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Trade Typhoon Over Japan: Turbulence Metaphor and Spatial Production Cycles Feedback Loops of the Japanese Economy, 1980–85–90

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This paper deals with the turbulence similitude between whirlpool structure of atmosphere disturbances and the spatial production cycles. Such an analogy leads to the production cycles feedback loops superposition analysis of trade feedbacks reflecting the economic phenomena of horizontal and vertical trade specifications. Moreover, the visualization of this process is achieved with the help of coloring the different permutation matrices presenting the hierarchy of production cycles feedback loops. In this manner the qualitative presentation of Japan inter-regional and inter-industry trade, 1980–85–90, is visualized and interpreted.

Keywords: Spatial production cycles; Feedback loops; "Matrioshka" imbedding principle; Turbulence analogy; Multi-regional econmic analysis

INTRODUCTION

The use of similarity between physical and economic phenomena has a long tradition in economic analysis. Such use started from application in economics of differential and integral calculus and methods of linear algebra and vector analysis, which came into existence for the description of physical phenomena. The reason for use of physical analogies is the possibility of utilization of strong well-established technique of mathematical analysis. The justification of this use can be achieved only if the meaning of results of analysis is economically sound without any reference to physical analogy. Thus, such justification can be achieved if there is a transfer of ideas from the deepness of understanding of physical phenomenon to the deepness of understanding of economic phenomenon. The purpose of this paper is to carry out such a transfer of ideas from the deepness of understanding of physical phenomenon of turbulence to the deepness of understanding of economic phenomenon of spatial production cycles.

In the hydrodynamic turbulence a flow of energy from large to small scales is one of the main characteristics of fully developed homogeneous isotropic turbulence in three spatial dimensions. Energy is pumping into the system at large scales, transferred to smaller scales through a hierarchy of eddies of decreasing sizes, and dissipates at the smallest scale. This cascade of kinetic energy generates the scaling behavior of eddies (Richardson, 1922).

The turbulence analogy means that the big inter-regional production cycles feedback loops of intermediate input flows are decomposed into feedback loops of intermediate input flows between economic activities and further decomposed into the loops of flows on the scale of individual industries. Moreover, the scaling of eddies is analogous to the hierarchy of economic subsystems which is presented with the help of so-called "Matrioshka" (Russian doll within doll, within doll...) embedding principle (*cf.* Sonis and Hewings, 1990).

The justification of consideration of a set of production cycles feedback loops of inter-regional trade flows is based on an important phenomenon of vertical specialization which describes the use of imported inputs for producing goods that are exported (Bruelhart and Hine, 1999).

Balassa (1967, p. 97), coined the term of vertical specialization. In the paper by Hummels *et al.* (1998, p. 81), the following definition of vertical specialization was introduced and discussed: "(1) a good must be produced in

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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 than once .... Thus, countries link sequentially to produce a final good."

The analysis of the hierarchy of spatial production cycles feedback loops of inter-industry flows has been elaborated in the series of papers by Sonis and Hewings (Sonis *et al.* 1993, 1995a,b, 1997).

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

While Krugman's ideas have been developed explicitly in the context of trading relationships between economies at one spatial level, there is not a 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. We will explore the hierarchy of trade flows not at only one spatial level (between regions within a country), but also within hierarchy of economic activities and their sub-divisions.

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 (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 production cycles feedback loop that includes the transactions between all sectors. The feedback loop analysis identifies the most prominent production cycle loops, first for flows for an aggregation of activity into just one region and then for a three-sector activity aggregation. Further, the analysis will continue with more detailed (and thus more complex) feedback loops for a number of sub-activities (*cf.* Sonis *et al.*, 1993).

The turbulence similitude leads to the application of the mathematical tool of the block-permutation matrices, naturally presenting the spatial economic trade feedback loops.

The application of the perturbation matrices for the analysis of flow matrices is well known (see, for example, Gower, 1977; Sonis, 1980; Slater, 1981). Part of them based on the transfer from flow matrix to double-stochastic matrix (Jurcat and Ryser, 1967; Feinberg, 1970), which allows the use of the well-known classical Birkhof–von Neumann theorem about the decomposition of a double-stochastic matrix into the convex combination of the permutation matrices (Christofides, 1975, p. 386) and, conceptually treats the flow as the stream of homogeneous unpressable liquid with the continuity property, which means the preservation of the flow volume. Furthermore, the transfer to double-stochastic matrix has a questionable economic meaning.

