(1) a good must be produced in multiple sequential stages, (2) two or more countries must specialize in producing some, but not all, stages, and (3) at least one stage must cross an international border more then once... Thus, countries link sequentially to produce a final good." Table 1 provides a summary interpretation of the distinction between vertical specialization and feedback loop analysis; essentially, the latter provides a more complete picture of the structure of flows, although there would be nothing to exclude a feedback interpretation applied to vertical specialization. One of the most important distinctions lies in the hierarchical extraction process of the flows, thus providing some sense of the ordering of the structure of spatial interaction.

<insert table 1 here>

There are two important economic reasons for choosing to analyze trade structure using feedback loop analysis. First, most analytical work on trade has focused on the explanation of flows, with

[2] Matrioshka dolls are constructed so that identical dolls of decreasing size fit one inside the other.

little attention being devoted to the *spatial geographic structure* of these flows. For example, issues of concentration of flows and the role of localization of particular industries have been shown by Krugman (1991, 1993) to be of considerable importance. For example, Krugman (1993) notes that: " ... international specialization and trade cannot be explained simply by an appeal to comparative advantage, that is, loosely speaking, by countries trading in order to take advantage of their differences." However, while Frankel (1998) correctly asserts that "…many of the most interesting aspects of regional trading arrangements require the introduction of a geographic dimension," the exact manner in which this spatial dimension is introduced is as critical as the acknowledgement of its importance. In addition, the method employed by Hummels *et al*. (1998) to measure vertical integration only captures part of the trade relationship since they only consider the perspective of an individual economy (country or region) whereas feedback loop analysis extends the notion to include the economy and its connections to all other economies. Hence, feedback loop analysis may be seen as a broader, system-wide approach to notions of vertical and horizontal specialization.

While Krugman's ideas have been developed explicitly in the context of trading relationships between economies at one spatial level, there is every reason to suggest that many of the same forces that condition international trade relationships will also influence those between regions within a country. What has yet to be explored is the identification of a spatial hierarchy of trade flows and it is here that feedback loop analysis provides the potential for uncovering the nature, strength and spatial linkages of trade flows. While this paper will explore the hierarchy of trade flows at only one spatial level (between regions within a country), it will also examine the hierarchy of economic activities and their sub-divisions at this one spatial scale. Obviously, it would be possible to extend the hierarchy in both directions – to the international scale and to the level of sub-regions

The second reason is that empirical models of trade tend to be either very macro in nature (such as computable general equilibrium models) or they operate at a very micro, sector-by-sector level. Feedback loop analysis is offered as a more meso-level approach; in essence, it shares some of the goals of structural path analysis (see Defourny and Thorbecke, 1984) in that both

methods attempt to reveal the multitude of paths or linkages within an economy. Whereas structural path analysis operates at a very micro-level (individual paths between sectors), it does offer the opportunity to provide some form of ranking or hierarchy for these paths. In addition, the methodologies share the property that each path in a structural path is part of a global feedback loop that includes the transactions between all sectors.

One particular attraction of feedback loop analysis is the ability to operate at a variety of aggregation levels – both sectoral and spatial – thereby offering the opportunity to view the emergence of economic structure in a consistent fashion. For example, feedback loop analysis might first identify the most prominent loops for the case where all flows are aggregated into one activity in each of several regions; the analysis can then continue with greater and greater levels of sectoral (or spatial) disaggregation, for example, identifying more detailed (and thus more complex) feedback loops for a number of sub-activities (*cf. Sonis et. al* 1993). This view of trade loops leads to the application of the mathematical tool of the block-permutation matrices, naturally presenting the spatial economic trade feedback loops. Applications of permutation matrices for the analysis of flow matrices are well known (see, for example, Gower, 1977, Slater, 1981, Sonis, 1980). Some applications focus on the transfer from flow matrices to double - stochastic matrices (Jurcat and Ryser, 1967, Feinberg, 1970) a form that allows the use of the well-known Birkhof-Von Neumann theorem about the decomposition of a double-stochastic matrix into the convex combination of the permutation matrices (see, Christofides, 1975, p. 386). Conceptually, this approach treats the flow as the stream of homogeneous unpressable liquid with the continuity property, which means the preservation of the flow volume. However, the transfer to double–stochastic matrix has a questionable economic meaning since the flow volume is fixed.

The feedback loop analysis used in this paper excluded the numerical manipulations of the flows leading to the construction of double stochastic matrix and focuses instead on consideration of non-homogeneous flows of different streams (goods). The objective of this particular application of feedback loops analysis is in its ability to shed light on the economic phenomenon of vertical specialization of interregional trade.

3. The multiregional feedback loop approach[3]

3.1. Closed feedback loops and block-permutation matrices.

Consider a multi-regional, multi-sector inter-industry system described with the help of a square block-matrix, *F*, of interregional inputs of the following form:

$$F = \begin{bmatrix} F_{11} & F_{12} & \dots & F_{1n} \\ F_{21} & F_{22} & \dots & F_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ F_{n1} & F_{n2} & \dots & F_{nn} \end{bmatrix} \tag{1}$$

It is assumed that there are *n* regions in which there exist *m* sectoral divisions of the economy, organized into activities at more than one level of aggregation. The central point of the feedback loops decomposition analysis is the use of spatial /functional feedback loops represented by the block-permutation matrices. By definition, a block-permutation matrix includes in each block-row and block-column only one non-zero block.

In the two-region case:

$$F = \begin{bmatrix} F_{11} & F_{12} \\ F_{21} & F_{22} \end{bmatrix} \tag{2}$$

There are only two block-permutation sub-matrices:

$$F_1 = \begin{bmatrix} F_{11} & 0 \\ 0 & F_{22} \end{bmatrix}, \quad F_2 = \begin{bmatrix} 0 & F_{12} \\ F_{21} & 0 \end{bmatrix} \tag{3}$$

and

$$F = F_1 + F_2 \tag{4}$$

[3] This section draws heavily on Sonis *et al*. (1997)

The matrix $F_1 = \begin{bmatrix} F_{11} & 0 \\ 0 & F_{22} \end{bmatrix}$ represents the circulation of intermediate goods in the same geographical region, and the matrix $F_2 = \begin{bmatrix} 0 & F_{12} \\ F_{21} & 0 \end{bmatrix}$ represents the bilateral connections between the two regions.

