The Characteristics of the Changes of the Distribution of Population of Cohorts in Japan

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I Introduction*

The distribution of population of Japan has steadily changed since we had the first statistics from the census of this country. Especially, it attracts our attention that the population has concentrated to urban regions. Table 1 and Figure 1 show the change of the proportion of the urban population to the total population in Japan.[1)]

The change is represented by the logistic curve:[2)]

$$p_U = \frac{89.87603}{1+4.1491e^{-0.28275(t-1920)/5}} \tag{1.1}$$

where p_U is the proportion of the urban population to the total population and t is year.

As the result of the ceaseless migration of population which caused the concentration of population to urban regions, the structure of population by age in urban areas became dissimilar to that in rural areas. For example, the type of the population pyramid of Minami-Kanto Region which is regarded as an urban region is different from that of Kita-Kanto Region which is regarded as a rural area and that of all Japan as shown in Figure 2.

The parts from 0 to 10 years of age and from 20 to 40 years of age of the population pyramid of Minami-Kanto Region are wide, while the same parts of Kita-Kanto Region and of all Japan are narrow. And the other parts of the population pyramid of Minami-Kanto Region are narrower as compared with the width of the parts of Kita-Kanto Region. This fact is caused by the particular behavior found in the migration of each class of population by age.

We would be able to find the particular behavior of migration by the analysis of the informa-

Table 1 Populations in the urban regions and the rural regions in Japan

Year	Population (thousand)		Proportion (%)	
	Urban regions	Rural regions	Urban regions	Rural regions
1920	10 097	45 866	18.0	82.0
1925	12 897	46 840	21.6	78.4
1930	15 444	49 006	24.0	76.0
1935	22 666	46 588	32.7	67.3
1940	27 578	45 537	37.7	62.3
1945	20 022	51 976	27.8	72.2
1950	31 366	52 749	37.3	62.7
1955	50 532	39 544	56.1	43.9
1960	59 678	34 622	63.3	36.7
1965	67 356	31 853	67.9	32.1
1970	75 429	29 237	72.1	27.9
1975	84 964	26 973	75.9	24.1

Source: Bureau of Statistics, Office of the Prime Minister, Japan: *Population of Japan, 1975 Population Census of Japan*, Abridged Report Series No. 1 Tokyo, Nihon Tokei Kyokai, 1977.

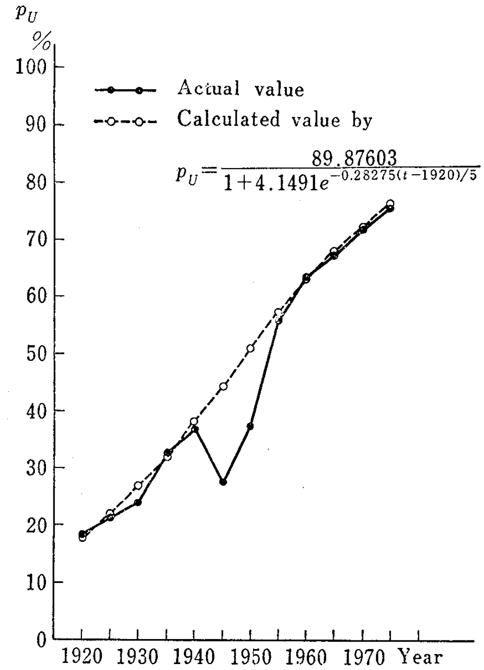
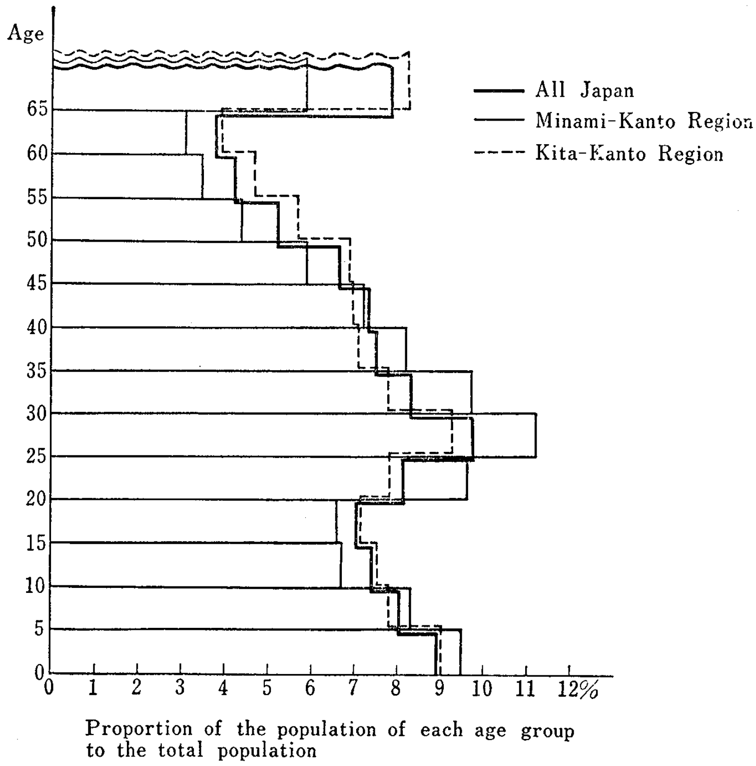


Figure 1 The proportion of the urban population to the total population in Japan



Source: Bureau of Statistics (1977): *op. cit.*, p. 41.

Figure 2 The population pyramids of Minami-Kanto and Kita-Kanto Regions and all Japan tion obtained from the data of cohorts (a group of persons who have the same year of age, or more precisely saying, a group of persons who have the same year of birth).

I studied previously the reaction of cohorts to the regional level of income.[3] According to the previous study, the reaction of young cohorts to regional level of income was very strong. Therefore, we would be able to expect to find some difference between the patterns of migration or changes of the positions of the geographical distributions of cohorts.

In this paper, I examined the characteristics of the change of the state of the geographical distribution of cohorts from two sides: (1) the movement of the location of central points of the distribution of cohorts and (2) the change of the pattern of the distribution of cohorts.

When I analyzed the behavior of the cohorts from the data, I proposed new methods to measure the characteristics of the behavior.

II Effect of the Differences of Regional Levels of Income to the Migration of Population of Cohorts

In this place, before the examinations of the characteristics of the changes of the geographical distribution of the cohorts are done, the effect of the differences of the levels of regional income to the migration of cohorts found by our previous study is stated for clarifying the fact that we can find the cohorts which strongly react to the levels of regional income and those which do not react so strongly to the level, and we would be able to find some difference between the patterns of migration of cohorts.

Suzuki and Nakamura[4] measured the strength of the difference of regional income level to the migration of cohorts by (1) the correlation coefficient between regional income level and migration and (2) the value of a parameter which is found in the regression equation expressing a relation between regional income level and migration.

The regression equation considered here is

$$m(s, x, h) = a + by \tag{2.1}$$

where $m(s, x, h)$ is the net migration rate of a cohort which has years of age from x to $x+h-1$ of a region by sex (s) during the period from year t to year $t+h-1$,[5] y is the income level of a region during the period from year t to year $t+h-1$[6] and a and b are parameters. For showing explicitly the net migration rates for male and female cohorts, symbol $m(M, x, h)$ was used for the net migration rate for male and symbol $m(F, x, h)$ was used for that for female. And the net migration rate for a cohort which contains populations of both sex was expressed by $m(W, x, h)$.

The correlation coefficient r observed here is the coefficient for the regression equation written above, namely equation (2. 1), and a parameter which is examined is the parameter b.

The correlation coefficient of the regression equation r is regarded as the index of the " certainty " of the relationship between the regional income level and the reaction of a cohort to the regional income level, and the value of the parameter b is regarded as an indicator of the " sensitivity " of the migration of a cohort to the regional income level.

The correlation coefficient and the regression equation were obtained for the periods of time from 1955 to 1960, from 1960 to 1965, and from 1965 to 1970 by using prefectural data in Japan.[7] In this analysis, the data for Okinawa were not contained.