The method of spatial production cycles feedback loop analysis used in this paper gives the possibility to avoid the numerical manipulations with flows and allows the consideration of the non-homogeneous flows of different streams (goods) and the use of turbulence analogy. In this paper the economic flows of intermediate goods devoid all mechanical properties of physical flows: the velocity and continuity of flows has no economic meaning; only the origin and destination of flow and their intensity are taken into consideration. Nevertheless, such "week" assumptions allows to consider the analog of the Birkhof-von Neumann theorem: each economic flow matrix can be presented as a sum of permutation matrices, presenting the spatial production cycles feedback loops.

THE MULTI-REGIONAL SPATIAL PRODUCTION CYCLES FEEDBACK LOOPS AND BLOCK-PERMUTATION MATRICES

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

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

It is assumed that there are n regions in which there exist m divisions of the economy, organized into activities and there is the subdivision of activities in the different sub-categories. The central point of the spatial production cycles 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.

Within a three-region system:

$$F = \begin{pmatrix} F_{11} & F_{12} & F_{13} \\ F_{21} & F_{22} & F_{23} \\ F_{31} & F_{32} & F_{33} \end{pmatrix} \tag{2}$$

there are six block-permutation sub-matrices:

$$F_{(1)(2)(3)} = \begin{pmatrix} F_{11} & 0 & 0 \\ 0 & F_{22} & 0 \\ 0 & 0 & F_{33} \end{pmatrix},$$

$$F_{(132)} = \begin{pmatrix} 0 & 0 & F_{13} \\ F_{21} & 0 & 0 \\ 0 & F_{32} & 0 \end{pmatrix}, \tag{3}$$

$$F_{(123)} = \begin{pmatrix} 0 & F_{12} & 0 \\ 0 & 0 & F_{23} \\ F_{31} & 0 & 0 \end{pmatrix},$$

$$F_{(1)(23)} = \begin{pmatrix} F_{11} & 0 & 0 \\ 0 & 0 & F_{13} \\ 0 & F_{32} & 0 \end{pmatrix},$$

$$F_{(12)(3)} = \begin{pmatrix} 0 & F_{12} & 0 \\ F_{21} & 0 & 0 \\ 0 & 0 & F_{33} \end{pmatrix}, \tag{4}$$

$$F_{(13)(2)} = \begin{pmatrix} 0 & 0 & F_{13} \\ 0 & F_{22} & 0 \\ F_{31} & 0 & 0 \end{pmatrix}$$

and

$$\begin{aligned} F &= F_{(1)(2)(3)} + F_{(132)} + F_{(123)} \\ &= F_{(1)(23)} + F_{(12)(3)} + F_{(13)(2)}. \end{aligned} \tag{5}$$

Here the block-permutation matrices $F_{(132)}$,$F_{(123)}$ represent the different three-lateral spatial production cycles, the block-diagonal matrix $F_{(1)(2)(3)}$ represent the "circulation" of intermediate flows within the same region and the block-permutations $F_{(1)(23)}$,$F_{(13)(2)}$,$F_{(12)(3)}$ represent the bilateral trade between two regions and the "circulation" within the remained 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 (5) is equal to $(n-1)!(n-2)!\cdots 2!$.

Thus, the problem erases to choose from this very big set of possible decompositions the decompositions with the 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 or, using the turbulence analogy to the construction of hierarchy of feedback loops (whirlpools) ordered with the help of aggregated cumulative flows within the blocks belonging to the loop. The production cycles feedback loops on the inner hierarchical level of economic activities should be places 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 spatial production cycles 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 spatial production cycles for the multi-regional economy.

SUPERPOSITION OF SPATIAL PRODUCTION CYCLES FEEDBACK LOOPS

The major element of the feedback loop approach is the identification of 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 which 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 called a feedback loop because each and every region in such 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 that each feedback loop represents the spatial production cycle that indicates how strongly (at each hierarchical level) each region is tied economically to all other regions

included into that loop. In the analysis, we will only look at complete loops. 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.

