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Time-Series Modeling of Gross Migration and Dynamic Equilibrium

by

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1: INTRODUCTION

The phenomenon of population dispersal identified in many developed countries post 1970 (Beale, 1977; Vining and Kontuly, 1978; Vining, Pallone and Plane, 1981; Vining, 1982) has become a major research issue. Against all expectations net in-migration to core regions has been consistently declining (Kuroda, 1977), and even became negative in some countries.[1]

One could argue that the agglomeration economies in big cities have apparently disappeared due to the improvement of communication facilities. Firm's locational decision may no longer be restricted by conventional Alfred Weber imperatives of distance and accessibility. Rather other determinants such as land rent, taxes and labor availability may be more important (Engle, 1979). Relocation of capital from the core regions to the periphery may have accelerated the recent phenomenon of urban/rural migration in many countries. From a viewpoint of workers, the attractiveness of big cities seems to have been reduced substantially, possibly due to the deterioration of the urban environment, long-distance commuting, the high cost of city living, and so on.

All of these factors can be considered to have caused

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[1] Throughout this paper, the core is defined as metropolitan area or urban area including suburbs, and the periphery is defined as rest of the nation.

population dispersal. However, questions remain to be unanswered. For example, is the pattern of gross migration flows consistent with the above description of population reversal? In this paper, gross migration, not net migration, is the analytical category. Net migration is not an adequate behavioral concept. After all there is no such thing as a "net migrant." Although net migration is becoming smaller due to the declining importance of rural/urban migration, Zelinsky(1971) has argued that gross migration flows seem nevertheless to be related to patterns of economic growth and social integration. Improvements in communication and transportation have increased information of job opportunities in far regions and has decreased the physical and psychic costs of movement. In addition, because of changing technology and the growth of "newer" industries, the demand for labor may be changing both with respect to skill and location. Thus, relocation of labor and hence urban/urban migration may be indispensable for rapidly growing economy.

To adequately describe the transition from net migration inflow to net migration outflow for core regions, conventional cross-sectional analysis is simply inadequate. Cross-sectional analysis deals only one period. Analysis of various years and their temporal interdependencies could yield different results from cross-sectional analysis and may not then lead to generalizations of the dynamics of migration itself. The static nature of cross-sectional studies is a serious problem especially when the reasons for migration or migrant's locational preferences may have changed so abruptly. Hence, to understand the dynamic behavior of interregional migration, time-series analysis is clearly preferable.

The recent phenomenon of sharp changes in net migration seems to be discontinuous and hence catastrophic modeling (Casetti, 1981) may be appropriate. However, this paper considers gross migration between cores and peripheries for which a continuous function seems adequate as will be seen later. This may be done by introducing a multivariate time-series model.

Migration is known to be selective. The propensity to migrate varies by migrant's attributes, such as age, income, education, and length of residence though these attributes tend to be highly correlated with each other. As is often the case with macro migration data, flows are recorded without disaggregation by the attributes causing the aggregation biases. Since the reasons for migration vary between groups, "aggregated" reasons are likely to be obscure specific patterns.

The propensity to migrate is also, empirically, a function of place attributes: origin, destination, interaction, and regional-competitive characteristics (Alonso, 1978). Misspecification and omission of significant explanatory variables would lead to different results concerning the significance of various coefficient estimates (Alperovich, Bergsman and Ehemann, 1977). As the determinants of migration vary according to migrant's characteristics as well as place attributes, there must also be various "aggregated" determinants of migration in macro data. It seems, therefore, almost impossible to obtain statistically significant results controlling for so many variables. Moreover, the more the explanatory variables are, the more one should worry about degrees of freedom and multicolinearity.

Based upon the foregoing, several strategies for dynamic modeling of interregional migration can be identified. In the first place, to describe the long-term transition of interregional mobility, time-series analysis is obviously appropriate. Secondly, to analyze the behavioral aspect of migration, gross flows should be analyzed instead of net flows. Thirdly, in order to reduce specification biases, disaggregation by reason to migrate should be conducted if possible.

Section 2 models in- and out-migration with respect to three categories of migration in a dynamic context. Aggregation through a simultaneous system of equations for in- and out-migration is then conducted. A bivariate time-series model is used to analyze the dynamic stability of equilibrium. In section 3, this proposed model is tested empirically using Japanese migration data, which is then compared with a U.S. migration analysis conducted in Section 4. These theoretical and empirical findings are summarized in the final section.

2: THEORETICAL RELATIONSHIPS BETWEEN IN- AND OUT-MIGRATION

It is widely observed that the propensity to out-migrate is negatively related to the length of residence.[2] It follows that the out-migration rate is a function of one's history; more recent in-migrants are more likely to move out compared to past in-migrants who have stayed. The purpose of this section is to analyze the temporal relationships between in- and out-migration in each region.

Under zero natural population growth, the components of regional population change can simply be written as

$$\begin{aligned} P(t) &= P(t-1) + IM(t-1) - OM(t-1) \\ &= P(0) + \sum_{\tau=0}^{t-1}[IM(\tau) - OM(\tau)] \end{aligned} \tag{1}$$

where P(t) is the population at t, IM(t) is the in-migration during the period t-1 to t, and OM(t) is the out-migration during the period t-1 to t. For the sake of simplicity, a subscript refering to a region is omitted in this paper.

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[2] For instance, see Gleave and Cordey-Hayes(1977), DaVanzo and Morrison(1976), and Bartel(1979).

This equation means that current regional population is a function of the history of in- and out-migration to and from the region.

Consider a cohort which consists of in-migrants who arrived in the region at time t-k. Suppose each cohort has a different propensity to out-migrate, then unlike equation (1) current population will consists of those cohorts as follows,

$$P(t)=a_1IM(t-1)+a_2IM(t-2)+\ldots+a_kIM(t-k)+\ldots$$
$$=\sum_{k=1}^{\infty}a_kIM(t-k), \qquad (2)$$

where a_k is the ratio of in-migrants who came the region between t-k and t-k+1 and still stay at t to in-migrants who came the region between t-k and t-k+1 (survival rate).