Table 2 and Figures 3 and 4 show the values of the correlation coefficient r and the parameter b. These values are regarded as a function of age of cohort. In general, r and b become higher at the vicinity of 15 years of age. From this fact, we can say that the cohorts which have years of age from 10 to 14 and from 15 to 20 react strongly to the regional income level. And since the signs of the coefficient and the parameter are positive, it can be said that they flow into the regions of higher income level from the regions of lower income level.[8]

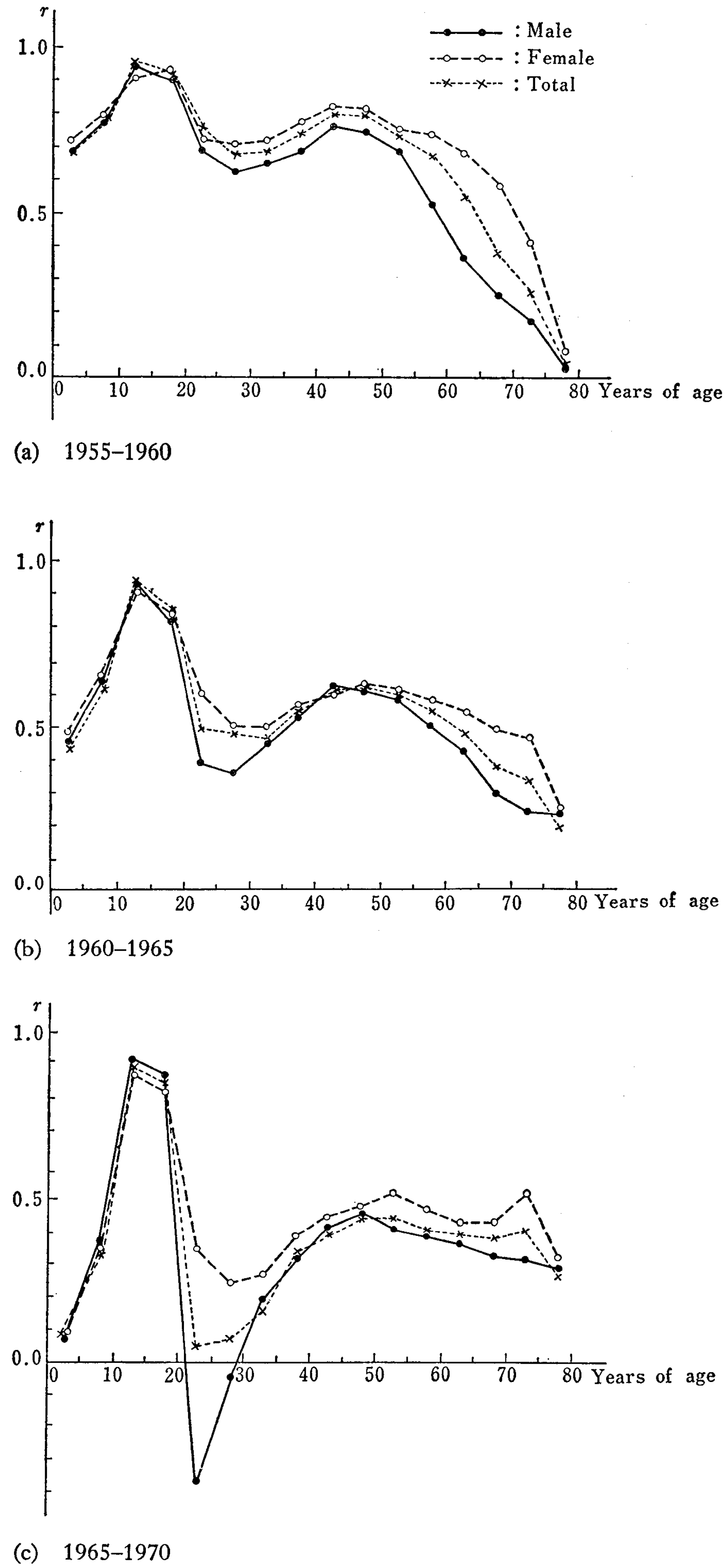
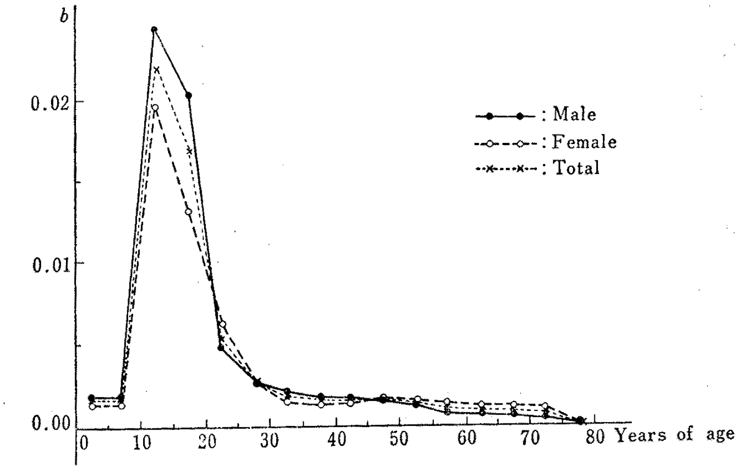
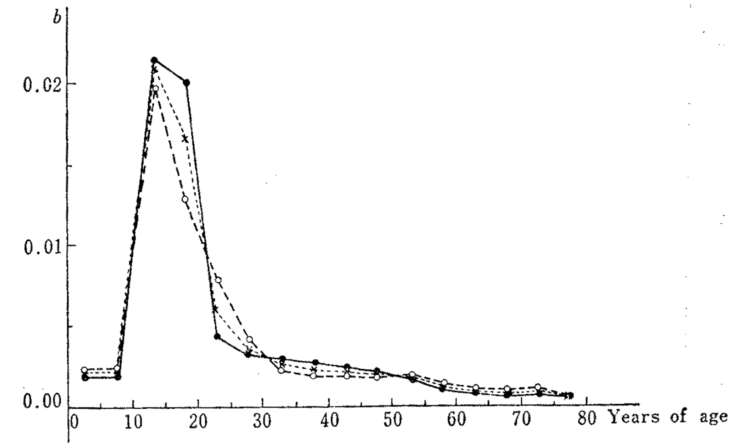


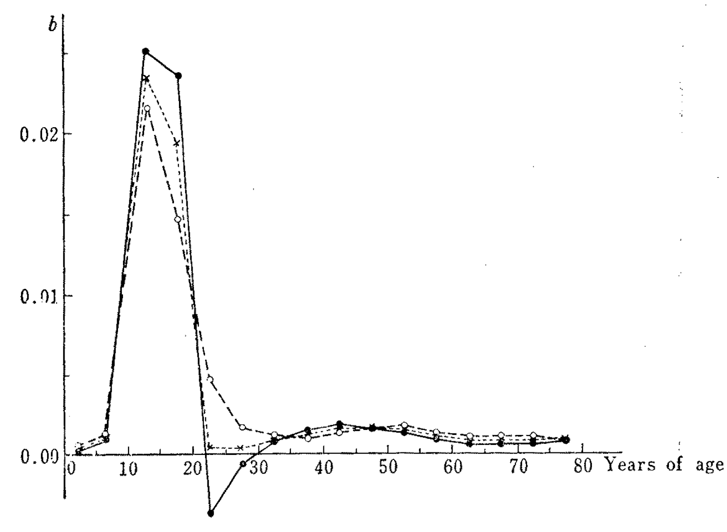
Figure 3 The correlation coefficient of the regression equation: $m(s, x, h)=a+by$ $(s=M, F, W)$ by age group



(a) 1955–1960



(b) 1960–1965



(c) 1965–1970

Figure 4 The value of the parameter b of the regression equation: $m\ (s,\ x,\ h)=a+by\ (s=M,\ F,\ W)$ by age group

Table 2 The values of the parameters a and b of the regression equation: $m(s, x, h)=a+by$ ($s=M, F, W$) and the correlation coefficient r