A production cycle, represented by 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 production cycle 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" in each stage of the selection process. The procedure continues until all transaction flows have been included. It is important to note that each block matrix F of the type (1) can be replaced by the numerical matrix T_F whose components are the sum of all economic flows in the corresponding block—the aggregated block-flows. Such a sub-matrix T_F represents a complete feedback loop if it includes in each row and in each column only one non-zero entry from the matrix **F** and zeros elsewhere. One can define the flow intensity of a complete feedback loop as the sum of all flows of the corresponding sub-matrix T_F.

If all non-zero entries of T_F are replaced by units, the result is a so-called permutation matrix P_F. This zero-one matrix corresponds to some permutation of the sequence of numbers $1, 2, \cdots, n$. Such a permutation (of regions) represents the structure of the corresponding production cycle complete feedback loop. The corresponding sub-matrices T_F are referred to as *quasi-permutation matrices*.

It is important to note that for each permutation matrix P_F there is an integer k such that P_F^k is the unit matrix I. For that k, the corresponding quasi-permutation matrix T_F has the property that T_F^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 sub-matrices T_F chosen according to the rank-size of their flow intensities. This means that on the top of the hierarchy, one finds the production cycle 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 (Dantzig, 1963; Sonis *et al.*, 1993). Here profit is defined by the size of the flows in matrix T_F.

THE APPROXIMATIVE PROCEDURE FOR THE DERIVATION OF PRODUCTION CYCLES FEEDBACK LOOPS

The following crude approximative procedure for the derivation of production cycles can be proposed: first of all in the matrix T_F of all intermediate flows we will chose the biggest flow. This flow will define the first component of production cycle. Second, we will exclude from matrix T_F the row and column including this component. In the remaining matrix we will chose the next biggest component of the production cycle, etc. After $n-1$ such steps the feedback loop usually will be identified.

Unfortunately, this simple procedure not always giving the closed loop, because there are cases when on some step it will be impossible to find the component for choice. In this case it is necessary to apply the Beckmann–Koopmans algorithm, which usually helps to find the second best component. It is possible to guess this second best component in many cases.

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 sub-matrices with the property:

$$T = T_{F_1} + T_{F_2} + \cdots + T_{F_n} \tag{6}$$

This decomposition, in turn, generates the decomposition of the matrix F of intermediate flows into a sum of block-permutation matrices $F_1, F_2, \ldots, F_n$, corresponding to the ordered set of all feedback loops:

$$F = F_1 + F_2 + \cdots + F_n \tag{7}$$

For the purposes of visualization it is possible to convert the matrix F of intermediate flows into colored map by coloring each block-permutation matrix F_k into different color in such a way that the rank-size hierarchy of production cycle feedback loops, corresponding to rank-size sequence of their flow intensities, will be colored according to the sequence of colors in a rainbow.

THE MATRIOSHKA IMBEDDING PRINCIPLE FOR THE NESTED HIERARCHY OF FEEDBACK LOOPS

It is necessary and possible to combine the inter-regional and inter-activity interdependencies. To this aim, the aggregated table needs to be replaced by the detailed table describing the interplay between the inter-activity and international interdependencies. Further, it is important to stress that the flexible form of the production feedback loop analysis employed in this analysis allows an easy extension to the spatio-sectional level. In such an extension, the analysis will relate to activities per region. Thus, the hierarchy of the feedback loops will reflect the