Let q_k be the propensity to out-migrate having the property:

$$q_k \geqq q_{k+1},$$

where k is interpreted as the <u>length of residence</u> usually measured by year. This implies that the probability of out-migrating is negatively associated with the length of residence as mentioned earlier. Then,

$$OM(t)=q_0IM(t)+q_1a_1IM(t-1)+\ldots+q_ka_kIM(t-k)+\ldots$$
$$=\sum_{k=0}^{\infty}q_ka_kIM(t-k), \qquad (3)$$

where a_0 is unity by definition. Since the survival rate a_k

is determined by the previous survival rate a_{k-1} times the probability of stay, then

$$\begin{aligned} a_k &= (1-q_{k-1})a_{k-1} \\ &= \prod_{m=0}^{k-1}(1-q_m). \end{aligned} \tag{4}$$

Substituting equation (4) into (3), one can obtain the following temporal relationship between in- and out-migration using the parameters q_k, the propensity to move out,

$$\begin{aligned} OM(t) &= \sum_{k=0}^{\infty} q_k \left[\prod_{m=0}^{k-1}(1-q_m)\right] IM(t-k) \\ &= \sum_{k=0}^{\infty} q_k \left[\prod_{m=0}^{k-1}(1-q_m)\right] B^k IM(t), \end{aligned} \tag{5}$$

where B is called the <u>backward</u> <u>operator</u> such that

$$B^k IM(t) = IM(t-k).$$

In order to understand the temporal relationship between OM(t) and IM(t), one has to specify the functional form of q_k as

$$q_k = cq^k,$$

where c is the out-migration rate for current in-migrants. In other words, c is the propensity to migrate again within a year. This equation has the form of <u>geometric</u> <u>distribution</u> which implies that the propensity to out-migrate is decreasing at the constant rate 1-q each year.

Consider two extreme cases: in the first instance q is close to zero, and in the second instance close to one. If q is small, the decreasing rate of out-migrating propensity 1-q is high. Then, q_k should decline quickly. If, on the other hand, q is large, the decreasing rate of the propensity is small, i.e., the propensity to out-migrate does not decay according to one's length of residence.

CASE I (q is small)

Since q_0 is much larger than $q_k (k>0)$, most of the out-migrants OM(t) from a region should consist of recent in-migrants IM(t) to the region. As an extreme, let q be zero. Then, the number of out-migrants OM(t) is only a function of IM(t), not IM(t-k) [k>0]. People who come to the region would move out from the region immediately (or in one year). One could interpret that vacancies created by the current out-migrants are immediately substituted by the current in-migrants.[3] This immediate substitution may be exemplified by both job-switching and intra-corporational transfer, which is stated by Clark(1982) using United States data and by Birg(1981) using West German data.

In this case the relationship between in- and out-migration may simply given by

$$OM(t) = \lim_{q \to 0} \sum_{k=0}^{\infty} dq^k \left[\prod_{m=0}^{k-1} (1 - dq^m) \right] B^k IM(t)$$

$$= dIM(t). \qquad (6)$$

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[3] For a further discussion of the notion of vacancy chains, see White(1970).

Since the level of out-migration is usually close to the level of in-migration in developed countries, c would be close to unity.

Thus, in- and out-migration are synchronized without any time lag. The level of in- and out-migration in this case may be determined by labor turnover, quits, layoffs and hires. A growing region would have a high rate of turnover especially voluntary quits as well as hires due to the rapid transformation of economic activity while a depressed region in general would have a low turnover rate except layoffs because the structure of the economy is unlikely to change (Clark, 1980; 1982). Consequently a growing region tends to experience both large in-migration and large out-migration flows whereas a depressed region would experience low in- and out-migration. Migrants are relatively young and likely to migrate again (Kriesberg and Vining, 1978).

<u>CASE II</u> (q is large)

At the other extreme, let q be 1, implying that the propensity to out-migrate q_k is constant over one's in-migration history, i.e., the length of residence. The underlying assumption here is conceptually similar to a Markov process: every cohort in the region has the equal probability of out-migration irrespective of cohort's history. Out-migrants OM(t) are then determined by the regional population, or each group of previous streams of in-migrants IM(t), IM(t-1), IM(t-2),... Mathematically,

$$OM(t)=\sum_{k=0}^{\infty} c a_k IM(t-k).$$

but, since

$$\begin{aligned} a_k &= (1-c)a_{k-1} \\ &= (1-c)^k a_0 \\ &= (1-c)^k . \end{aligned}$$

then

$$OM(t) = \sum_{k=0}^{\infty} c(1-c)^k IM(t-k). \tag{7}$$

This equation (7) expresses the other extreme of the temporal relationship between in- and out-migration. Out-migration is determined by the previous inflows of migration if the natural increase is neglected; in-migration is first, then out-migration occurs (Alonso, 1980). As the propensity to migrate in a year c is constant over time, out-migration becomes a geometrically weighted function of in-migration. This geometric weight $c(1-c)^{k-1}$ is identical to the Koyck distributed lag which is popular in the field of econometrics(Maddala, 1977; Dhrymes, 1971).

Using elementary calculus, eqation (7) can be transformed as

$$OM(t) = \frac{(1-c)c}{1-(1-c)B} IM(t) . \tag{8}$$

or

$$OM(t) = (1-c)OM(t-1) + c(1-c)IM(t) . \tag{9}$$

Indeed this equation (9) is empirically testable by use of a simple regression technique,[4] but the meaning of this model is well represented by eqation (7). That is, out-migration is determined by the long term effects of previous in-migration stream IM(t), IM(t-1), IM(t-2),... Note that although the propensity to out-migrate is constant here, the volume of recent in-migrants is greater than that of previous in-migrants because previous out-migration has caused the decrease in the volume of previous in-migrants.

Presumably equation (9) would describe a nation where <u>return migration</u> is dominant. For instance, in-migrants to urban areas may work or attend school for a few years, but eventually may decide to return to their hometowns for a variety of reasons. For example, dissatisfaction with urban life, the high cost of living, deteriorated environment, poor housing conditions, commuting congestion, and so forth. DaVanzo(1980; 1983) argued that their location-specific capital at their hometown is crucial due to their home ownership and due to much information on opportunities there.

So far only two kinds of migration, job-switching and return migration, are discussed. According to several micro survey data as listed in Table 1, other important reasons for interregional migration are job-search and family related factors such as marriage, both of which are highly depen-

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[4] Properly speaking, non-linear least square regression is suggested in order to remove the autocorrelation in error terms(Maddala, 1977).

dent of the level of information on destination's opportunities(Nelson, 1959; MacKinnon and Rogerson, 1980; Rogerson and MacKinnon, 1982). These opportunities may often be brought by friends and relatives through personal communication. And these friends and relatives are likely to have an experience to be at the destination, or friends' friends might be there. From the employer's perspective, similar issues could be advanced. Employer's decision to hire new employees may depend on labor-supply information, which may be brought by current employees. The more the previous employees from a specific origin is, the more the future recruitment from the same origin would be taken place because the employees could provide more certain information on labor supply at their origin.

Thus, these job-search and marriage types of migration may be determined by previous migration flows which is referred to as <u>chain</u> <u>migration</u> (White and Woods, 1980). This may be formulated as:

$$OM(t)=\sum_{k=1}^{\infty} r_k B^k OM(t)\,. \qquad (10)$$

where r_k is an autoregressive coefficient. If an error term is introduced, this equation can be termed an autoregressive process(AR) in time series analysis(Box and Jenkins, 1976). Usually the coefficients r_k are positive, implying that the previous level of information positively affects the current out-migration. Suppose the destination is economically depressed, however, then the information brought by previous out-migrants might intervene present out-migration. In that case, the parameter on r_k could be negative.