(a) 1955–1960

Sex	Male			Female			Total		
Age group	a	b	r	a	b	r	a	b	r
All ages	−0.6276	0.006141	0.914	−0.2382	0.004844	0.916	−0.4209	0.0055	0.916
0– 4 years	0.8608	0.001417	0.701	0.7788	0.001374	0.703	0.8207	0.0014	0.695
5– 9	0.1806	0.001441	0.778	0.1992	0.001429	0.780	0.1900	0.0014	0.774
10–14	−0.7210	0.024390	0.938	1.5634	0.019580	0.916	0.4076	0.0220	0.944
15–19	−5.5866	0.020353	0.916	−1.7021	0.013093	0.933	−3.5923	0.0168	0.927
20–24	−1.3708	0.004831	0.693	−2.3115	0.006198	0.729	−2.0115	0.0054	0.753
25–29	0.4472	0.002712	0.630	−0.7828	0.002685	0.713	−0.1797	0.0027	0.676
30–34	0.2015	0.002127	0.656	−0.2733	0.001585	0.718	−0.0509	0.0018	0.687
35–39	−0.0756	0.001651	0.690	−0.4351	0.001427	0.773	−0.2740	0.0015	0.745
40–44	−0.2268	0.001708	0.769	−0.3771	0.001544	0.817	−0.3110	0.0016	0.813
45–49	−0.1785	0.001383	0.750	−0.1940	0.001545	0.809	−0.1908	0.0015	0.800
50–54	0.0631	0.001110	0.684	0.1285	0.001347	0.753	0.0915	0.0012	0.750
55–59	−0.1478	0.000694	0.515	0.1273	0.001267	0.741	−0.0158	0.0010	0.676
60–64	−0.1058	0.000599	0.366	−0.2200	0.001171	0.679	−0.1674	0.0009	0.548
65–69	0.0887	0.000546	0.256	0.2619	0.001183	0.585	0.1874	0.0009	0.382
70–74	−0.4675	0.000346	0.182	−0.3323	0.000962	0.415	−0.3747	0.0007	0.258
75–79	−1.3140	0.000096	0.022	−1.0020	0.000245	0.089	−1.0991	0.0001	0.044

(b) 1960–1965

Sex	Male			Female			Total		
Age group	a	b	r	a	b	r	a	b	r
All ages	0.6732	0.006469	0.745	0.8481	0.005631	0.987	0.7677	0.0060	0.760
0– 4 years	1.0748	0.002163	0.465	1.9680	0.002204	0.465	1.5107	0.0022	0.443
5– 9	0.3741	0.002259	0.628	1.2533	0.002282	0.638	0.8037	0.0023	0.622
10–14	1.5773	0.022456	0.938	4.2896	0.020007	0.902	2.9095	0.0213	0.931
15–19	−5.6693	0.020100	0.818	−1.8037	0.012953	0.838	−3.6859	0.0166	0.841
20–24	3.1815	0.004438	0.386	0.6082	0.007906	0.586	1.5631	0.0061	0.490
25–29	3.3186	0.003422	0.353	1.1880	0.003926	0.490	2.2244	0.0037	0.392
30–34	1.8287	0.002875	0.448	0.9134	0.002369	0.497	1.3772	0.0026	0.451
35–39	0.9956	0.002636	0.538	0.2770	0.001921	0.555	0.6079	0.0023	0.535
40–44	0.6854	0.002443	0.611	0.2876	0.001861	0.604	0.4683	0.0021	0.601
45–49	0.4441	0.002055	0.608	−0.0631	0.001888	0.614	0.1711	0.0020	0.607
50–54	1.1042	0.001867	0.575	−0.0457	0.001790	0.612	0.5092	0.0018	0.589
55–59	0.2713	0.001090	0.500	−0.4120	0.001332	0.585	−0.0760	0.0012	0.543
60–64	0.4466	0.000818	0.416	−0.3833	0.001016	0.537	0.0256	0.0009	0.473
65–69	1.0015	0.000603	0.293	0.3462	0.000984	0.485	0.6615	0.0008	0.377
70–74	1.3394	0.000554	0.239	0.6313	0.001032	0.469	0.9551	0.0008	0.331
75–79	0.4044	0.000583	0.234	0.0931	0.000493	0.249	0.2287	0.0005	0.198

(c) 1965–1970

Sex	Male			Female			Total		
Age group	*a*	*b*	*r*	*a*	*b*	*r*	*a*	*b*	*r*
All ages	0.6873	0.005318	0.634	0.7129	0.004729	0.649	0.7024	0.0050	0.631
0– 4 years	1.8829	0.000405	0.073	1.3018	0.000411	0.076	1.5979	0.0004	0.074
5– 9	1.1151	0.001292	0.369	0.6419	0.001220	0.356	0.8827	0.0013	0.336
10–14	2.6174	0.025175	0.916	4.4397	0.021789	0.879	3.5142	0.0235	0.908
15–19	−4.4574	0.023650	0.865	−1.2051	0.014613	0.832	−2.7583	0.0193	0.861
20–24	6.0771	−0.003871	−0.363	0.9244	0.004715	0.348	2.9274	0.0006	0.055
25–29	3.9306	−0.000518	−0.046	1.3375	0.001774	0.246	2.5583	0.0007	0.068
30–34	1.5204	0.000924	0.197	0.9166	0.001173	0.259	1.2202	0.0011	0.168
35–39	−0.0069	0.001525	0.318	−0.5111	0.001433	0.388	−0.2577	0.0015	0.335
40–44	0.9886	0.001790	0.417	0.9896	0.001553	0.417	0.9865	0.0017	0.395
45–49	0.9372	0.001739	0.445	0.8858	0.001739	0.466	0.9060	0.0017	0.439
50–54	−0.0013	0.001537	0.413	−0.4076	0.001730	0.505	−0.2262	0.0016	0.437
55–59	0.2246	0.001002	0.483	0.6497	0.001307	0.460	0.4412	0.0012	0.396
60–64	0.7432	0.000774	0.364	0.9027	0.001002	0.420	0.8247	0.0009	0.378
65–69	1.7197	0.000698	0.327	1.7441	0.001007	0.422	1.7363	0.0009	0.372
70–74	1.8449	0.000780	0.304	1.6331	0.001134	0.504	1.7366	0.0010	0.395
75–79	2.2103	0.000670	0.272	2.3549	0.000731	0.309	2.3020	0.0007	0.264

III Movements of the Location of the Central Point of the Distribution of Cohorts

Here, the movements of the location of the central point of the distribution of cohorts are examined.

The location of the central point of the distribution of a cohort is shown by two kinds of indicators: center of population for a cohort and population center for a cohort.

In general, the longitude and latitude of the center of population, $\bar{E}$ and $\bar{N}$ are determined by

$$\bar{E}=\frac{\sum_{i=1}^{n}P_iE_i}{\sum_{i=1}^{n}P_i} \qquad (3.1.1)$$

$$\bar{N}=\frac{\sum_{i=1}^{n}P_iN_i}{\sum_{i=1}^{n}P_i} \qquad (3.1.2)$$

respectively, where

P_i: population in the ith region ($i=1, 2, \ldots, n$)

E_i: the longitude of the position of the ith region

N_i: the latitude of the position of the ith region

This point, the center of population, is the point at which the total value of the squares of the lengths of the movements of people becomes the smallest when the people move along straight lines to gather at a point.[9]

On the other hand, the population center is the point at which the total length of the movements of people to gather at a point becomes the smallest. The position of this point which is expressed by longitude $\bar{X}^*$ and latitude $\bar{Y}^*$ is found by the Kuhn-Kuenne's method.[10] When we use the Kuhn-Kuenne's method to find the position of the population center, we can obtain it by the following iterative calculations.

First of all, we must calculate the initial preliminary position (longitude and latitude) of the population center expressed by $\bar{E}^{(1)}$ and $\bar{N}^{(1)}$ which are defined by the equations written below:

$$\bar{E}^{(1)} = \frac{\sum_{i=1}^{n} P_i E_i}{\sum_{i=1}^{n} P_i} \tag{3.2.1}$$

$$\bar{N}^{(1)} = \frac{\sum_{i=1}^{n} P_i N_i}{\sum_{i=1}^{n} P_i} \tag{3.2.2}$$

The $\bar{E}^{(1)}$ and $\bar{N}^{(1)}$ are equal to the $\bar{E}$ and $\bar{N}$ which express the location of the center of population (see equations (3. 1. 1) and (3. 1. 2)).