TABLE I The hierarchy of Japan production cycles feedback loops, 1990

	Hokkaido	Tohoku	Kanto	Chubu	Kinki	Chugoku	Shikoku	Kyushu	Okinawa
Hokkaido	9,798,167	430,812	1,776,477	371,324	477,711	128,120	88,052	183,349	7,550
Tohoku	406,671	19,778,971	5,910,538	795,146	1,046,758	332,722	209,854	299,941	22,690
Kanto	1,900,456	5,493,068	49,564,641	9,782,012	8,011,189	3,568,741	1,537,155	4,225,170	283,701
Chubu	516,919	1,249,460	9,485,123	38,666,029	4,595,327	1,582,695	467,947	1,229,819	54,791
Kinki	521,374	1,203,132	9,742,347	5,336,958	33,476,093	2,770,283	1,261,139	3,344,174	119,643
Chugoku	135,901	408,563	3,638,986	1,549,948	3,065,274	15,958,145	754,272	1,506,565	45,432
Shikoku	45,202	151,240	1,566,936	551,626	1,228,188	558,504	6,947,276	807,161	16,938
Kyushu	132,234	311,542	3,662,138	1,174,198	1,243,681	1,353,305	391,581	20,981,276	125,791
Okinawa	2,127	7,748	137,506	23,659	46,370	27,602	15,744	66,397	1,318,435

	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	

inter-activity interdependencies intertwined spatially, enabling one to distinguish the spatial extent of multi-regional industrial complexes.

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.

DATA

The data used in this analysis were derived from publications of Ministry of International Trade and Industry of Japan, 1980–1995.

First of all these data were aggregated on the geographical level of nine big economic regions: Hokkaido, Tohoku, Kanto, Chubu, Kinki, Chugoku, Shikoku, Kyushu and Okinawa. Further, the level of three main economic activities was considered: Primary (P) (agriculture), Manufacturing (M) and Services (S). In turn, the Primary, Manufacturing and Services activities were sub-divided into 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).

VERTICAL SPECIALIZATION OF THE JAPANESE TRADE, 1980–85–90

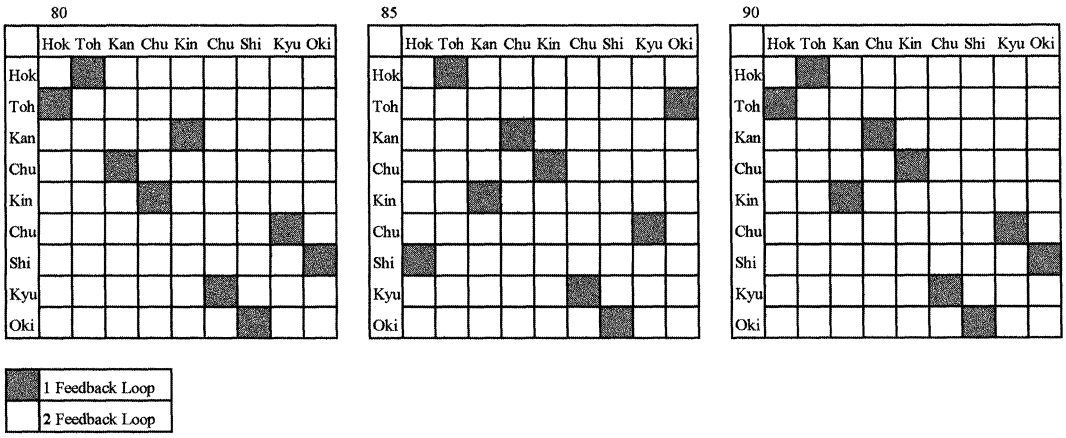
The analysis of the vertical specialization of the trade is naturally placed on three hierarchical levels of the spatial economy: *First level* is the geographical level of different economic regions (countries); *Second level* is the spatial macro-economic level of inter-regional Primary (Agriculture), Secondary (Manufacturing) and Tertiary (Services) economic activities; and third *level* of inter-regional intra-activities, presenting the overall trade between industries belonging to different economic activities. In this paper, we consider the following sub-division of the Primary, Manufacturing and Services activities 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). These three hierarchical level of loops are connected with the help of Matrioshka principle: the spatial feedback loops 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 introduced on the base of overall intensity (sum) of the trade flowing through the loops. This hierarchical structure of trade feedback loops represent the turbulence similitude described and explained in introduction.

Hierarchy of Spatial Production Cycles Inter-regional Feedback Loops

The application of linear programming personnel assignment algorithm to the tables of inter-regional trade in Japan, 1990 is presented with the help of colored Table I.