For simplicity, assume the order of AR is just one, AR[1]:

$$OM(t)=rOM(t-1)+e_t\,, \tag{11}$$

where e_t is the error term or the random shock. This means that the current level of OM(t) is merely a function of previous level of OM(t-1) and the random shock at t. Note that this does not mean that OM(t) is irrelevant to OM(t-2), OM(t-3),... As OM(t-1) is also a function of OM(t-2), OM(t) is indirectly a function of OM(t-2) and so is OM(t-3), OM(t-4)... Although the AR[1] assumption may be too strong, parsimony is its advantage. Unless time series data have cyclical components longer than one year, the AR[1] model would reasonably describe the process of migration dynamics.

Summarizing the analytical methodology, the following equations could express the three types of migration:

(1) Job transfer and switching

$$OM(t)=cIM(t)$$

(2) Job search and marriage

$$OM(t)=rOM(t-1)+e_t$$

(3) Return to origin

$$OM(t)=(1-c)OM(t-1)+c(1-c)IM(t)\,.$$

Since these reasons for migration sometimes overlap, aggregated macro data of migration might sum to a linear combination of these three equations with arbitrary weights. Namely, introducing a constant term b'_2 and an error term e'_{2t} , for empirical purposes these three equations could be condensed to

$$OM(t)=a'_{21}IM(t)+a'_{22}OM(t-1)+b'_2+e'_{2t}\,.$$

where a'_{21} and a'_{22} are determined by c and r. It should be noted that in empirical analysis these three kinds of migration reasons are not precisely distinguishable without employing time-series micro data which is currently nonexistent. The empirical estimates of the parameters using macro time-series data only help one to infer the relative importance roughly among those reasons.

In the national account of interregional migration, however, in-migration to a region is identical to out-migration from the rest of the nation while out-migration from a region is equal to in-migration to the rest assuming no international migration (Kriesberg and Vining, 1978). And so, one can exchange OM(t) for IM(t) in all of the previous equations so that in- and out-migration can be viewed from the rest of the nation. If the nation is considered as a system containing two regions: the region itself and the rest of the nation, then the following simultaneous system of equations would describe a complete set of interregional migration flows[5]:

$$\begin{cases} IM(t)=a'_{11}IM(t-1)+a'_{12}OM(t)+b'_1+e'_{1t} \\ OM(t)=a'_{21}IM(t)+a'_{22}OM(t-1)+b'_2+e'_{2t}\,. \end{cases}$$

Essentially, this simultaneous estimation is adequate when the two error terms are correlated or they are influenced simultaneously by random shocks like reces-

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[5] It should be pointed out that unlike most of migration models appeared in the literature, this model does not incorporate socio-economic variables which may depict behavioral aspects of interregional migration. For the purpose of describing gross migration flows in a time-series context, however, it will be shown that these variables are unnecessary because of the adequate Durbib-Watson ratios and the high t-values in simultaneous regression equations in Section 3.

sions. Unlike the single equations system the simultaneous equations system is able to deal with feedbacks between in- and out-migration. Substitution each other in equations (12) yields the following simultaneous difference equations:

$$\begin{cases} IM(t)=a_{11}IM(t-1)+a_{12}OM(t-1)+b_1+e_{1t} \\ OM(t)=a_{21}IM(t-1)+a_{22}OM(t-1)+b_2+e_{2t} \,, \end{cases} \qquad (13)$$

where each a, b and e are uniquely determined by a', b' and e' in equations (12). This set of equations (13) not only incorporates feedbacks both from OM(t-1) to IM(t) and from IM(t-1) to OM(t), but also is appropriate for forecasting purposes due to the lags in right-hand side of equations (13).[6]

Note that unlike a conventional multiple regression model which breaks down origin, destination and interaction factors, this model might be less free from aggregation biases. This proposed model aims to explain the dependent variable (migration) only by the set of interaction terms (also migration but counter streams and previous streams), which must be however a function of origin, and destination characteristics. Although this model cannot deal with an impact of an abrupt change in origin or destination conditions on migration, it would rather describe a long term

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[6] Olvey(1972), Greenwood(1973; 1981) and Williams(1981) introduced the concept of endogeneity of in- and out-migration <u>across region</u> given a period whereas of concern here is the concept of feedbacks <u>over time</u> given a region.

trend of mobility, which seems suitable in modeling the interregional mobility transition.

Next, consider the equilibrium issue of in- and out-migration in the system. Rearranging equations (13),

$$\begin{cases} \Delta IM(t)=(a_{11}-1)IM(t-1)+a_{12}OM(t-1)+b_1+e_{1t} \\ \Delta OM(t)=a_{21}IM(t-1)+(a_{22}-1)OM(t-1)+b_2+e_{2t}. \end{cases} \tag{14}$$

If the error terms could be ignored, the following equilibrium solution of IM^* and OM^* is obtained by solving the linear simultaneous equations setting the changes in IM(t) and OM(t) in equation (14) be zero:

$$\begin{cases} IM^*=\dfrac{(1-a_{22})b_1+a_{12}b_2}{(1-a_{11})(1-a_{22})-a_{12}a_{21}} \\ OM^*=\dfrac{a_{21}b_1+(1-a_{11})b_2}{(1-a_{11})(1-a_{22})-a_{12}a_{21}.} \end{cases} \tag{15}$$

Furthermore, the stability of this solution can be achieved if

(i) $(a_{11}-a_{22})^2+4a_{12}a_{21}\geqq 0$ and $(1-a_{11})(1-a_{22})-a_{12}a_{21}<0$,

or if

(ii) $(a_{11}-a_{22})^2+4a_{12}a_{21}<0$ and $a_{11}+a_{12}\neq 2$.

The former conditions (i) yield a *node* while the latter conditions (ii) yield a *focus* in two-dimensional phase diagram(Pielou, 1969; Yamaguchi, 1971).

It is noted, however, the whole stability issue collapses when the error terms have a certain systematic biases as in the case of misspecification. For instance, imagine the case that the error terms are a function of a business cycle. Then, instead of convergence and stability of the solution, the trajectory in two-dimensional phase diagram must be influenced by recessions and hence may be diverging. The systematic errors can be statistically detected by examining the Durbin-Watson statistic in regression unless there exist complicated errors of more than the first-order autocorrelations.

3: CALIBRATION USING JAPANESE MIGRATION DATA

Using the Japanese annual interprefectural data from 1954 to 194-79 (Japanese Bureau of Statistics, 1954-79), parameter estimation of simultaneous equations (13) is conducted for each region. In order to avoid intrametropolitan migration like suburbanization, forty-six prefectures are aggregated into thirty-two regions: three of which constitute three largest metropolitan areas or core regions, and twenty-nine of which are periphery regions.