Regarding these values as the approximate values showing the position of the population center at the first step of the calculation, we obtain the approximate values $\bar{E}^{(k)}$ and $\bar{N}^{(k)}$ at the kth ($k=2, 3, 4, \ldots$) step of the calculation by the following expressions:

$$\bar{E}^{(k)} = \frac{\sum_{i=1}^{n} P_i^{(k-1)} E_i}{\sum_{i=1}^{n} P_i^{(k-1)}} \tag{3.3.1}$$

$$\bar{N}^{(k)} = \frac{\sum_{i=1}^{n} P_i^{(k-1)} N_i}{\sum_{i=1}^{n} P_i^{(k-1)}} \tag{3.3.2}$$

$$P_i^{(k-1)} = \frac{P_i}{d_i^{(k-1)}} \tag{3.3.3}$$

$$d_i^{(k-1)} = \sqrt{(E_i-\bar{E}^{(k-1)})^2+(N_i-\bar{N}^{(k-1)})^2} \tag{3.3.4}$$

The $\bar{E}^{(k)}$ and $\bar{N}^{(k)}$ are regarded as the longitude and latitude of the position of the population center, $\bar{E}^*$ and $\bar{N}^*$, when

$$\bar{E}^{(k)} = \bar{E}^{(k-1)} \tag{3.4.1}$$

$$\bar{N}^{(k)} = \bar{N}^{(k-1)} \tag{3.4.2}$$

by increasing the number of the step, k.

Therefore, the center of population and the population center for a cohort which has years of age from x to $x+h-1$ at time t are obtained by substituting the population in the ith region P_i with the population of the cohort which has years of age from x to $x+h-1$ at time t in the ith region $P_{it}^{(x)}$.

In this place, the longitude and latitude of the center of population for the cohort which has years of age from x to $x+h-1$ at time t are expressed by $\bar{E}_t^{(x)}$ and $\bar{N}_t^{(x)}$, respectively, and those of the population center for the cohort by $\bar{X}_t^{*(x)}$ and $\bar{Y}_t^{*(x)}$.

The values of $\bar{E}_t^{(x)}$ and $\bar{N}_t^{(x)}$, and $\bar{E}_t^{*(x)}$ and $\bar{N}_t^{*(x)}$ for Japan are shown in Table 3. These values are calculated by the prefectural data obtained from the population censuses in 1965, 1970 and 1975.[11] (The data of Okinawa were not considered here.)

From Table 3, we can find two kinds of courses of the movement of the position of the central

Table 3 The location of the central points of cohorts

(a) Central points for 1965

Age group	C.P.		P.C.	
	LA (N)	LO (E)	LA (N)	LO (E)
Total	35.78	136.93	35.41	137.05
0– 4	35.81	137.01	35.44	137.15
5– 9	35.83	136.85	35.46	137.04
10–14	35.88	136.79	35.51	137.03
15–19	35.79	136.99	35.39	137.06
20–24	35.75	137.26	35.52	137.62
25–29	35.80	137.20	35.54	137.53
30–34	35.80	137.06	35.48	137.26
35–39	35.79	136.94	35.43	137.07
40–44	35.77	136.85	35.41	136.99
45–49	35.78	136.85	35.42	137.00
50–54	35.75	136.80	35.39	136.92
55–59	35.70	136.72	35.37	136.84
60–64	35.68	136.69	35.38	136.82
65–69	35.59	136.54	35.36	136.76

(b) Central points for 1970

Age group	C.P.		P.C.	
	LA (N)	LO (E)	LA (N)	LO (E)
Total	35.76	137.01	35.42	137.14
0– 4	35.75	137.12	35.45	137.29
5– 9	35.79	137.02	35.43	137.14
10–14	35.82	136.87	35.45	137.05
15–19	35.82	137.04	35.49	137.25
20–24	35.75	137.25	35.53	137.63
25–29	35.74	137.26	35.51	137.59
30–34	35.77	137.20	35.52	137.50
35–39	35.78	137.06	35.45	137.22
40–44	35.78	136.96	35.43	137.08
45–49	35.77	136.90	35.43	137.04
50–54	35.76	136.87	35.41	137.00
55–59	35.72	136.82	35.37	136.93
60–64	35.69	136.74	35.37	136.86
65–69	35.67	136.69	35.37	136.82
Net product	35.66	137.24	35.49	137.63

(c) Central points for 1975

Age group	C.P.		P.C.	
	LA (N)	LO (E)	LA (N)	LO (E)
Total	35.74	137.06	35.44	137.21
0- 4	35.72	137.13	35.43	137.27
5- 9	35.74	137.11	35.45	137.29
10–14	35.78	137.02	35.44	137.16
15–19	35.77	137.03	35.45	137.20
20–24	35.76	137.26	35.59	137.82
25–29	35.74	137.21	35.51	137.53
30–34	35.73	137.24	35.50	137.56
35–39	35.76	137.19	35.52	137.50
40–44	35.77	137.06	35.45	137.22
45–49	35.77	136.97	35.43	137.10
50–54	35.76	136.90	35.43	137.05
55–59	35.75	136.88	35.41	137.01
60–64	35.71	136.82	35.37	136.94
65–69	35.68	136.74	35.36	136.86
Net product	35.66	137.24	35.50	137.69

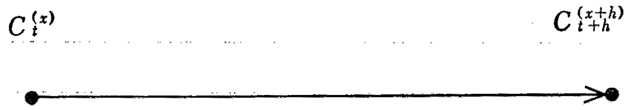
Notes: C.P.: center of population
P.C.: population center
LA (N): north latitude
LO (E): east longitude

points of cohorts. One of them is the course of the movement of the position of the central points of a cohort which has given years of age in 1965 during the period of time from 1965 to 1970 and from 1970 to 1975. For example, the course for the cohort which has years of age from 20 to 24 in 1965, $C_{1965}^{(20)}$ is found. This course is obtained by connecting the central points of the cohort which has years of age from 20 to 24 in 1965, $C_{1965}^{(20)}$ and those of the cohort which has years of age from 25 to 29 in 1970, $C_{1970}^{(25)}$ or by connecting the central points of the cohort which has years of age from 25 to 29 in 1970, $C_{1970}^{(25)}$ and those of the cohort which has years of age from 30 to 34, $C_{1975}^{(30)}$.

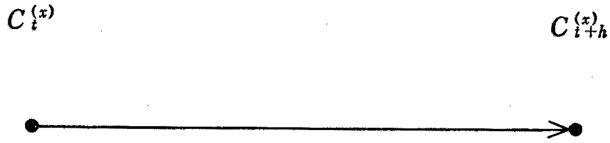
In general, we can obtain the course of the movement of the position of the central point for the cohort $C_t^{(x)}$ (which is the cohort which has years of age from x to $x+h-1$ at year t, where h is a given number of years) from time (year) t to time $t+h$ by connecting the central points of the cohorts $C_t^{(x)}$ and $C_{t+h}^{(x+h)}$ since the cohort which has years of age from x to $x+h-1$ at year t, $C_t^{(x)}$ will become the cohort which has years of age from $x+h$ to $x+2h-1$ at time $t+h$, $C_{t+h}^{(x+h)}$ after h years from year t (in other words, $C_t^{(x)}$ will become $C_{t+h}^{(x+h)}$ at year $t+h$). We may call the course "the trace of the position of cohort by birth year group."

Another is the course of the movement of the position of the central points of cohorts which have given years of age in 1965, 1970 and 1975. For example, the courses for the cohorts which have years of age from 20 to 24 in 1965, 1970 and 1975 ($C_{1965}^{(20)}$, $C_{1970}^{(20)}$ and $C_{1975}^{(20)}$) are found. These courses are obtained by connecting the central points of the cohorts $C_{1965}^{(20)}$ and $C_{1970}^{(20)}$, and those of the cohorts $C_{1970}^{(20)}$ and $C_{1975}^{(20)}$.

In general, we can obtain the course of the movement of the position of the central point fo the cohorts which have years of age from x to $x+h-1$ at time (year) t and time $t+h$ ($C_t^{(x)}$ and $C_{t+h}^{(x)}$)



(a) The trace of the position of cohort by birth year group



(b) The trace of the position of cohort by age group

Figure 5 The traces of the position of cohort

We may call the course " the trace of the position of cohort by age group." (see Figure 5)

Therefore, we can say that we can find the course of the movement of a cohort occurred with the passage of time, in other words, the stream of migration of a cohort by the former course, namely, " the trace of the position of cohort by birth year group," and we can depict historically the positions of a given age group by the latter course, namely, " the trace of the position of cohort by age group."