Within a three-region system:

$$F = \begin{bmatrix} F_{11} & F_{12} & F_{13} \\ F_{21} & F_{22} & F_{23} \\ F_{31} & F_{32} & F_{33} \end{bmatrix} \tag{5}$$

There are six block-permutation sub-matrices:

$$F_{(1)(2)(3)} = \begin{bmatrix} F_{11} & 0 & 0 \\ 0 & F_{22} & 0 \\ 0 & 0 & F_{33} \end{bmatrix} \quad F_{(132)} = \begin{bmatrix} 0 & 0 & F_{13} \\ F_{21} & 0 & 0 \\ 0 & F_{32} & 0 \end{bmatrix} \quad F_{(123)} = \begin{bmatrix} 0 & F_{12} & 0 \\ 0 & 0 & F_{23} \\ F_{31} & 0 & 0 \end{bmatrix} \tag{6}$$

$$F_{(1)(23)} = \begin{bmatrix} F_{11} & 0 & 0 \\ 0 & 0 & F_{13} \\ 0 & F_{32} & 0 \end{bmatrix} \quad F_{(12)(3)} = \begin{bmatrix} 0 & F_{12} & 0 \\ F_{21} & 0 & 0 \\ 0 & 0 & F_{33} \end{bmatrix} \quad F_{(13)(2)} = \begin{bmatrix} 0 & 0 & F_{13} \\ 0 & F_{22} & 0 \\ F_{31} & 0 & 0 \end{bmatrix} \tag{7}$$

And

$$\begin{aligned} F &= F_{(1)(2)(3)} + F_{(132)} + F_{(123)} = \\ &= F_{(1)(23)} + F_{(12)(3)} + F_{(13)(2)} \end{aligned} \tag{8}$$

Here, the block-permutation matrices $F_{(132)}, F_{(123)}, F_{(1)(23)}, F_{(12)(3)}$ represent the different tri-lateral trade connections between three regions, the block-diagonal matrix $F_{(1)(2)(3)}$ represent the "circulation" of intermediate flows within the same region and the block-permutation $F_{(13)(2)}$ represents the bilateral trade between first and third regions and the "circulation" within the second region.

In the case of *n* regions, there exists *n!* different block-permutation matrices and it is possible to prove that the number of possible additive decompositions of the type (8) is equal to *(n-1)!(n-*

2)!...2!. Thus, the problem devolves to a choice from this very large set of possible decompositions those decompositions with sound economic meaning. This problem can be solved through the adoption of a hierarchical stepwise approach; the procedure operates at successive levels in the system, but the approach at each stage is similar. This top-down decomposition may be considered analogously to an exfoliation process in the removal of the layers of an onion. The feedback loops on the inner hierarchical level of economic activities should be placed into the loops of the higher levels in the form of the *Matrioshka* doll 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 drawing upon the superposition principle conceptual framework (see Sonis, 1982). The superposition principle considers the economic system as a decentralized system that is comprised of a set of subsystems acting according to different and often conflicting and non-commensurable objectives. These objectives may be presented in the form of extreme tendencies or trends; the hierarchical viewpoint enables the analyst to extract the tendencies from the most to the least important. In this fashion, the procedure is not unlike that used in principal component analysis.

In the next section, the methodology for extracting the system of closed feedback loops will be presented together with the additive decomposition of the matrix of direct inputs. In this fashion, it will be possible to produce a superposition of feedback loops for the multi-regional economy.

3.2. The application of the Koopmans-Beckmann Linear Programming Personnel Assignment Algorithm[4]

The major element of the feedback loop approach is the identification of a series of (aggregate) block-permutation matrices such that each region is allowed precisely one aggregated block-flow entering it and one block-flow leaving it. A series of block-flows economically of course represents a chain of bilateral influences that are based on either backward of forward linkages depending on the point of view one takes. Such a series of block flows, in which each region appears only once with one incoming block-flow and one outgoing block-flow, may indeed be

[4] See Sonis *et al.*, 1993 for more details

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 into that loop. In the analysis, we will only look at complete loops primarily for institutional reasons. 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 including 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. 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 region are identical, we have the smallest closed sub-loop possible, *i.e.* the influence that a region directly exerts on itself; this is the domestic self-influence.

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 hierarchical feedback loop approach attempts to extract complete feedback loops that successively account for the most "explanation" at each stage of the selection process. The procedure continues until all transaction flows have been included. Full details of the methodology based on the well-known Koopmans, Beckman (1957) algorithm (see also Dantzig, 1963) of the solution of Personal Assignment Linear Programming Problem may be found in Sonis *et al*. (1993).

3.3. Matrioshka Principle for the description and visualization of the nested hierarchy of feedback loops.

It is necessary and possible to combine the interregional and interactivity interdependencies. For this purpose, the aggregated table needs to be replaced by a detailed table describing the interplay between the interactivity and interregional interdependencies. Further, it is important to

stress that the flexible form of the spatio-economic feedback loop analysis employed in this analysis allows an easy extension to the spatio-sectoral level. In such an extension, the analysis will relate to activities per region. Thus, the hierarchy of the feedback loops will reflect the interactivity interdependencies intertwined spatially, enabling one to distinguish the spatial extent of multi-regional industrial complexes.

This hierarchy of feedback loops can be visualized by identifying different feedback loops using alternative shading schemes in the trade table. Consider as an example, the tree-region/two-activity trade table 2, corresponding to the feedback loop decompositions (8) and (4).

< insert table 2 here >

Here feedback loops represented by the regional block–permutation matrices $F_{(1)(2)(3)}, F_{(132)}, F_{(123)}$ are shadowed in black and gray, while the activity feedback loop block-permutation matrices F_1, F_2 are shadowed in light gray colors.

A structure of nested feedback loop hierarchies could be extracted for the general case of an *n*-region/*m*-activities input-output system. Of course, the Matrioshka principle is applicable to the disaggregation of regions into sub-regions and further successive spatial and activities disaggregation.

3.4. Data.

The data used in this analysis were derived from publications of Ministry of International Trade and Industry of Japan, 1980-1995: " 1980, 1985, 1990 Interregional Input-Output Tables". First, these data were aggregated to the level of nine economic regions: Hokkaido, Tohoku, Kanto, Chubu, Kinki, Chugoku, Shikoku, Kyushu and Okinawa. Sectorally, three main economic activities were considered: Primary *P* (agriculture), Manufacturing *M* and Services *S*. Thereafter, these aggregated activities were sub-divided in the following groups: Primary: *P* (agricultural activities), *p* (non-agricultural); Manufacturing: *M* (non-durable goods), *m* (durable goods); Services: *S* (Business services) and *s* (personal services).

4. Analysis

It was noted in the introduction that Hitomi *et al*. (2001) had identified changes in interregional trade as a major contributor to regional growth in a factor decomposition of the Japanese economy. The analysis to be presented here will explore in greater detail the ways in which the regional economies of Japan are linked and whether these linkages have changed over the period 1980-85-90.