In- and out-migration in these three core regions (Kanto, Tokai and Kinki) exhibit a qualitative resemblance as illustrated in Figure 1a. Most of the peripheral prefectures also show the similar migration patterns but in- and out-migration are reversed as compared to those in the core regions (see Figure 1b for a typical periphery). This may indicate that rural/urban and urban/rural migration are dominant relative to urban/urban and rural/rural migration in postwar Japan.

So as to conduct the joint estimation of a's and b's, the "seemingly unrelated regression" technique is used (see Maddala(1977) for details). The estimation result for each region is tabulated in Table 2. One would find the validity of the simultaneous modeling due to the significance in most of the coefficient estimates. Also as little evidence in serial correlation of residuals measured by the Durbin-Watson statistic is detected, there exist less specification biases showing the validity of the proposed model.

The "autoregressive" coefficients a_{11} and a_{22} are consistently positive and close to unity, indicating the importance of the previous migration flow to explain the current migration flow. The "cross" coefficients a_{12} and a_{21} differ significantly but systematically between the core and periphery regions; in cores $a_{12}<0$ and $a_{21}>0$ whereas in most of peripheries $a_{12}>0$ and $a_{21}<0$.

As mentioned above, this clear contrast in the signs between cores and peripheries would come from the dominance of rural/urban and urban/rural migration during the study period. IM(t) in cores behaves similar to OM(t) in peripheries, OM(t) in cores on the other hand is close to IM(t) in peripheries.

Let us consider the meaning of signs of a_{12} and a_{21}. The significant positive values of a_{21} in the cores and a_{12} in the peripheries suggest the very existence of return migration. Rural/urban (or periphery/core) migration is exogenous to urban/rural (or core/periphery) migration, in other words, previous rural/urban migration affects current urban/rural migration with a time lag. Needless to say, as discussed in the previous section, not only migration of the last year but migration of more than one year also indirectly influence the current level of migration.

Using the notations M_{ru} denoted by rural/urban (core/periphery) migration, and M_{ur} denoted by urban/rural (periphery/core) migration, equation for OM(t) in the cores and equation for IM(t) in the peripheries listed in Table 2 may be summarized by

$$M_{ur}(t) = a''_{11} M_{ur}(t-1) + a''_{12} M_{ru}(t-1) + b''_1 + e_{1t} . \qquad (16)$$

where a''_{12} is close to, but greater than 0.0, and a''_{11} is close to, but less than 1.0.[7]

Likewise, IM(t) equations in the cores and OM(t) equations in the peripheries are summarized by

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[7] The only exception out of 32 regions is Hiroshima. As Hiroshima Prefecture has been industrialized, and is recently gaining population through net inflows, it could be classified into core regions.

$$M_{ru}(t) = -a''_{21}M_{ur}(t-1) + a''_{22}M_{ru}(t-1) + b''_2 + e_{2t}\,, \qquad (16')$$

where a''_{22} is close to, but usually greater than 1.0, and a''_{21} is close to, but greater than 0.0.

The negative values of a_{12} in the cores and a_{21} in the peripheries (i.e., the minus sign in the first term of the right-hand-side of equation (16')) requires more careful interpretation. Since $a''_{22}>1$ which means a positive feedback, rural/urban migration seems to have a potential to grow geometrically (or exponentially in a continuous case). However, since $a''_{21}>0$, past urban/rural migration has a <u>negative</u> effect on present urban/rural migration. Although M_{ru} and M_{ur} are normally positively correlated, equation (16') implies that if $M_{ru}(t-1)$ is controlled, $M_{ru}(t)$ is negatively associated with $M_{ur}(t-1)$.

Information of urban areas brought by past return migrants does not necessarily exert a positive influence on future rural/urban migration as is often assumed. It might be plausible that the information of urban areas consists of "bads", such as high cost of living and low quality of life, which rural/urban migrants did not recognize before move. In this instance, they are likely to return-migrate and may intervene prospective rural/urban migrants by giving "bad" information of urban areas.

Alternatively, equation (16') can be rearranged as

$$M_{ru}(t) = \frac{a''_{21}B}{a''_{22}B-1}M_{ur}(t) - \frac{b''_2}{a''_{22}-1} - \frac{1}{a''_{22}B-1}e_{2t}$$

$$=\frac{a_{21}''/a_{22}''}{1-F/a_{22}''}M_{ur}(t)-\frac{b_2''}{a_{22}''-1}-\frac{F/a_{22}''}{1-F/a_{22}''}e_{2t}$$

$$\doteq\frac{a_{21}''}{a_{22}''}\sum_{k=0}^{\infty}a_{22}''^{-k}M_{ur}(t+k)-\frac{b_2''}{a_{22}''-1}-\sum_{k=1}^{\infty}a_{22}''^{-k}e_{2(t+k)}, \qquad (16'')$$

where $B^{-1}=F$ (the *forward operator*). Equation (16") may provide another interpretation that ignoring the error terms current rural/urban migration is a linear function of *future* urban/rural migration, i.e., current in-migrants to metropolitan areas have a potential to out-migrate in future. Recall that equation (7) shows that current out-migrants from metropolitan areas consists of *past* streams of in-migrants.

Let us now consider the equilibrium solution and its dynamic stability based on the estimates of the simultaneous equations. Calculating those conditions of (i) and (ii) in Section 2, it was found that gross migration is expected to approach a stable equilibrium: thirty-one regions have a focus and one region (Ishikawa) has a node in two-dimensional phase diagram. Figure 2a of a typical core and Figure 2b of a typical periphery respectively illustrate the each trajectory approaching the focus. The solid lines in these figures depict actual observations from 1954 to 1979 that are two-dimensional mapping of Figures 1a and 1b respectively. The broken lines spiraling to the focus exhibit forecasts from 1980 which are computed by the simultaneous system of equations (13). Note that these nonlinear curves can be depicted by the simultaneous equations.

Two other core regions behave similar to Figure 2a, and the other peripheries are also similar to Figure 2b although some of them cut across the 45 degree line, i.e., switching the sign of net migration. Indeed, whether net migration is positive or negative is of importance in a short-run regional planning, especially in terms of labor supply and housing demand, but it may be a transient net flow in view of long-run regional growth. What is important for long-run growth of region would be the accumulation of net migration determined by dynamic behavior of in- and out-migration.

Provided that the future trend in in- and out-migration would follow the previous trend as estimated by equations (13), irrespective of the future random shocks the predicted trajectory in each region would attain the stable equilibrium point listed in Table 3. Comparing in- and out-migration at the equilibrium solution in this table, it is predicted that all of the cores would experience population gains from net in-migration in future although two of them (Tokai and Kinki) were always losing population through net outflows during 1970s. Therefore, this suggests that under zero natural increase, population in the cores is expected to grow almost linearly in future and that most of the peripheral populations are expected to decline linearly.