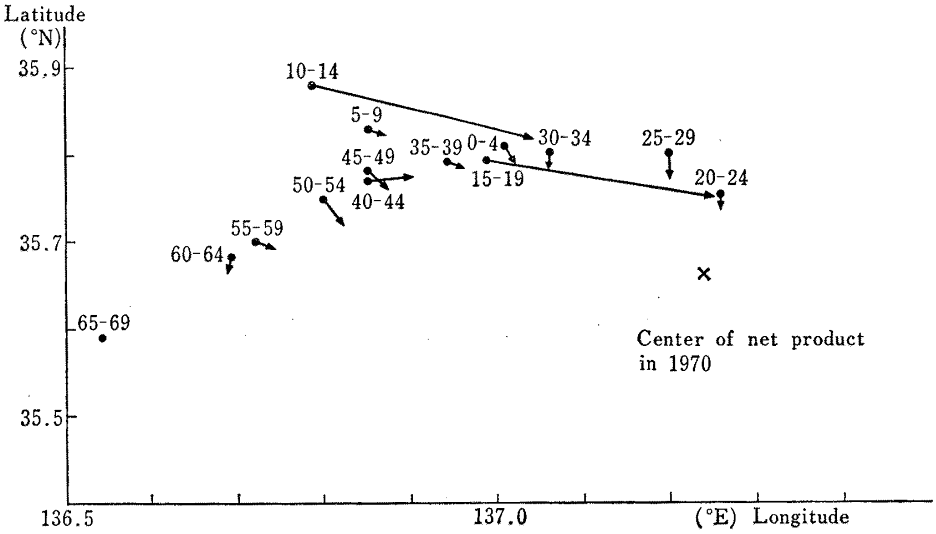
It appears to me that " the trace of the position of cohort by birth year group " is a substantial record of the position of a cohort, on the other hand, " the trace of the position of cohort by age group " is a simple historical record of the position of a certain age group.

In Figure 6, the traces of the position of cohort by birth year group for the periods from 1965 to 1970 and from 1970 to 1975 obtained by center of population and population center. And, in Figure 7, the traces of the position of cohort by age group for the periods from 1965 to 1970 and from 1970 to 1975 obtained by center of population and population center.

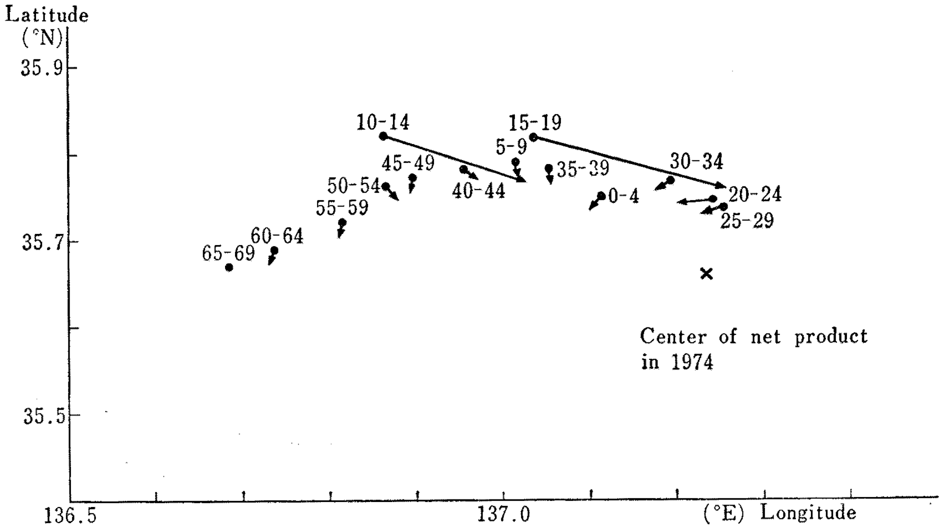
According to Figure 6, which shows the streams of migrations of cohorts, the cohorts which have years of age from 10 to 14 and from 15 to 19 showed long-distance movements of main streams of migration, as we can expect from our previous study.

It is very interesting to be able to find that the main movement of the central points of the cohorts $C_t^{(10)}$ and $C_t^{(15)}$ ($t=1965$, 1970) proceeds in the direction of the central points of net product in 1970 or 1974, where the positions of the central points of net product, " the center of net product " and " net product center " are the points which are determined by substituting the population in the ith region P_i with the net product of the ith region Q_i in the formulae expressed by equations (3. 1. 1) and (3. 1. 2) and by equations from equation (3. 2. 1) to equation (3. 4. 2), respectively. The locations of the center of net product and the net product center are shown in Table 3 ((b) and (c)).[12] They were calculated by the data estimated by the Economic Planning Board.[13]

When we observe the directions of the streams of the migrations of cohorts other than those of the main stream by the traces of the position of cohort by birth year group, the directions of the streams are not necessarily the direction of net product.