The hierarchy of the spatial feedback loops is presented by the sequence of colors of the light spectrum in such a

TABLE II Qualitative description of two biggest spatial production cycles feedback loops, 1980–85–90



way that trade flows in each identified feedback loop is colored in the same color. Comparing the results of analysis of 1990-year data with the data for 1980–1985 it is possible to see that the hierarchy of spatial production cycles for all 3 years is very similar and the intensities of feedback loops are diminished in the same rate. Especially important the similarity of two first biggest feedback loops: each of them in each time period, 1980–85–90, 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 II).

The meaning of this growing spatial symmetry is in that there is a tendency towards the intensive bilateral trade

TABLE III Qualitative characterization of the vertical specialization feedback loops for the triad (Kanto, Chubu, Kinki) from the first inter-regional, inter-activities feedback loop, 1990

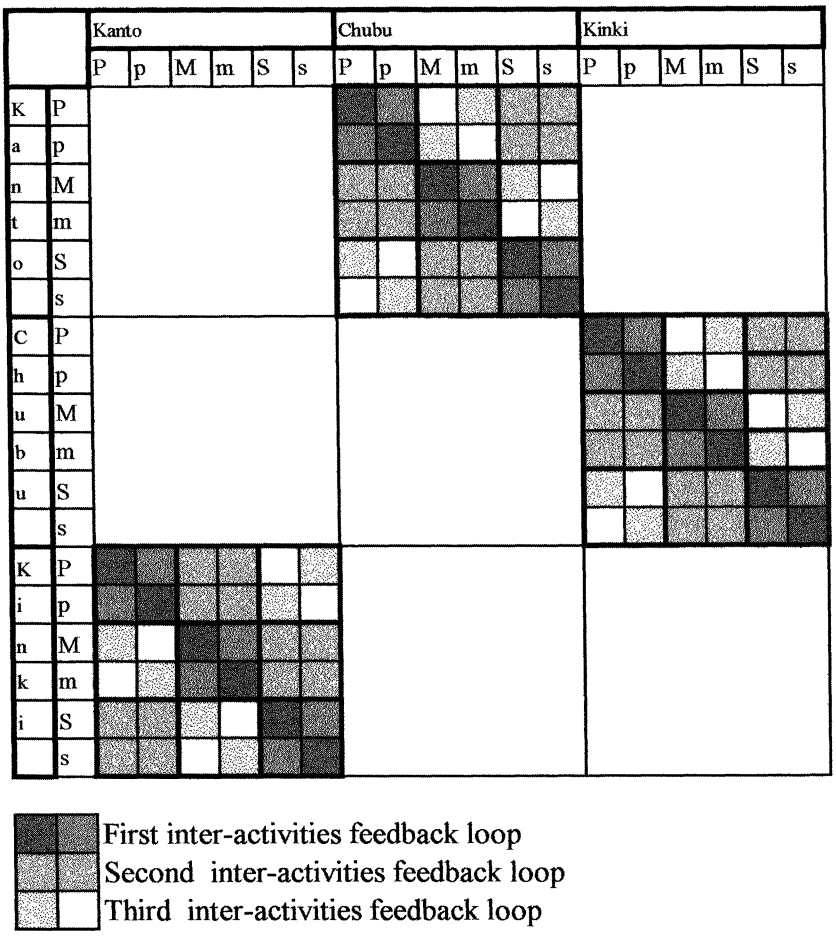
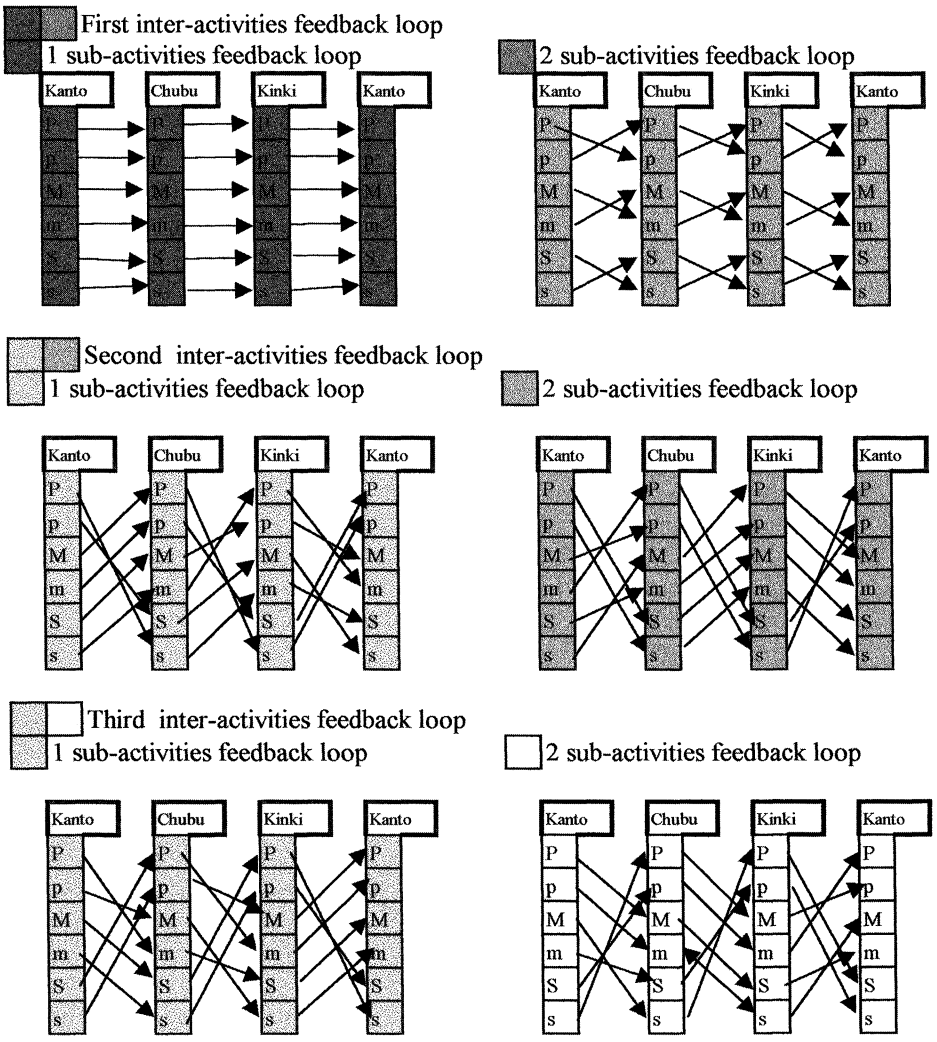