4: COMPARISON WITH U.S. LABOR FORCE MIGRATION

The identical analysis was conducted by use of the annual estimates of the U.S. labor force migration from 1958 to 1975 which are derived from the Continuous Work History

Sample of the Social Security Administration and the U.S. Bureau of Economic Analysis(1976). Again so as to lessen the suburbanization movements, fifty States were aggregated into forty-five regions. For inter-country comparison, of interest here is the three largest metropolitan areas: New York urbanized area, Chicago urbanized area, and Los Angeles urbanized Area.[8]

Table 4 exhibits the parameter estimates of equations (13) for these three cores. Unlike the Japanese case of Table 2, more than half of the estimates are insignificant indicating less adequacy of the model. Presumably U.S. labor force migration does not contain a one-year lag structure, that is, in- and out-migration are synchronized in time possibly due to the dominance of job switching and transfer. On the other hand, a great portion of Japanese migration may be rural/urban migration especially during the rapid growth period before 1970 which is followed by return (urban/rural) migration during 1970's. The bivariate time-series model may thus be able to depict the mobility transition from rural/urban to urban/rural migration in Japan, but not the urban/urban and circulation migration in the United States.

Substituting those estimates in Table 4 into equation

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[8] In this paper, New York urbanized area consists of four States: New York, New Jersey, Pennsylvania and Conneticut. Chicago urbanized area consists of three States: Illinois, Indiana and Wisconsin. And, Los Angeles urbanized area means California State.

(14), it is found that a stable equilibrium (node) is obtained in New York and Los Angeles urbanized areas, but not in Chicago urbanized area, as shown in Table 5. Firstly, these steady state values are much greater than the current level (1958-75) of in- and out-migration. One may infer that both gross migration flows in these core regions would continue to grow if they followed the previous trends. Secondly, since the steady state out-migration (if existed) overweighs in-migration in every core, future net migration would be negative all the way.

Interestingly these two results, however, are opposite to the Japan's results. It goes without saying that there must be many social, economic, political, geographic and demographic reasons for the differences between the two nations. The former difference(the levels of steady state values between the two nations) may be ascribed to to the fact that U.S. migration has been nonstationary, i.e., steadily increasing during the study period whereas Japanese migration has experienced the turndown, as seen in Figures 1a and 1b. That is, in the stationary process the steady state values converge close to current values of migration whereas they do not in the nonstationary process of the United States.

The latter difference (the signs of net migration between the two nations) is difficult to interpret. If these trends continued forever under zero natural growth of population, the large metropolitan areas in the United States would diminish while those in Japan would absorb all of the nonmetropolitan population owing to the never-ending net inflows albeit to attain such a state would require much time.[9] Needless to say, this is unrealistic as compared to the existing seemingly stable distribution of city sizes in every nation (Auerbach, 1913; Richardson, 1973; Tabuchi, 1982). As Zipf(1949) advocated several decades ago, the force of diversification like the U.S. forecast and the force of unification like Japan's forecast might have to be balanced in some way. It is presumably needed to incorporate the concept of "saturation" as a constraint, which seems to be extremely difficult without imposing strong assumptions.

The model presented here may be thus applied to descriptive purposes and it's validity may be limited to only a short-term forecast. Nevertheless, this simple model not only avoids the complex specification problems of functional forms argued by Tabuchi(1983), but also could make the description of the recent population turnaround possible by introducing the feedbacks and lag structures of in- and out-migration.

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[9] This finding is compatible with Okabe(1980)'s analytical result that the stable population distribution under zero natural growth (i.e., net migration convergence) is rarely attained in population-dependent gravity models.

5: SUMMARY

Firstly, the high association between in- and out-migration is investigated in a time-series context and modeled with respect to three categories: (1) job transfer, (2) job search and marriage, and (3) return migration. Under certain conditions it is shown that aggregation of these migrations yields a bivariate time-series model having feedbacks in both directions.

Secondly, the recent phenomenon of sharp changes in net migration seems to be discontinuous and hence catastrophic modeling (Casetti, 1981) may be appropriate. However, this paper considers gross migration between cores and peripheries for which a continuous function seems adequate. This is done by introducing a multivariate time-series model. This model is empirically supported, especially in Japan, by t-tests and Durbin-Watson ratios although it does not contain any economic variables such as employment growth and wage differentials. This may imply that the recent dispersal may be explained primarily by feedbacks due to the existence of return migration.

Finally, provided that future streams of gross migration follow the past trends given by simultaneous equation estimates, it is shown that in- and out-migration would approach a stable state in most of regions. In other words, irrespective of random shocks in the future, in- and out-migration would tend to approach a stable equilibrium. According to the estimation of the stable states, the core regions in the United States would continue to lose population through net outflows while those in Japan would continue to gain.

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Source	Data	Reason for migration	%
Lansing and Mueller (1967)	1962-63 U.S. intercounty migration	Transfer, reassignment of head	20
		Unemployment; moved to find new, more, or steadier work	15
		Higher rate of pay; A better job	29
		Other economic reason	16
		Non-economic reason	26
Long and Hansen (1979)	1974-76 U.S. interstate migration	Job transfer	23.8
		New job or looking for work	23.6
		Other employment reason	2.4
		Wanted change of climate	5.1
		Moved to be closer to relatives	7.5
		Other family reason	9.1
		Retirement	3.4
National Land Agency (1982)	1980 Japanese inter-prefectural migration	Job transfer	30.0
		Job search or change	23.2
		Family reason (to live with or closer to family, or succession of family business)	19.1
		Marriage	7.4
		School	7.5
		Other reason	12.8

Table 1. Percent Distribution of Reasons for Migration in the United States and in Japan