4.1 Intra-regional trade and horizontal specialization of the Japanese trade, 1980-85-90.

Horizontal specialization of trade refers to pure intra-regional trade, flows that do not cross the boundaries of the region, although, of course, the final product from a commodity chain of production may become part of interregional trade. Hence, horizontal specialization may be considered to be the subset of interactions that involve movements between sectors but not between regions. A further perspective may be offered by suggesting that they form part of a regional cluster of interactions; feedback loop analysis will help explore the degree to which this spatial cluster of flows strengthens or weakens over time in response to changes in regional and interregional competitiveness. An examination of the Chicago economy over the period 1970-1990 found clear evidence of a weakening or hollowing out of horizontal specialization, while the reverse was observed for a five-region division of Indonesia between 1980-1993 (see Hewings *et al*., 1998; Sonis and Hewings, 2001; Sonis *et al*, 1998). For the Japanese case, the feedback loop analysis identified the feedbacks between the activities: Primary *P* (agriculture), Manufacturing *M* and Services *S*.

Table 3 identifies four different types of such feedbacks; the I and IV types are characterized by most intensive bilaterally (dyadic) connections between activities (*P*,*M*), (*P*,*S*) or (*M*,*S*); the III and IV types characterized by intensive intra-activities flows (*P*), (*S*), (*M*) and tri-lateral connections between activities (*P*,*M*,*S*) or (*P*,*S*,*M*). Moreover, the most economically developed central regions, Kanto, Chubu and Kinki, during time periods 1980-85-90 maintain type I intra-regional loops; the adjusted developed economic regions, Chugoku, Shikoku and Kyushu,

maintain III type of feedback loops, while the peripheral regions Hokkaido and Tohoku travel from the I type of loops to II and III, and the Okinawa region maintains throughout the period IV type of feedbacks.

<insert here table 3>

The more detailed sub-division of the Primary, Manufacturing and Services activities into the following groups: Primary: *P* (agricultural activities), *p* (non-agricultural); Manufacturing: *M* (non-durable goods), *m* (durable goods); Services: *S* (Business services) and *s* (personal services) reveal the fine structure of the intra-activities, inter-sub-activities feedback loops. This structure is illustrated for the case of II type of the intra-regional feedback loops in Kanto, Chubu and Kinki economic regions, which are hierarchically stable during all periods 1980-85-90

<insert here tables 4 and 5>

This stable hierarchy is presented in table 4 for all the time periods and in greater detail, for 1990 in table 5. Table 5 reveals the intensive intra-activities and sub-activities feedback loops accounting for 52.35 % of all intra-regional trade in these three regions, supplemented by two inter-activities loops. It is important to stress that really informative feedback loop analysis of the horizontal specialization of the intra-regional trade should be done on the level of various industries, which is beyond the scope of the present paper.

4.2 Vertical specialization of the Japanese trade, 1980-85-90.

The analysis of the vertical specialization of the trade is naturally placed on three hierarchical levels of the spatial economy: *First level* is the geographical level of different economic regions; *Second level* is the spatial macro-economic level of interregional Primary, Secondary and Tertiary economic activities; and, the *third level* of inter-regional, intra-activities, presenting the overall trade between industries belonging to different economic activities. In this paper, the same sub-divisions of economic activities used earlier are employed. These three hierarchical level of loops are connected with the help of Matrioshka principle: the spatial feedback loops are decomposed into inter-regional activities loops, which, in turn, are decomposed into the inter-regional sub-inter-activities feedback loops. On each hierarchical level within this hierarchical

Matrioshka, the hierarchy of feedback loops is introduced on the basis of the overall intensity (sum) of the trade flowing through the loops.

4.3. Spatial Hierarchy of Inter-regional Feedback Loops.

The application of Linear Programming Personnel Assignment Algorithm (see section 3.2) to the tables of inter-regional trade in Japan, 1980-85-90 is presented with the help of tables 6-8.

<insert here tables 6,7,8>

The hierarchy of the spatial feedback loops is presented by the sequence of shading in such a way that trade flows in each identified feedback loop is shaded similarly. In these tables, only the two top feedback loops are shown. It is possible to see that the spatial hierarchy of trade flows is very similar and the intensities of feedback loops diminish at the same rate. Note the similarity between the two first largest feedback loops: each of them, in each time period 1980-85-980, include the very intensive triad of three central economic regions, Kanto, Chubu and Kinki, supplemented by bilateral dyads of feedback between other regions. Moreover, the first and second inter-regional loops are almost symmetrical, and this symmetry is complete in the period 1990. (see table 9).

<insert here table 9>

The meaning of this growing spatial symmetry is that there is a tendency towards the intensive bilateral trade relationships between regions. In the midst of this bilateral trade, the triads (Kanto, Chubu, Kinki) and (Kanto, Kinki, Chubu) are emerging

The prominence of these two triads has already been stressed in the recent literature. Ihara (1999) concludes that "about 66.1% of total number of the total Japanese population are found in the Kanto, Kinki and Chubu regions, and the same three regions' product amount to 72.9% of the total value of national products. In other words, these regions have already formed a megalopolis in Japan." Moreover, Ihara noted the essential difference between the economic intensity of flows in the triads (Kanto, Chubu, Kinki) and (Kanto, Kinki, Chubu): "… the indirect input-inducing effect derived from Chubu to Kinki via Kanto, turned out to be relatively smaller than that derived from Kanto to Kinki via Chubu…" Further, in the special research

devoted to evaluation of the role of the Kanto region in the growth of Japanese Regional economies, Akita (1999) provided an extended growth–factor decomposition method based on a three-region interregional system.

Table 10 represents the qualitative characterization of vertical specialization of these three regions included in the first spatial feedback loop. The functional economic content of this feedback loop is presented in table 11.

<insert here tables 10 and 11>

Revealed here is an hierarchy of three inter-activities feedback loops each of which includes two sub-activities loops. Within the first inter-activities feedback loop, the most prominent is 1 sub-activities feedback loop which includes the trade flows not abandoning the sub-activity; 2 sub-activity loop which flowing between sub-activities within the activity; second and third interactivities loops present the more complicated flow structure between the sub-activities.

4.4. Activities and sub-activities Feedback Loop analysis.

The fine structure of the inter-regional economic activities and sub-activities feedback loops can be extracted from the tables 12 and 13 presenting these loops in myriad of details.