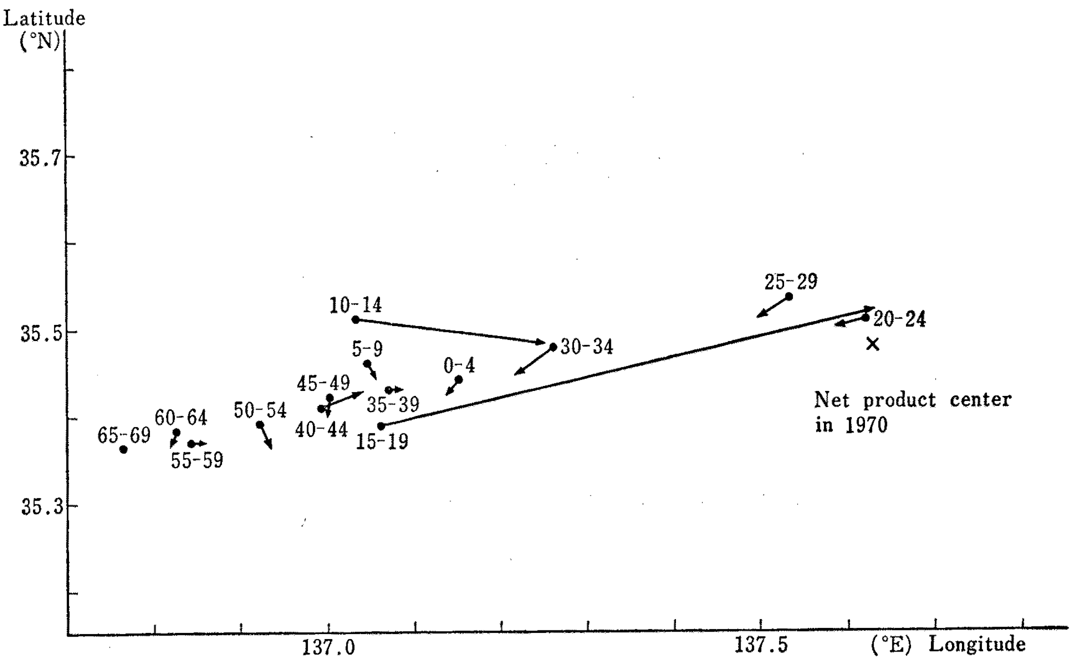
(1–a) 1965–1970



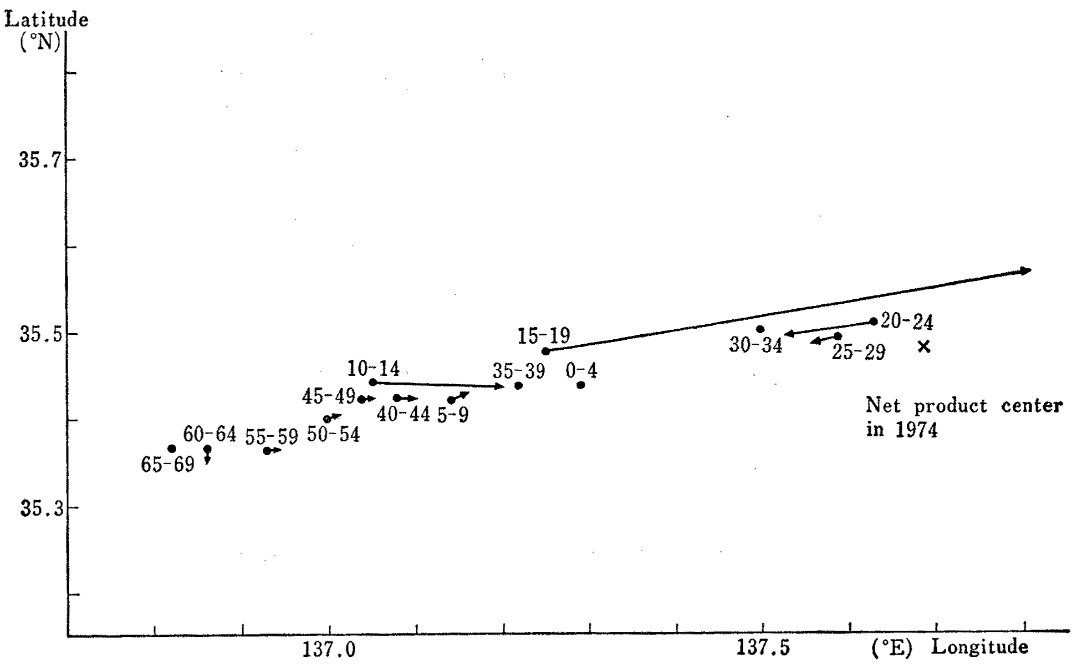
(1–b) 1970–1975

(1) The trace obtained by center of population

Figure 6 The trace of the position of cohort by birth year group



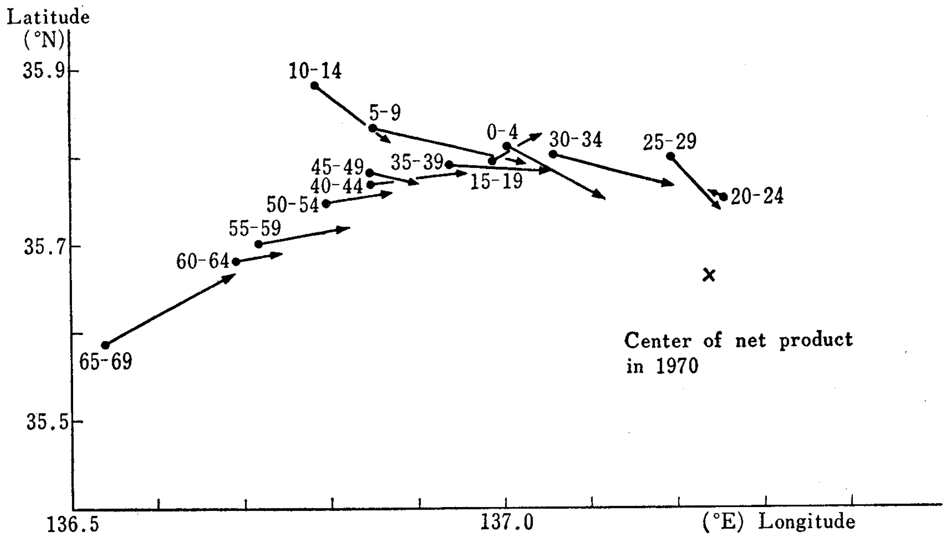
(2–a) 1965–1970



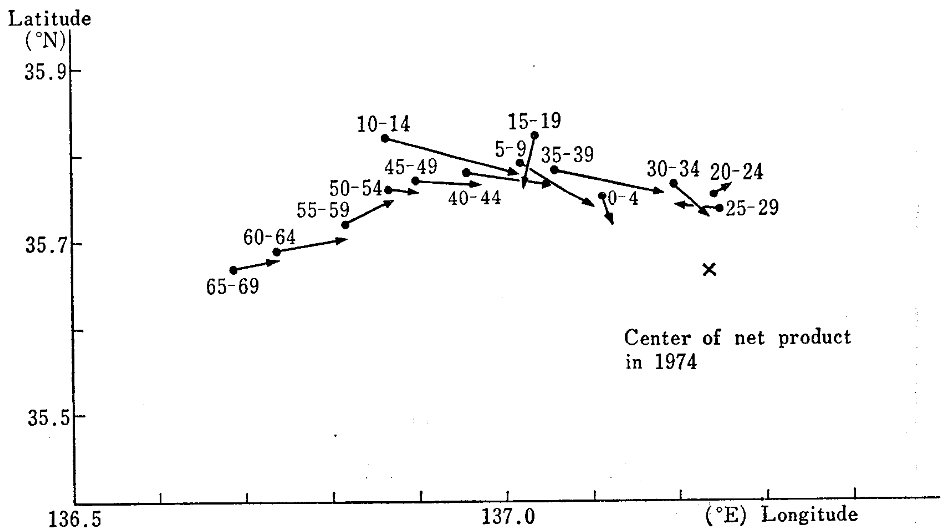
(2–b) 1970–1975

(2) The trace obtained by population center
Note: See the note for Figure 7.