	a_{11}	a_{12}	b_1	a_{21}	a_{22}	b_2	D.W.	D.W.
[CORE]								
Kanto	1.101*	-.209*	262.	.223*	.819*	-565.	1.20	2.69
Tokai	1.155*	-.333*	351.	.279*	.654*	98.4	1.46	1.43
Kinki	1.066*	-.229*	435.	.223*	.829*	-275.	1.87	2.36
[PERIPHERY]								
Hokkaido	.731*	.101*	105.	-.403*	1.021*	265.	2.31	1.51
Aomori	.790*	.157*	5.08	-.173	1.037*	44.9	2.77	1.55
Iwate	.844*	.119*	.235	-.228*	1.043*	46.5	2.85	1.59
Miyagi	.774*	.397*	-90.7	-.074	.972*	57.3	2.66	2.20
Akita	.868*	.156*	-26.2	-.309*	1.051*	48.2	2.14	1.57
Yamagata	.942*	.085*	-16.1	-.351*	.949*	90.5	2.24	1.57
Fukushima	.933*	.155*	-69.3	-.180*	.955*	95.9	2.21	1.97
Niigata	.885*	.577	4.02	-.303*	.967*	132.	1.48	1.72
Toyama	.851*	.177*	-12.2	-.144*	1.083*	5.56	1.60	1.43
Ishikawa	.770*	.343*	-31.4	-.000	.916*	21.3	1.59	1.47
Fukui	.885*	.201*	-16.0	-.082	.913*	26.7	1.92	1.70
Yamanashi	.958*	.213*	-41.5	-.101	.909*	35.9	1.79	2.11
Nagano	.959*	.027	4.43	-.141	.852*	115.	1.43	1.78
Tottori	.870*	.181*	-13.0	-.176*	1.034*	19.5	2.42	2.67
Shimane	.898*	.124*	-14.5	-.326*	1.018*	57.3	1.70	2.29
Okayama	.574*	.544*	-120.	-.085	1.028*	26.5	1.47	1.74
Hiroshima	1.153*	-.316	123.	.225*	.657*	91.6	1.04	1.72
Yamaguchi	.597*	.188*	32.2	-.389*	1.075*	131.	2.58	2.12
Tokushima	.878*	.168*	-19.8	-.219*	1.010*	33.4	2.21	2.50
Kagawa	.717*	.509*	-76.4	-.106	.959*	41.8	2.20	2.35
Ehime	.849*	.180*	-29.9	-.266*	1.023*	75.4	2.51	1.95
Kochi	.845*	.182*	-15.2	-.297*	1.006*	52.2	2.20	2.40
Fukuoka	.790*	.154*	65.5	-.277*	1.019*	327.	2.49	1.25
Saga	.789*	.067	28.7	-.777*	.980*	203.	1.77	1.43
Nagasaki	.780*	.137*	7.24	-.473*	.951*	243.	2.09	1.75
Kumamoto	.843*	.164*	-27.1	-.359*	1.013*	157.	2.08	1.70
Oita	.801*	.267*	-47.4	-.208*	1.039*	52.0	1.92	2.19
Miyazaki	.850*	.177*	-21.5	-.271*	1.011*	85.2	2.48	1.59
Kagoshima	.935*	.195*	-.112	-.266*	.911*	206.	2.00	2.18

Note: Kanto consists of 7 prefectures: Tokyo, Saitama, Chiba, Kanagawa, Gumma, Tochigi and Ibaraki.
Tokai consists of 4 prefectures: Aichi, Gifu, Shizuoka and Mie.
Kinki consists of 6 prefectures: Osaka, Hyogo, Kyoto, Shiga, Nara and Wakayama.
Names under PERIPHERY is corresponding to prefectures.
Estimates of b's are by 100.
* implies significant at 0.05 level.

Table 2. The Estimates of Simultaneous Equations in Japan

	IM*	OM*
[CORE]		
Kanto	5843	4077
Tokai	2258	2105
Kinki	3453	2895
[PERIPHERY]		
Hokkaido	704	834
Aomori	346	405
Iwate	270	353
Miyagi	566	551
Akita	214	349
Yamagata	210	333
Fukushima	388	578
Niigata	428	67
Toyama	152	197
Ishikawa	242	254
Fukui	150	165
Yamanashi	153	225
Nagano	381	414
Tottori	145	176
Shimane	191	274
Okayama	479	508
Hiroshima	711	734
Yamaguchi	441	539
Tokushima	163	236
Kagawa	277	304
Ehime	321	435
Kochi	181	236
Fukuoka	1270	1307
Saga	252	365
Nagasaki	445	662
Kumamoto	459	605
Oita	329	423
Miyazaki	335	405
Kagoshima	697	232

NOTE: The sum of IM* (2,245,400) is not equal to that of OM* (2,124,300) because the estimation and forecast are performed separately by region. However, a method to incorporate the cross-sectional system constraint in a time-series context is not developed to the author's knowledge.

Table 3. The Steady State Solutions in Japan (by 100)

Urbanized area	a_{11}	a_{12}	b_1	a_{21}	a_{22}	b_2	D.W.	D.W.
New York	1.103*	-.091	182.	2.168	-.653	1650.	1.67	1.83
Chicago	.081	.735*	603.	-.149	1.125*	214.	1.52	1.74
Los Angeles	.879*	.065	413.	1.608*	-.250	-1680.	1.91	2.10

NOTE: The estimates of b's are by 100.
* implies significant at 0.05 level.

Table 4. The Estimates of Simultaneous Equations in the U.S.

Urbanized Area	IM*	OM*
New York	16657	20855
Chicago	∞	∞
Los Angeles	8845	9954

Table 5. The U.S. Steady State Solutions (by 100)