<insert here tables 12 and 13>

These two tables are constructed according to the analytical and visualization procedures described in sections 2 and 3. Analogously, all sets of the feedback loops can be visualized, presenting the hierarchy of interregional economic activities feedbacks. In the same manner as in table 10 and 11, the hierarchy of interregional economic activities-sub-activities feedbacks loops can be presented (table 10 contains only the triad of regions included in the first inter-regional activities-sub-activities loop).

The findings and interpretations here can now be considered in the context of the parallel analysis noted earlier that explored a factor decomposition of growth in the Japanese regional economies over the same time period (Hitomi *et al*., 2001). In this decomposition analysis, attention was focused on the role of international trade, technological change and interregional

trade in generating changes in the levels of output in each region. Given the role of the Kanto region in the hierarchy of feedback loops, it should not be surprising to learn that about 50% of growth in Japan could be accounted for by the change in all factors occurring in Kanto. The dependency on the Kanto economy increased slightly from 48.7% in 1980-1985 to 49.9% in 1985-1990. For almost all regions, over 45% of regional output growth can be ascribed to changes in Kanto during 1980-1985. This dependency decreased slightly in 1985-1990, but it is still relatively high. For example, during this period, 38% of output growth in Chugoku, and 36% of output growth in Tohoku depends on changes in Kanto. Over these same time periods, technological changes, in contrast, played a much less role. Thus, the circulation implied in the feedback loops contains important economic signals that generate growth; the strengthening of interregional at the expense of intraregional flows between 1980-85 reflects a continuation of a hollowing-out phenomenon that has been observed at many spatial scales (see Hewings *et al*., 1998; Sonis *et al*., 1993), although there was a slight reversal between 1985-90. As Hitomi *et al*. (2001) noted, it will be important to analyze change in the regional economies after 1990, after the end of the so-called bubble economy and Japan's entry into a period of serious recession.

5. Final Remarks

The case study of Japan suggests the following simplified scheme in the emergence of the rank-size network hierarchy of feedback loops. In the two regions context, the historical evolution of bilateral trade was characterized by asymmetric flows – with the direction of flows reflecting, in large part, regional comparative advantages, and the character of flows being inter-industry, reflecting a value chain of production that was relatively simple. As the structure of national economy became more complex, bilateral flows were complimented by increasing multi-lateral exchanges and thus to the emergence of an hierarchy of multi-lateral feedback loops (*cf.* Krugman 1995). Further, the exchanges would come to be dominated by intra-industry rather than inter-industry flows, reflecting the emergence of trends towards equalization of regional per capita incomes and the consequent demands for greater production variety. What happens next remains uncertain: will the growth of global trade and the pressures for greater economic

efficiency lead back to bilateral exchanges dominating as a result of the disaggregation of the large multi-lateral loops into smaller dyadic and even triadic exchange?

The notion of trading blocks within nations (i.e. at regional level) requires a different qualitative interpretation than similar grouping at the international level. In most countries, like Japan and the US, regions have severely limited abilities to introduce tariff or even non-tariff instruments to gain economic power and with ownership of plants increasingly dominated by multi-regional and multi-national organizations, the structure of exchange responds to difference of economic incentives.

It is important to note that consideration of feedback loops in trade theory is a relatively new approach to the detailed analysis of vertical specialization of trade flows. This approach leads the decomposition of global trade into feedback loops. Thus, the analytical technique of block-permutation matrices and the decomposition of trade into feedback loops can be utilized in trade theory (in the form of the Koopmans-Beckmann Linear Programming Personnel Assignment Algorithm). Furthermore, the spatial and functional economic disaggregations of the trade offer the opportunity to apply the Matrioshka principle of hierarchical inclusion of economic activities flows into the spatial trade loops. The essential consequence of the decomposition of the overall matrix trade flow into the sum of block-permutation matrices of feedback loops is the possibility to visualize the trade feedback loops with the help of shadowing of different feedback loops. This visualization represents in fine detail the rich information about spatial and economic interdependencies within inter-regional trade at different levels of aggregation. In such a manner the trade tables can be converted into shadowed spatial and functional maps of the hierarchy of trade feedback loops.

Two further developments need to be explored; first, attention has to be directed to more detailed sectoral analysis to explore the role of *intraindustry* vis a vis *interindustry* trade (see Munroe and Hewings, 1999). Secondly, there needs to be a formal link between international and interregional feedback loop analysis to trace the way in which international exchange signals ripple across the internal space of individual countries. Furthermore, with regional economies in countries like Japan and the US moving towards greater uniformity in levels of welfare, the issue

of trading blocks and welfare implications that is a prominent feature of debate at the international level assumes far less importance (see Spilimbergo and Stein, 1998).

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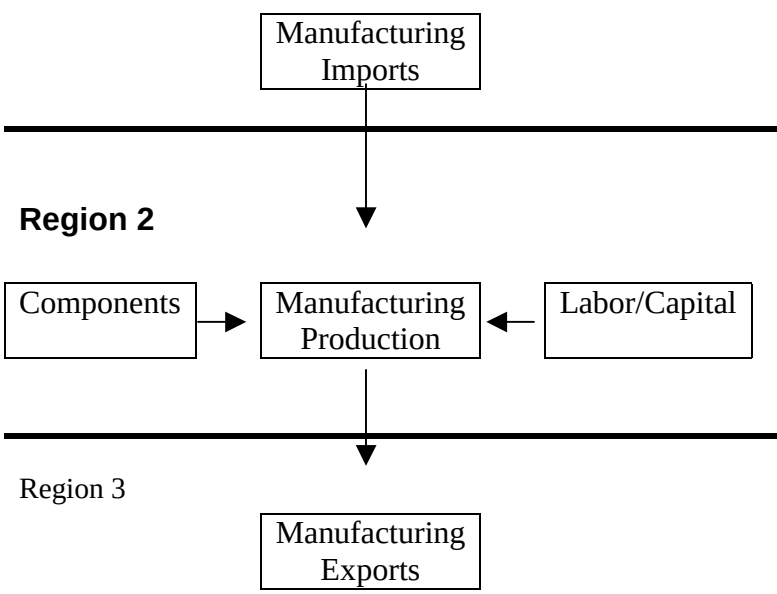
Table 1: Vertical Trade: Two Interpretations

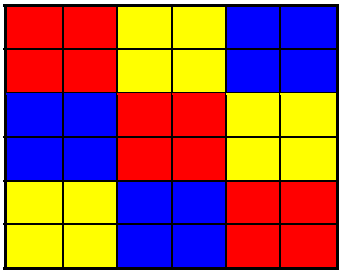
Vertical-Specialization-Based Trade (after Hummels, *et al*., 1998)