Figure 6 *(cont'd)*



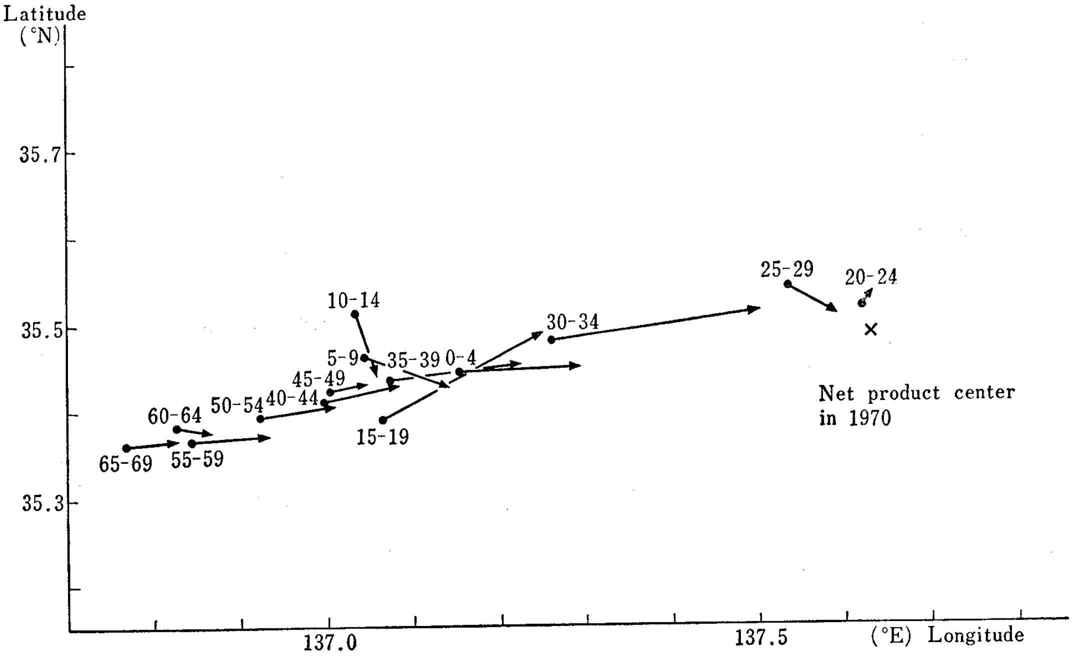
(1–a) 1965–1970



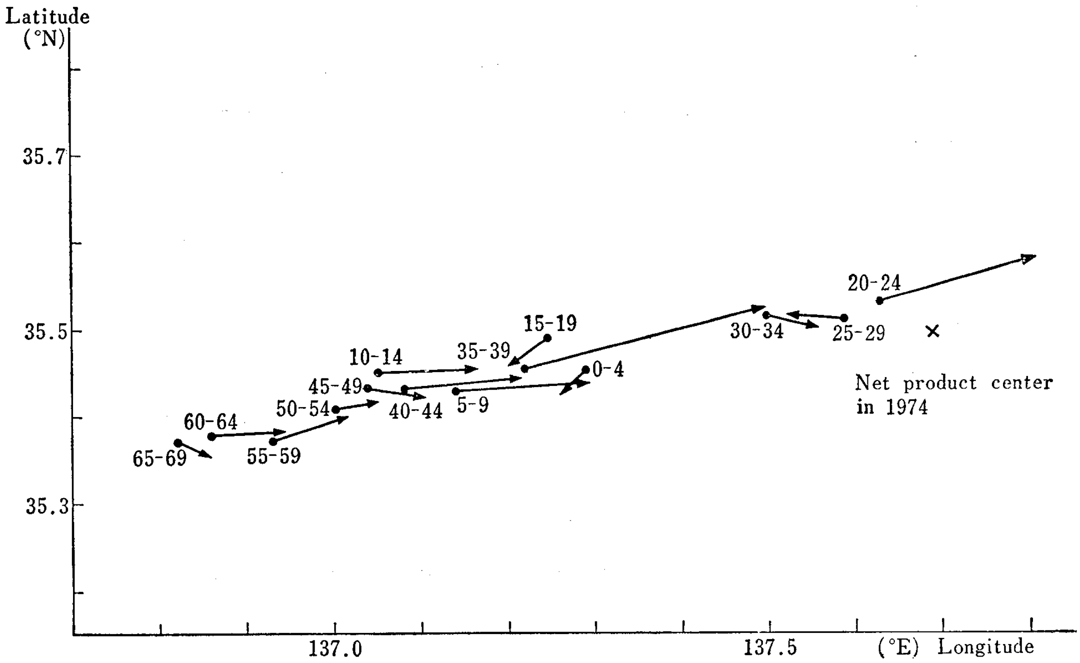
(1–b) 1970–1975

(1) The trace obtained by center of population

Figure 7 The trace of the position of cohort by age group



(2-a) 1965-1970



(2-b) 1970-1975

(2) The trace obtained by population center

Note: The years of age for the birth year group and the age group in the graph are shown by those at the beginning of the period of time observed. For example, the years of age in Figure 6 (1-a) and Figure 7 (1-a) are the years of age in 1965.

Figure 7 *(cont'd)*

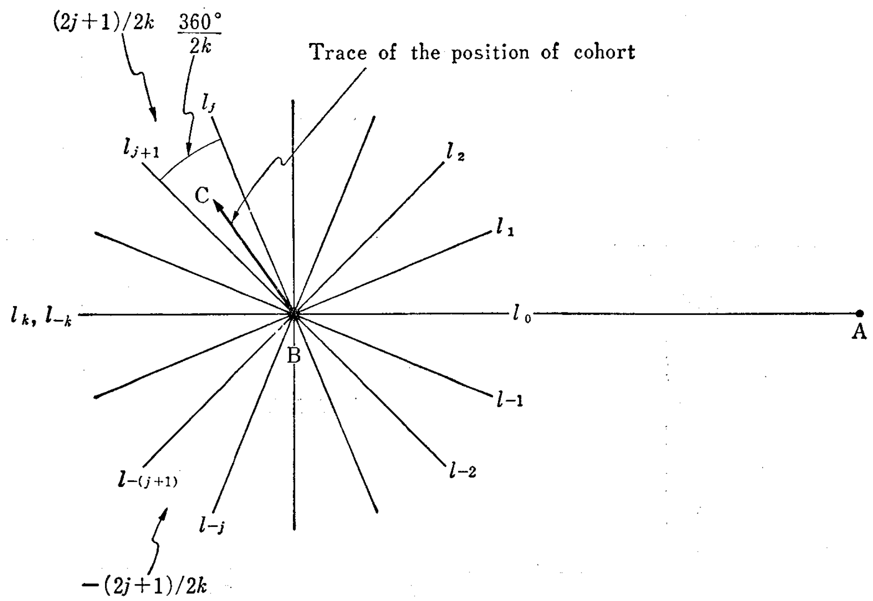


Figure 8 Measurement of the direction of the trace of the position of cohort

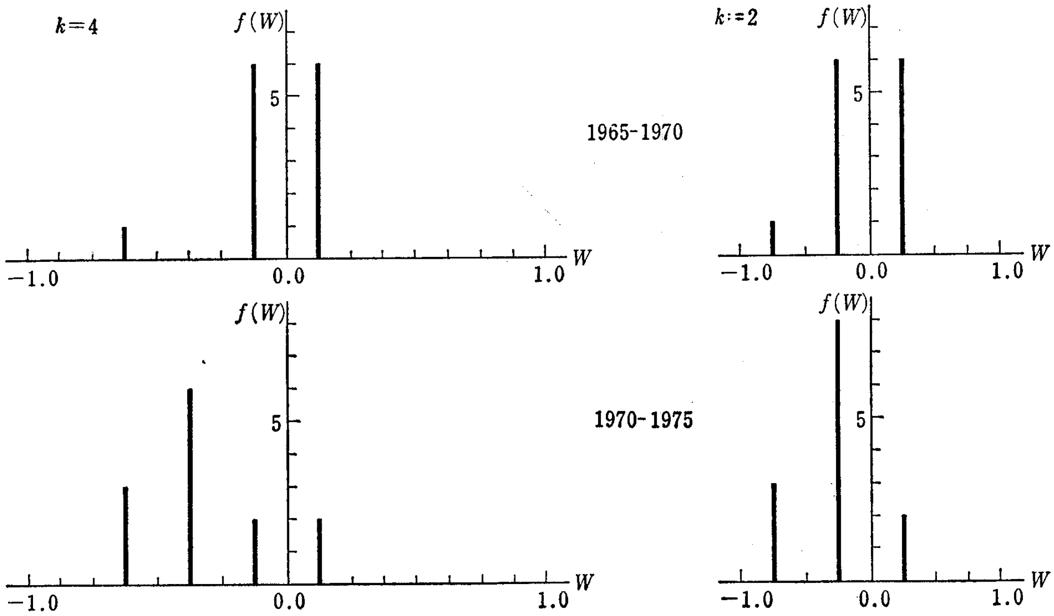
I made a new method to judge statistically whether the directions of the movements of the positions of central points of cohorts are the direction of the central point of net product or not.

If a point A is the position of the central point of net product, a point B is the position of the central position of a cohort, and an arrow BC is the movement of the position of the central point of a cohort, then the direction of the arrow will be measured by the following method.

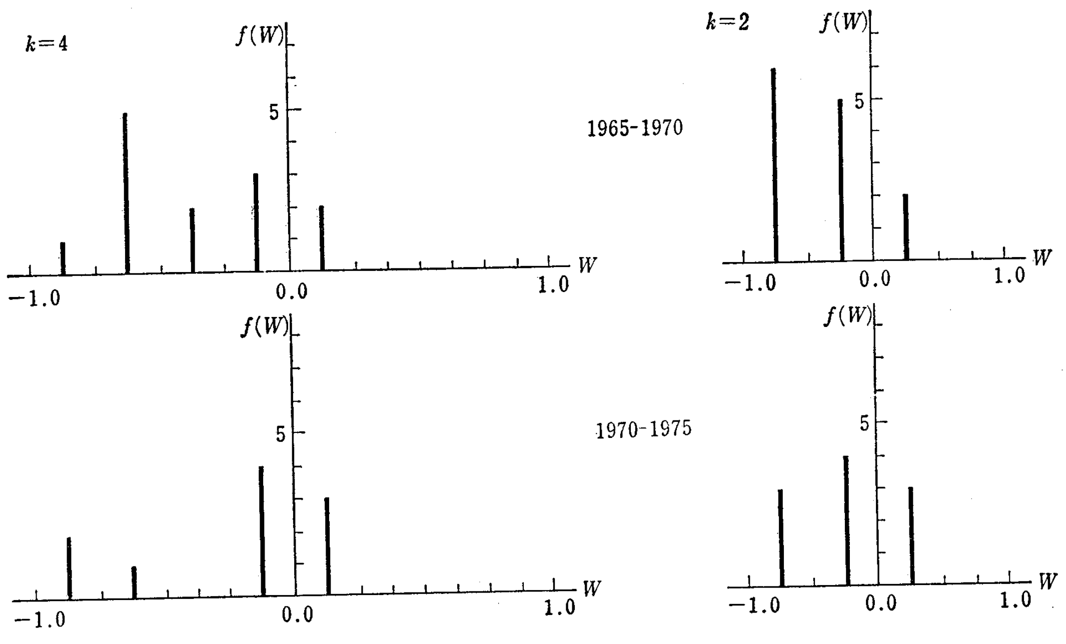
First of all, we draw radially even number of lines, namely, $2k$ lines from the point B as shown in Figure 8. We call the lines l_i $(i=-k, -(k-1), \ldots, -2, -1, 0, 1, 2, \ldots, k-1, k)$. The line l_0 is always drawn on the line which is drawn between the points A and B, and the angle which is contained between the lines l_j and l_{j+1} is $360°/2k$. Therefore, the line l_k is identical with the line l_{-k}. The value of the direction which is contained between the lines l_j and l_{j+1} (counterclockwise) is expressed by $(2j+1)/2k$ and the value of the direction which is contained between the lines l_{-i} and $l_{-(j+1)}$ (clockwise) is expressed by $-(2j+1)/2k$.