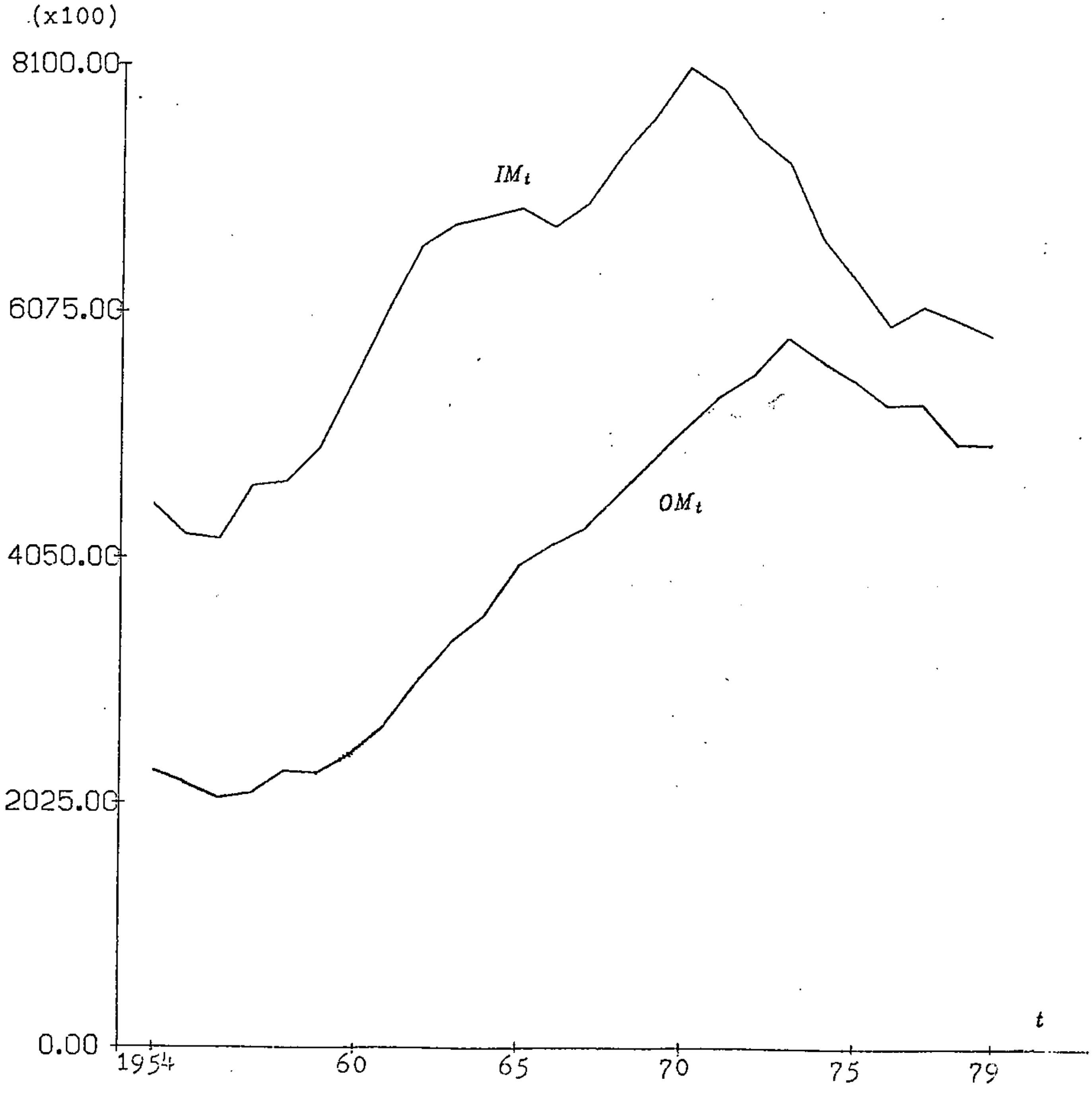

Figure 1a. In- and Out-Migration in a Typical Core (Kanto Region)

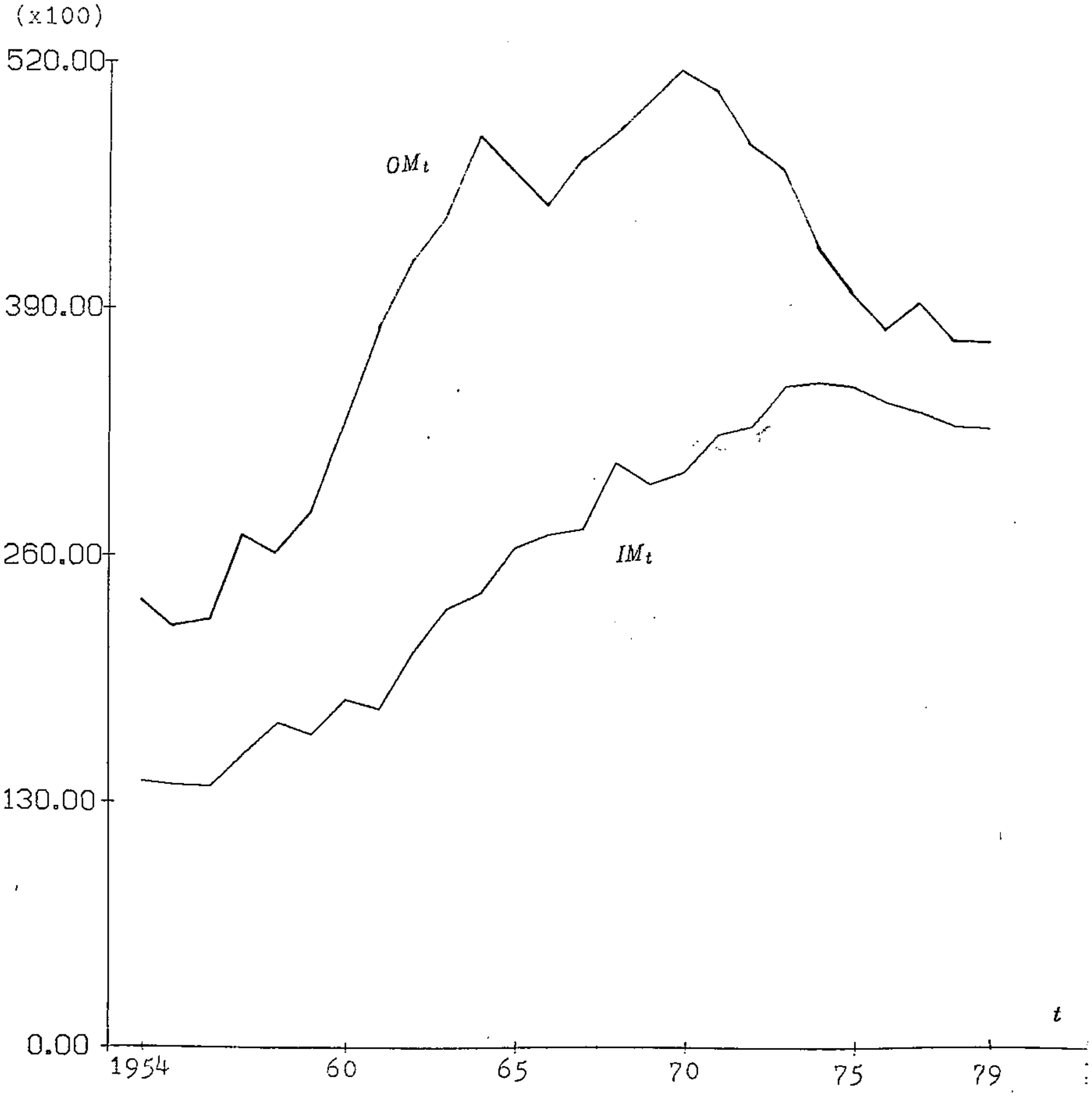

Figure 1b. In- and Out-Migration in a Typical Periphery (Iwate Prefecture)