TABLE IV Total inter-regional, inter-activities and sub-activities feedback loops structure for the triad (Kanto, Chubu, Kinki), 1990



relationships between regions. In the midst of this bilaterally connected production cycles the triads (Kanto, Chubu, Kinki) and (Kanto, Kinki, Chubu) are emerging. The prominence of these two triads is already recently stressed in the literature. Ihara (1999, p. 104), concludes "about 66.1% 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 inter-regional system.

Table III represents the qualitative characterization of vertical specialization of these three regions included in the first spatial production cycle feedback loop. The functional economic content of this feedback loop is presented in Table IV.

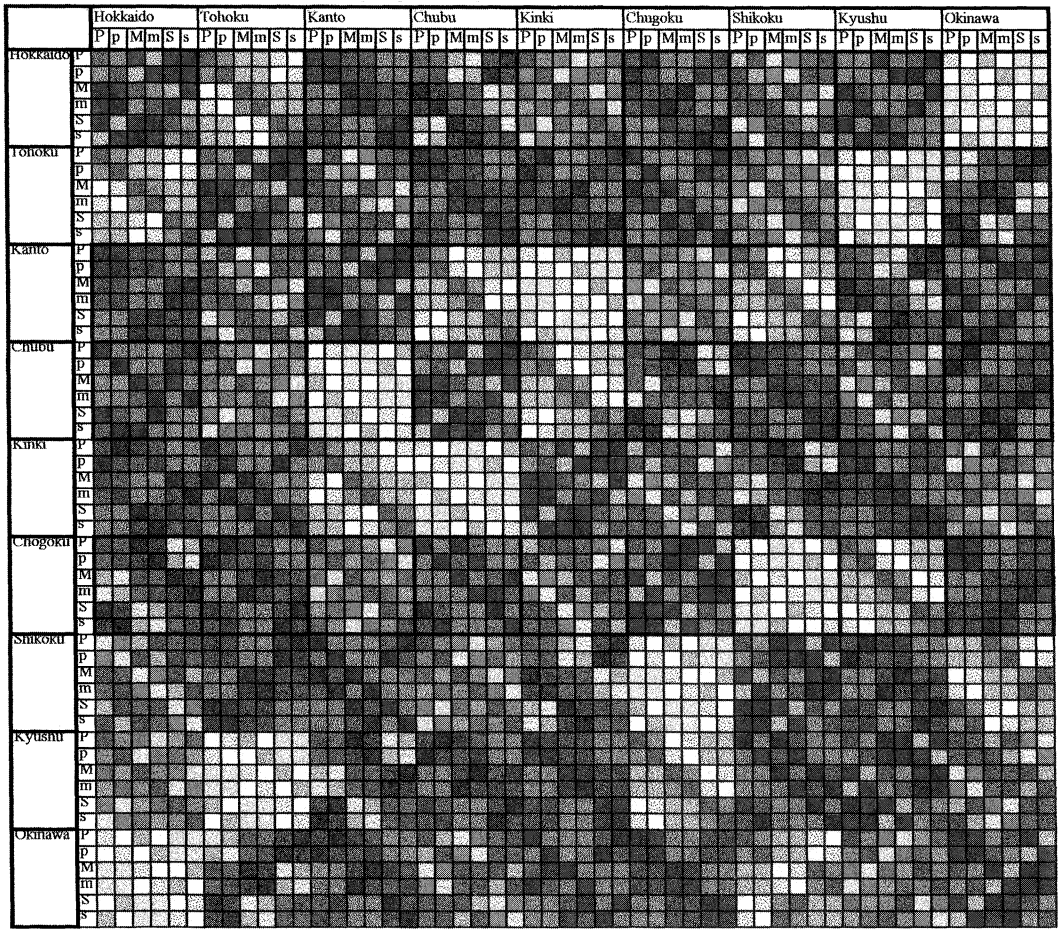
We have a hierarchy of three inter-activities production cycle feedback loops each of it including two sub-activities loops. Within the first inter-activities feedback loop the most prominent is: (1) sub-activities feedback loop which include the trade flows not abandoning the sub-activity; (2) sub-activity loop which flowing between sub-activities within the activity. The second and third inter-activities loops present the more complicated flow structure between the sub-activities.

The fine structure of production cycles of the inter-regional economic activities and sub-activities feedback loops can be extracted from the Table V presenting these loops in myriad of details.

THE USEFULNESS OF TURBULENCE ANALOGY IN THE ANALYSIS OF INTER-REGIONAL TRADE

It is important to note that the consideration of the production cycle feedback loops in the trade theory is a

TABLE V Hierarchy of inter-regional, activities, inter-activities spatial production cycles, 1990



relatively new substantial event connected to the detailed analysis of vertical specialization of trade flows. Thus, the turbulence analogy is connected with an essential phenomenon in trade theory.

Further, this analogy leads to the decomposition of the global trade into spatial production cycle feedback loops whose structural role is similar to the role of individual whirlpools in the turbulence theory. Thus, the analytical technique of the permutation matrices and of the decomposition of flow into feedback loops can be utilized in trade. Moreover, the economic intensity of different feedback loops is analogous to the distribution of energy between different whirlpools. Such a similarity leads to the hierarchical ordering of the production cycle feedback loops with respect to intensity of flows within the production cycle loop.

Furthermore, the scaling of feedback loops, which is connected to spatial and functional production cycle economic disaggregation of trade, leads to the Matrioshka imbedding principle of hierarchical inclusion of economic activities flows into the spatial loops.

The essential consequence of the decomposition of the overall matrix trade flow into the sum of block-permutation matrices of production cycles feedback loops is the possibility to visualize the trade feedback loops with the help of coloring of different feedback loops in different colors. This visualization represents in fine detail the rich information about spatial and economic interdependencies within inter-regional trade on the spatial macro-economic level of inter-regional Primary Secondary and Tertiary economic activities, sub-activities and individual industries. In such a manner the trade tables can be converted into colored spatial and functional maps of the hierarchy of production cycles feedback loops.

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