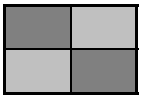
Feedback Loop Interpretation

Table 2. Visualization of the "Matrioshka" Principle

a) Three-regions feeedback loop decomposition:



b) Two activities feedback loop decomposition:



c) Three-regions, two-activities feedback loop decomposition:

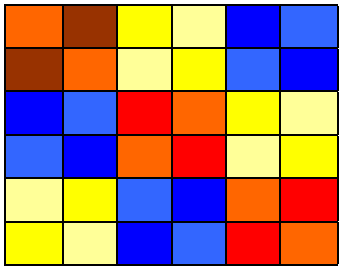


Table 3. Types of intra-regional feedback loops, 1980-85-90

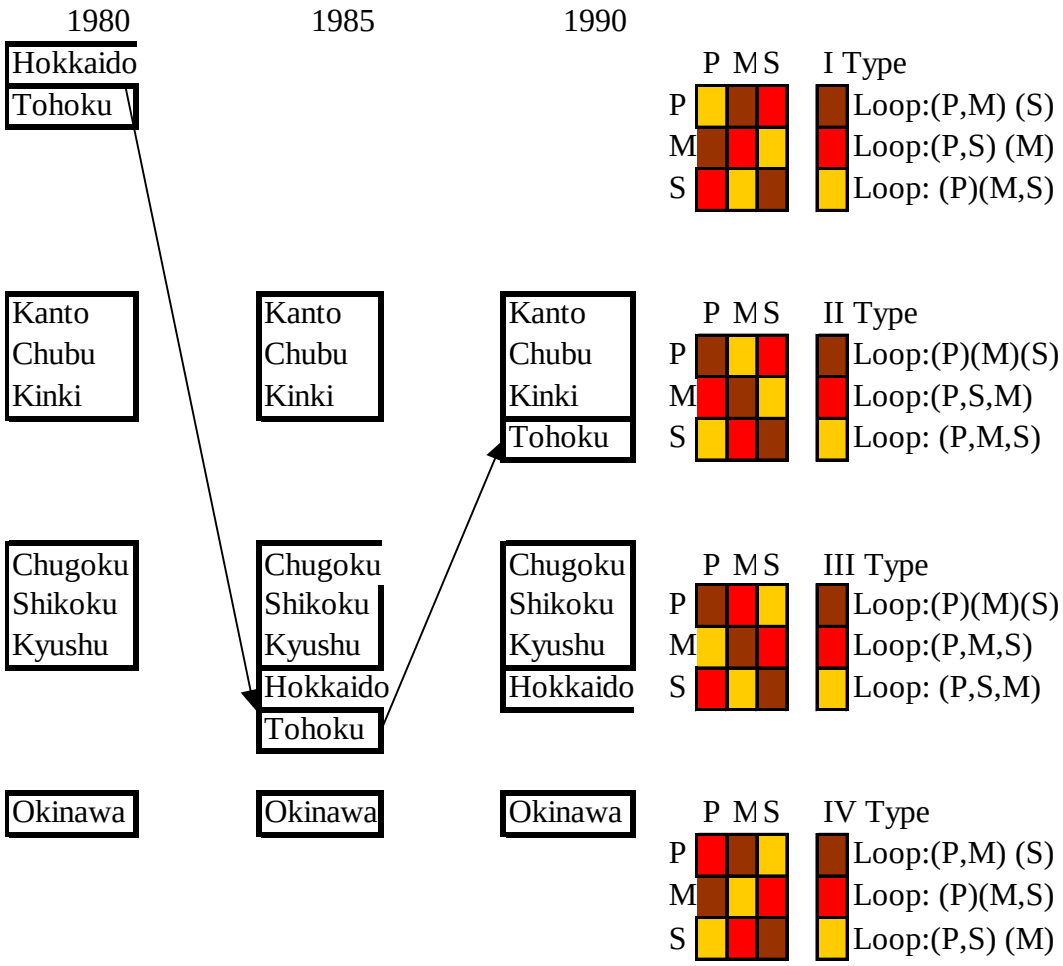


Table 4. Qualitative characterization of the horizontal specialization feedback loops in Kanto, Chubu and Kinki economic regions, 1980-85-90.

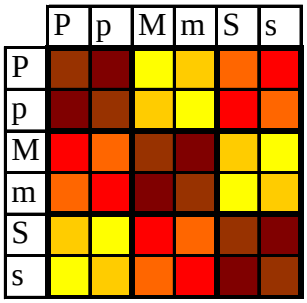


Table 5. Kanto intra-regional inter-activities and sub-activities trade flow, 1990.