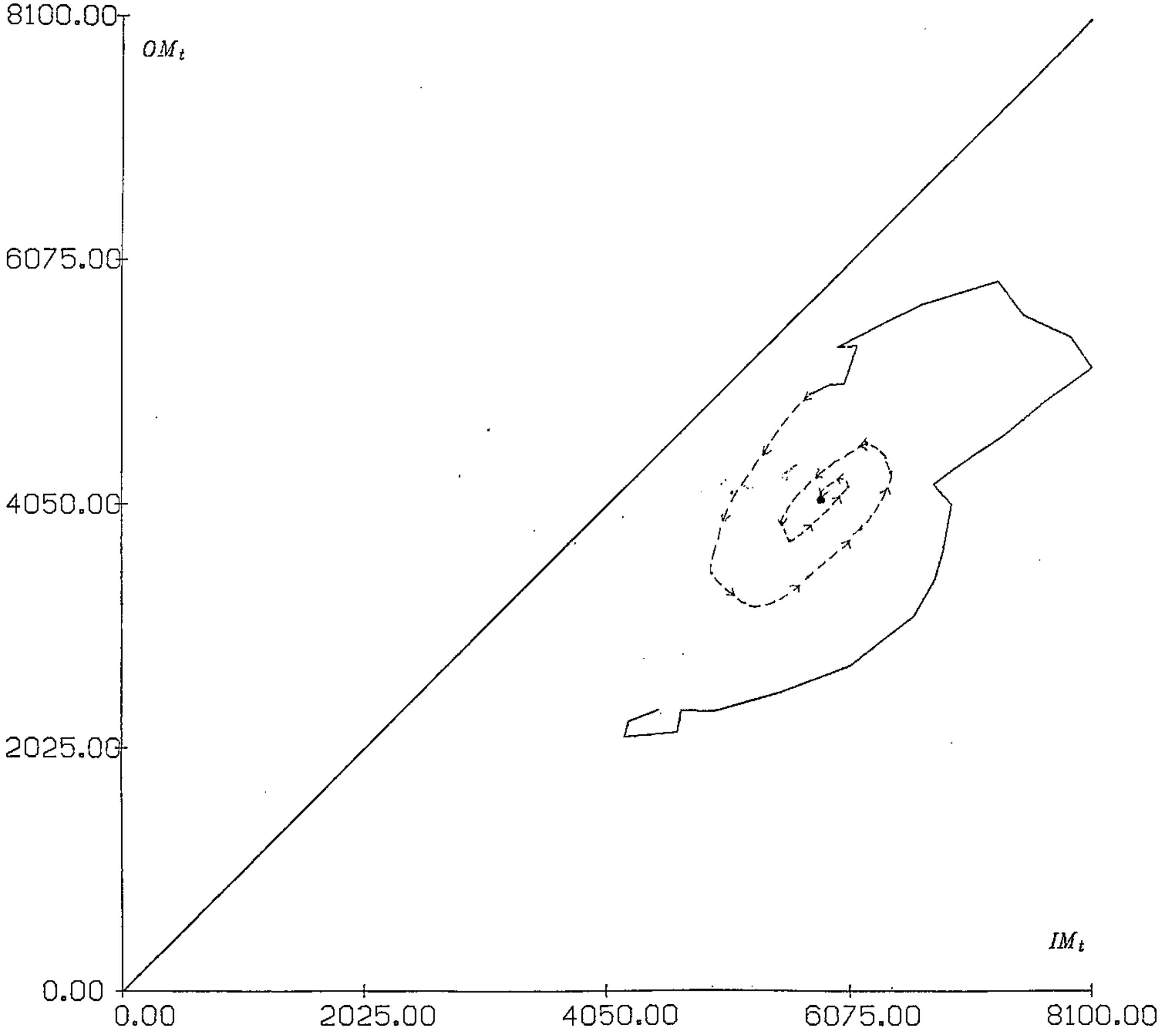

Figure 2a. Phase Diagram of a Typical Core (Kanto Region) by 100

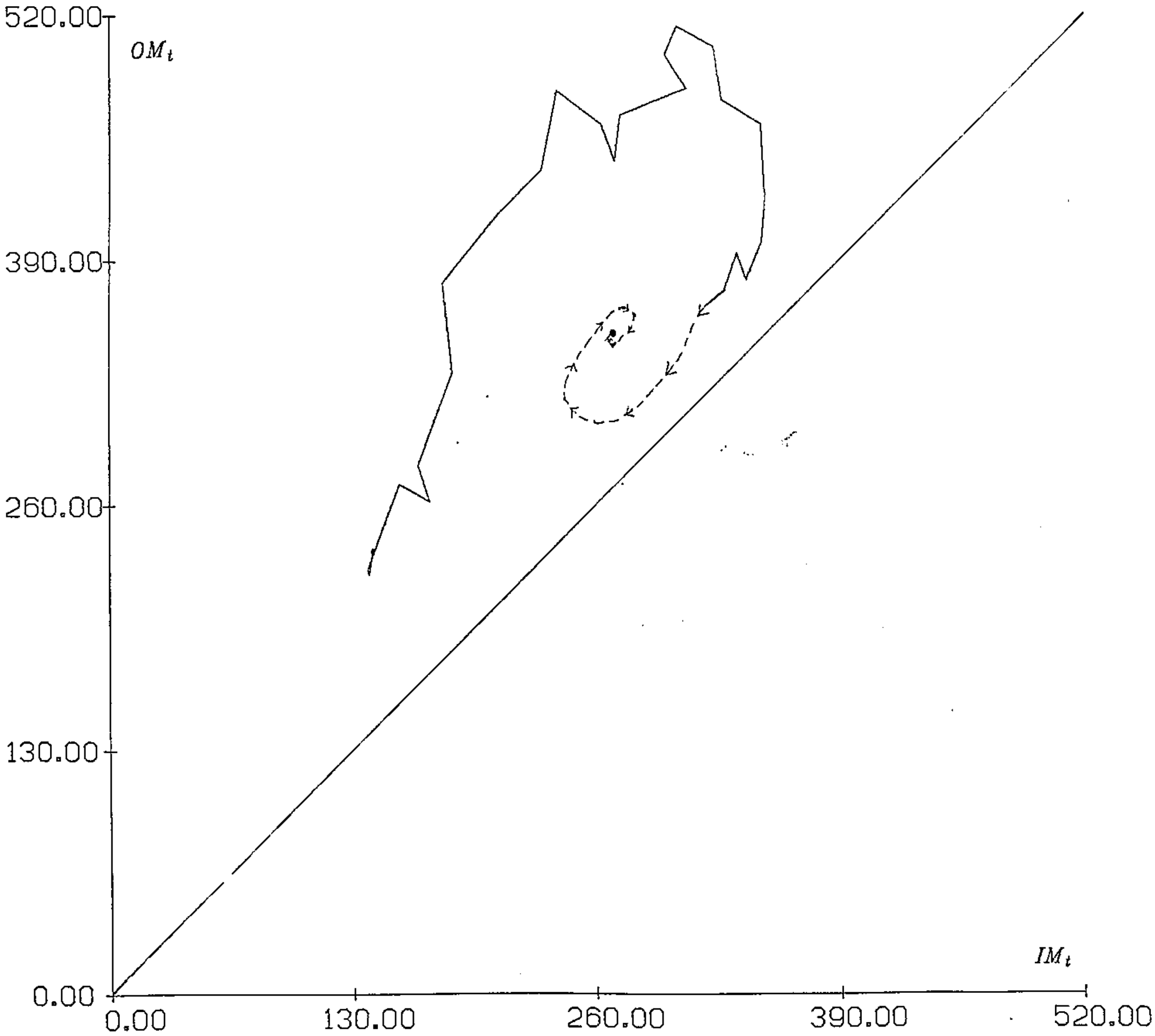

Figure 2b. Phase Diagram of a Typical Periphery (Iwate Prefecture) by 100