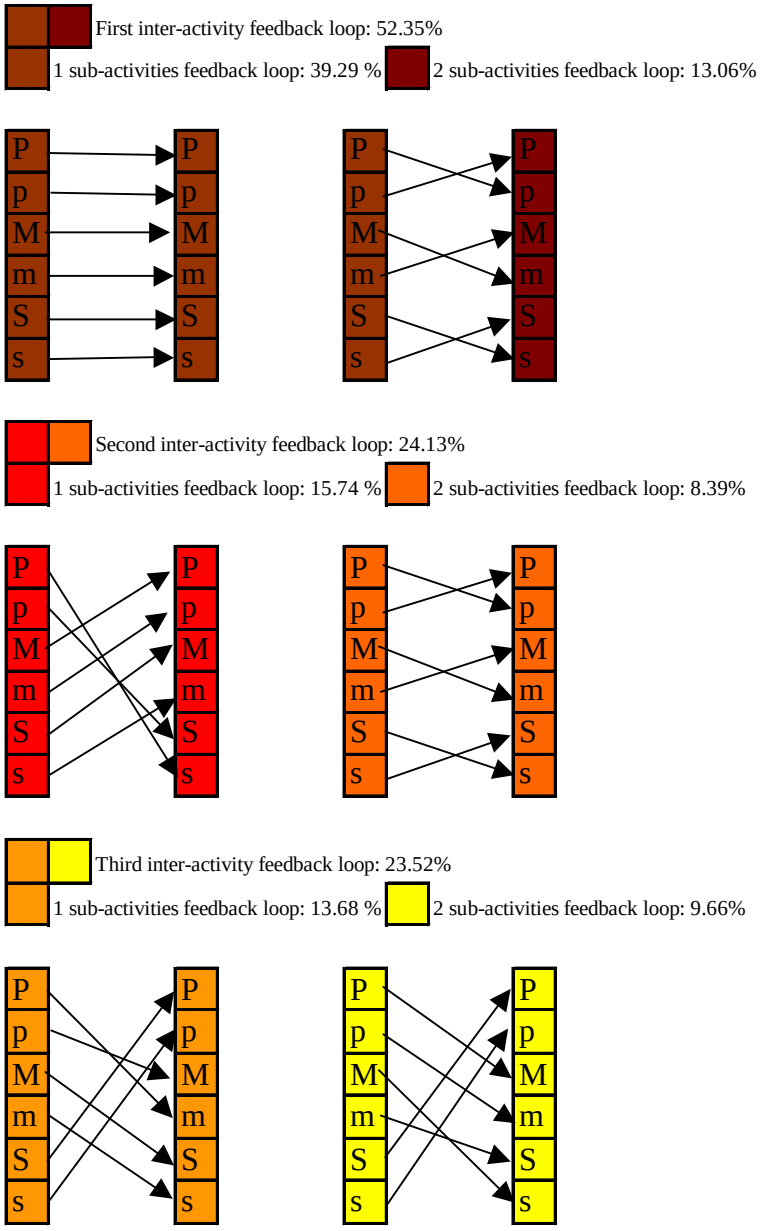


Table 6. The hierarchy of Japan Trade Feedback Loops, 1980

	Hokkaido	Tohoku	Kanto	Chubu	Kinki	Chugoku	Shikoku	Kyushu	Okinawa
Hokkaido	9,146,680	318,410	1,158,246	277,987	458,736	80,589	38,081	78,392	2,330
Tohoku	233,490	12,041,041	3,180,651	413,443	598,430	187,673	72,706	116,773	11,456
Kanto	1,388,647	3,227,078	95,002,696	4,337,311	4,753,871	1,940,187	796,930	2,013,071	119,669
Chubu	340,916	542,824	5,573,457	28,241,323	3,039,244	879,636	319,953	888,213	42,300
Kinki	412,004	720,866	5,396,792	3,194,979	39,077,234	1,841,676	1,115,650	1,657,568	81,378
Chugoku	96,787	185,127	1,767,871	1,134,057	2,047,829	18,557,969	451,872	1,117,130	27,921
Shikoku	44,440	100,565	1,024,520	376,124	930,536	368,914	6,384,438	417,708	12,614
Kyushu	89,199	198,191	1,871,359	836,664	1,297,013	724,675	260,344	18,651,512	90,371
Okinawa	10,247	2,214	128,586	18,431	40,671	59,545	10,594	35,878	1,177,886

	Total intra-regional flow	228,280,779	
	1 Feedback Loop: (Kanto, Kinki, Chubu) (Hokkaido,Tohoku) (Chugoku, Kyushu) (Shikoku, Okinawa)	15,939,220	23.57%
	2 Feedback Loop; (Kanto, Chubu, Kinki) (Hokkaido, Okinawa) (Tohoku,Chugoku,Shikoku, Kyushu)	14,041,368	20.76%
	3 Feedback Loop: (Kanto, Tohoku) (Kinki, Chugoku) (Chubu, Kyushu, Okinawa) (Hokkaido, Shikoku)	11,376,770	16.82%
	4 Feedback loop; (Kanto, Kyushu) (Kinki, Shikoku) (Chubu, Hokkaido, Chugoku) (Tohoku, Okinawa)	7,499,848	11.09%
	5 Feedback Loop; (Kanto,Chugoku) (Kinki, ,Kyushu, Hokkaido),Chubu, Okinawa) (Tohoku, Shikoku)	5,989,054	8.86%
	6 Feedback Loop: (Kanto, Hokkaido) (Kinki, Kyushu) (Chubu, Shikoku, Tohoku) (Chugoku, Okinawa)	5,730,881	8.47%
	7 Feedback Loop:(Kanto, Okinawa, Kinki, Tohoku, Chugoku< Chubu, Hokkaido, Kyushu, Shikoku)	4,014,157	5.94%
	8 Feedback Loop: (Kanto, Shikoku, Kyushu, Chubu, Okinawa) (Kinki, Hokkaido, Chugoku, Tohoku)	3,038,312	4.49%
	Total inter-regional flow	67,629,610	100.00%
	Total Trade flows	295,910,389	

Table 7. The hierarchy of Japan Trade Feedback Loops, 1985.

	Hokkaido	Tohoku	Kanto	Chubu	Kinki	Chugoku	Shikoku	Kyushu	Okinawa
Hokkaido	9,427,904	432,670	1,478,922	330,388	488,801	98,939	40,698	106,349	3,557
Tohoku	362,347	11,992,411	5,029,436	536,249	1,024,791	175,600	59,462	209,198	10,597
Kanto	1,438,437	4,350,926	109,699,122	7,568,097	7,684,095	3,139,547	1,295,037	3,038,009	158,670
Chubu	429,829	902,237	7,112,278	31,054,977	4,438,644	1,004,597	477,845	940,143	61,540
Kinki	517,481	1,150,511	8,492,348	4,016,437	39,602,352	2,449,982	1,225,071	2,150,410	108,962
Chugoku	119,048	264,452	2,628,576	1,330,323	3,068,076	17,533,421	636,403	1,381,461	45,404
Shikoku	35,114	76,059	1,244,184	471,868	1,259,468	432,612	5,725,534	432,043	9,644
Kyushu	86,788	225,392	2,815,103	963,947	1,836,171	933,550	322,671	18,906,350	115,990
Okinawa	1,347	5,341	113,682	22,289	53,746	28,685	13,192	63,417	1,278,296

	Intra-regional flows	245,220,367	
	1 Feedback Loop: (Kanto,Chubu,Kinki) (Hokkaido,Tohoku, Okinawa, Shikoku) (Chugoku,Kyushu)	23,305,673	24.38%
	2 Feedback Loop: (Kanto,Kinki,Chubu) (Hokkaido,Kyushu, Okinawa, Tohoku) (Chugoku, Shukoku)	20,471,852	21.42%
	3 Feedback Loop: (Kanto, Tohoku) (Kinki, Chugoku) (Chubu,Kyushu) (Hokkaido,Shikoku, Okinawa)	16,854,199	17.63%
	4 Feedback Loop: (Kanto, Chugoku,, Chubu, Hokkaido, Okinawa, Kinki, Kyushu) (Tohoku, Shikoku)	10,058,036	10.52%
	5 Feedback Loop: (Kanto, Hokkaido) (Kinki, Tohoku) (Chubu, Chugoku, Okinawa) (Shikoku, Kyushu)	6,919,665	7.24%
	6 Feedback Loop: (Kanto, Okinawa, Chugoku, Hokkaido, Chubu, Tohoku, Kyushu, Kinki, Shikoku)	6,053,652	6.33%
	7 Feedback Loop: (Kanto, Kyushu, Hokkaido, Chugoku, Tohoku, Chubu, Shikoku, Kinki, Okinawa)	5,984,394	6.26%
	8 Feedback Loop: (Kanto, Shikoku, Chubu, Okinawa, Kyushu, Tohoku, Chugoku) (Kinki, Hokkaido)	5,927,712	6.20%
	Total Inter-regional flows	95,575,183	100.00%
	Total Trade flows	340,795,550	

Table 8. The hierarchy of Japan Trade Feedback Loops, 1990

	Hokkaido	Tohoku	Kanto	Chubu	Kinki	Chugoku	Shikoku	Kyushu	Okinawa
Hokkaido	9,998,163	430,812	1,776,470	371,324	477,711	128,120	58,052	153,149	7,550
Tohoku	406,671	13,778,391	5,910,538	795,140	1,046,758	332,722	109,854	299,941	22,690
Kanto	1,900,456	5,493,008	142,178,803	9,782,012	8,011,189	3,568,744	1,537,155	4,225,170	263,264
Chubu	516,919	1,249,460	9,485,123	38,666,020	4,595,327	1,582,695	467,947	1,229,819	54,791
Kinki	521,374	1,203,332	9,742,547	5,336,958	52,676,087	2,770,243	1,261,139	2,344,171	119,643
Chugoku	135,901	408,563	3,648,986	1,549,948	3,065,274	18,058,145	754,272	1,506,565	45,932
Shikoku	45,202	153,240	1,506,836	551,626	1,228,188	558,504	6,347,276	307,161	16,938
Kyushu	132,234	311,542	3,662,138	1,174,198	1,943,081	1,353,305	383,885	20,981,279	125,791
Okinawa	2,127	7,748	137,506	23,659	46,371	27,002	15,744	66,397	1,318,935

	Total intra-regional flow	304,003,099	
	1 Feedback Loop: (Kanto,Chubu, Kinki) (Hokkaido,Tohoku) (Chugoku, Kyushu) (Shikoku, Okinawa)	27,849,921	24.33%
	2 Feedback Loop; (Kanto, Kinki, Chubu) (Hokkaido, Okinawa) (Chugoku, Shikoku) (Tohoku, Kyushu)	24,767,206	21.63%
	3 Feedback Loop: (Kanto, Tohoku) (Kinki, Chugoku) (Chubu, Kyushu, Okinawa) (Hokkaido, Shikoku)	18,721,586	16.35%
	4 Feedback loop; (Kanto, Kyushu) (Kinki, Shikoku) (Chubu, Chugoku, Hokkaido) (Tohoku, Okinawa)	12,496,993	10.92%
	5 Feedback Loop; (Kanto,Chugoku) (Kinki, Okinawa,Kyushu, Hokkaido) (Chubu, Tohoku, Shikoku)	9,924,655	8.67%
	6 Feedback Loop: (Kanto, Hokkaido) (Kinki, Kyushu) (Chubu, Shikoku, Tohoku) (Chugoku, Okinawa)	9,453,439	8.26%
	7 Feedback Loop:(Kanto, Okinawa, Kinki, Tohoku, Chugoku< Chubu, Hokkaido, Kyushu, Shikoku)	5,956,426	5.20%
	8 Feedback Loop: (Kanto, Shikoku, Kyushu, Chubu, Okinawa) (Kinki, Hokkaido, Chugoku, Tohoku)	5,315,626	4.64%
	Total inter-regional flow	114,485,852	100.00%
	Total Trade flows	418,488,951	

Table 9. Qualitative descrition of two biggest feedback inter-regional loops, 1980-85-90

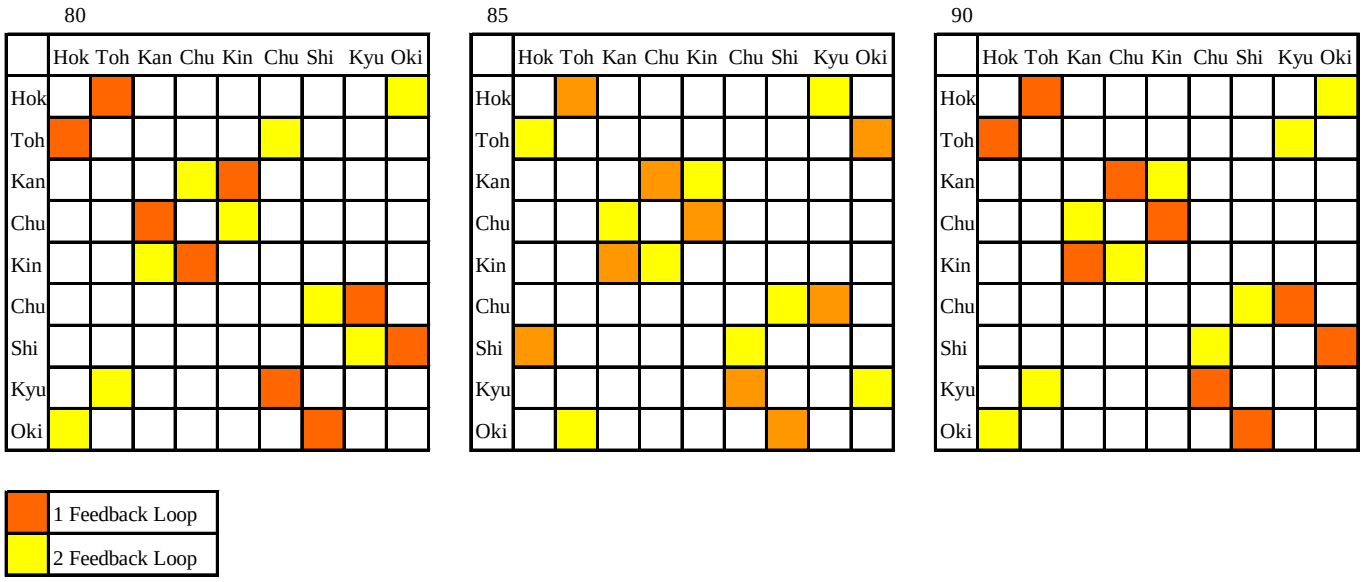


Table 10. Qualitative characterization of the vertical specialization feedback loo
for the triad (Kanto, Chubu, Kinki) from the first inter-regional inter-activiti
feedback loop, 1990.

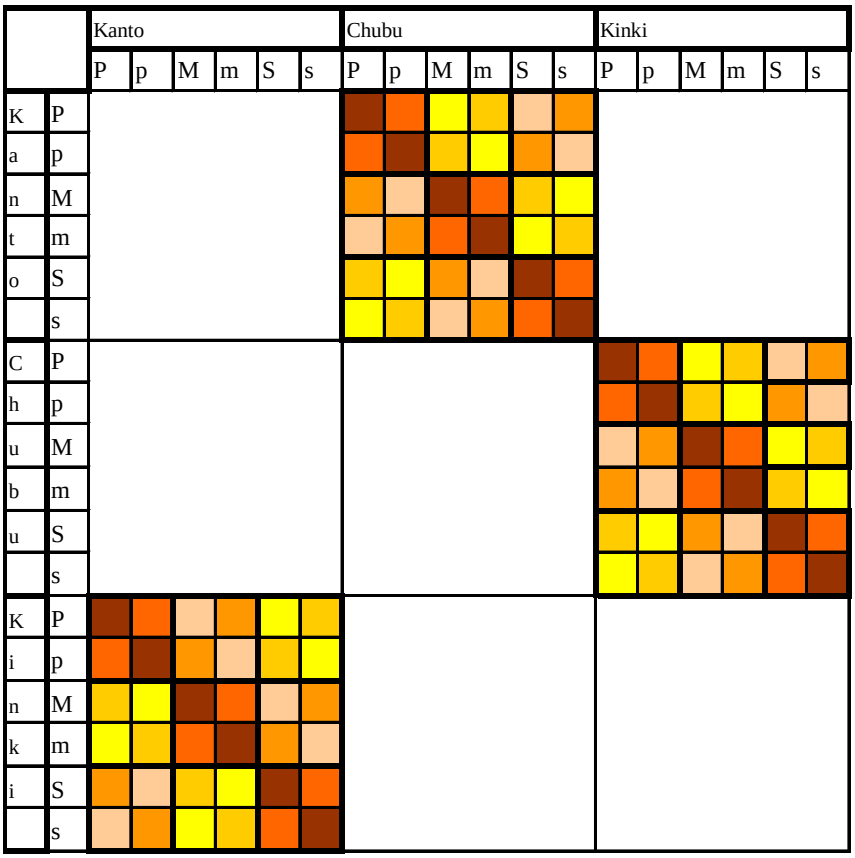
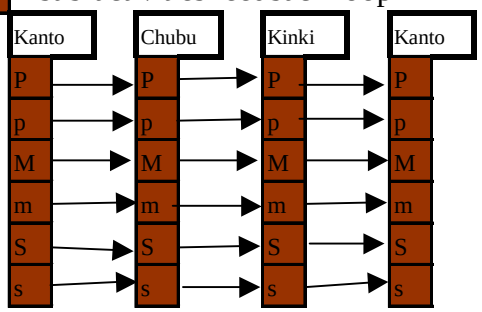


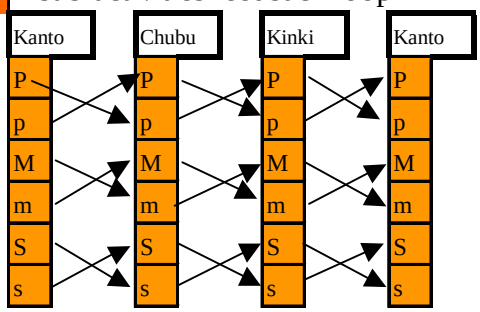
Table 11. Total inter-regional, inter-activities and sub-activities feedback loops structure for the (Kanto, Chubu, Kinki), 1990.

First inter-activities feedback loop

1 sub-activities feedback loop

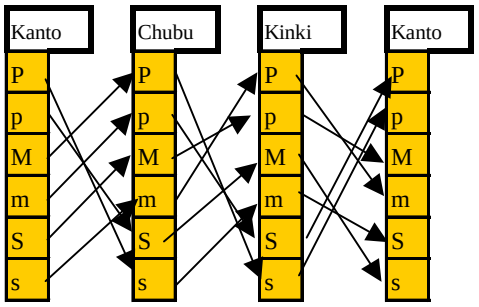


2 sub-activities feedback loop

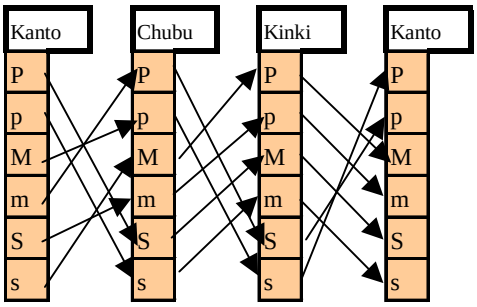


Second inter-activities feedback loop

1 sub-activities feedback loop

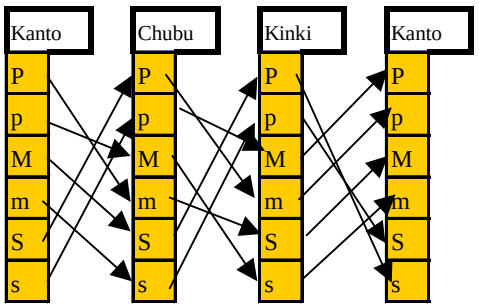


2 sub-activities feedback loop



Third inter-activities feedback loop

1 sub-activities feedback loop



2 sub-activities feedback loop

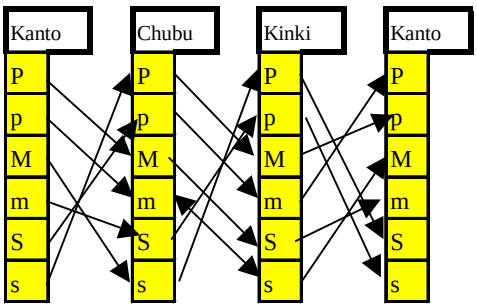


Table 12. Trade in Japan, 1990: Qualitative presentation of the hierarchy of inter-activities feedback loops.

		Hokkaido			Tohoku			Kanto			Chubu			Kinki			Chugoku			Shikoku			Kyushu			Okinawa		
		P	M	S	P	M	S	P	M	S	P	M	S	P	M	S	P	M	S	P	M	S	P	M	S	P	M	S
Hokkaido	P																											
	M																											
	S																											
Tohoku	P																											
	M																											
	S																											
Kanto	P																											
	M																											
	S																											
Chubu	P																											
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	S																											
Kyushu	P																											
	M																											
	S																											
Okinawa	P																											
	M																											
	S																											

Table 13. Trade flows of Japan, 1990. Hierarchy of interregional, activities,inter-activities feedback loops.