The direction of the trace is measured quantitatively by the value of the direction mentioned above. Therefore, when the trace is appeared between the lines l_j and l_{j+1}, the direction of the trace, W is expressed quantitatively by $(2j+1)/2k$, and when it is drawn between the lines l_{-j} and $l_{-(j+1)}$, the direction of the trace, W is expressed by $-(2j+1)/2k$.[14]

If we make a frequency distribution of the directions of the movement of the position of central point of cohort, W obtained by the method written above and calculate the mean $\bar{W}$ and variance or standard deviation of the W (V_W, s_W), we will be able to find the characteristics of the direction of the movement of the position of central point of cohort from the shape of the frequency distribution. Figures 9. 1 and 9. 2 are the graphs of the frequency distributions of the directions of the traces of the position of cohort by birth year group and by age group for the cases that $k=4$ and $k=2$. (Then, the number of the lines drawn from the point B is 8 when the k is 4, and it is 4 when the k is 2.) Tables 4. 1 and 4. 2 are the means, variances and standard deviations of the frequency distributions. In Table 5, we can find the actual confidence intervals of the mean directions of populations of the traces of the position of cohort by birth year group and by age group, μ_0 calculated by the frequency distribution shown in Figures 9. 1 and 9. 2, which are expressed in degree and minute and in degree.[15]

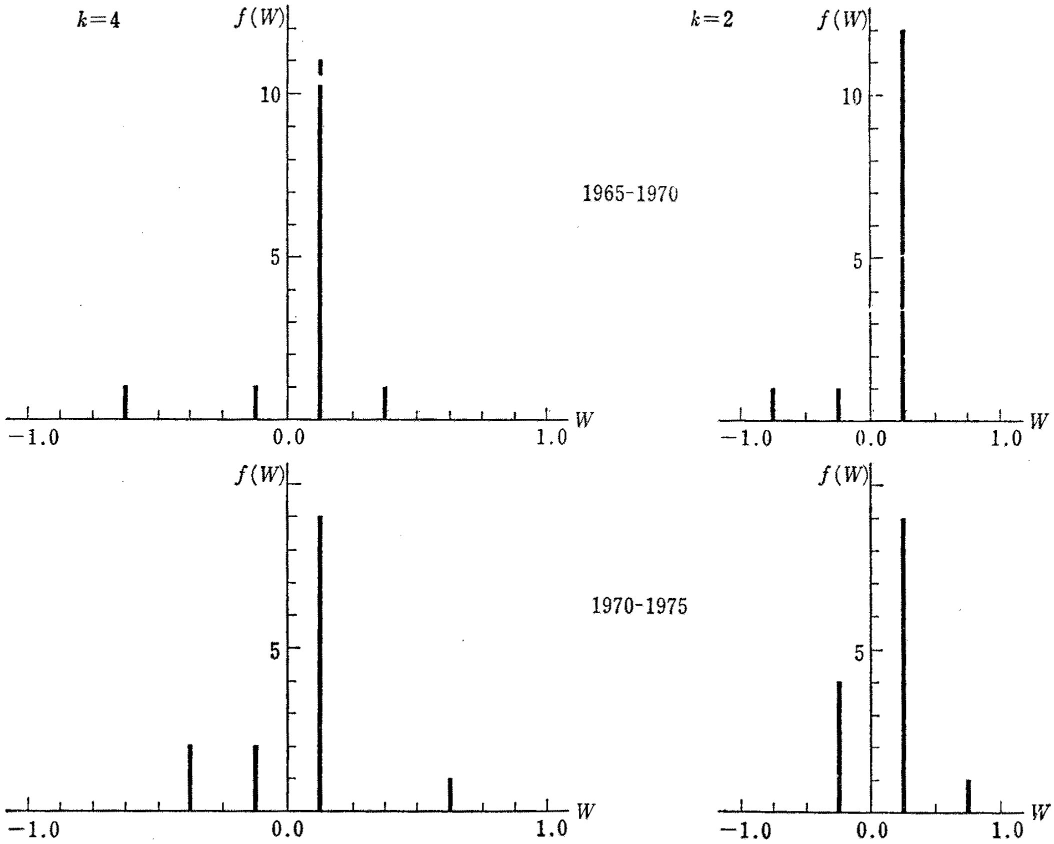


A. Center of population

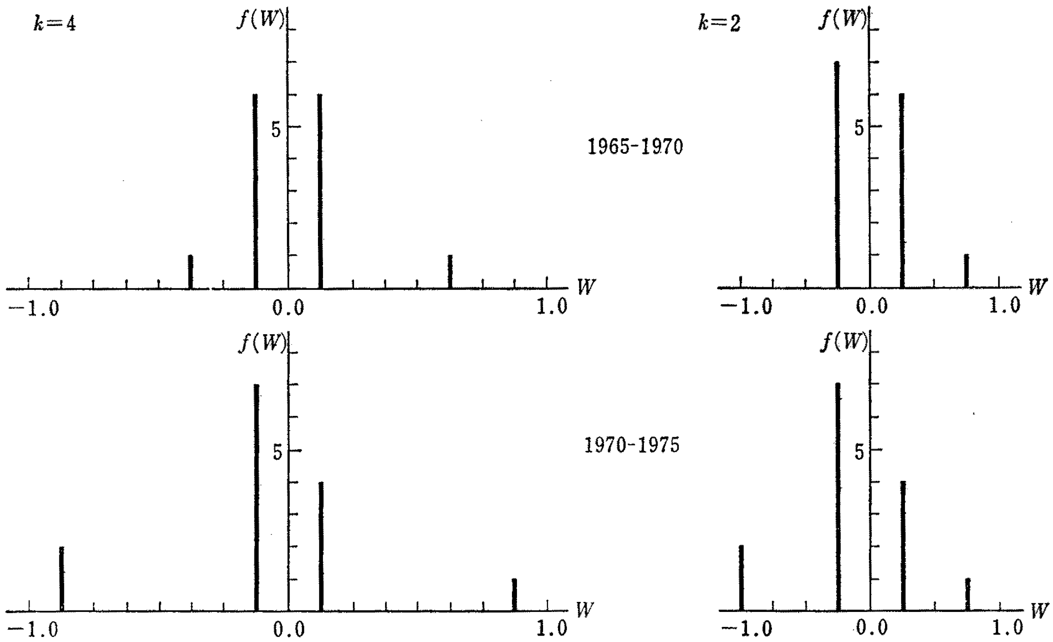


B. Population center

Figure 9.1 Frequency distribution of the direction of the trace of the position of cohort by birth year group



A. Center of population



B. Population center

Figure 9. 2 Frequency distribution of the direction of the trace of the position of cohort by age group

Table 4. 1 Mean, variance and standard deviation of α for the trace of the position of cohort by birth year group

A. Center of population

Period	n	k	$\bar{W}$	V_W	s_W
1965–1970	13	4	−0.04808	0.16235	0.40293
			−0.05769	0.09763	0.31246
1970–1975	13	4	−0.31731	0.05917	0.24325
		2	−0.28846	0.09468	0.30769

B. Population center

Period	n	k	$\bar{W}$	V_W	s_W
1965–1970	13	4	−0.37500	0.09615	0.31008
		2	−0.40385	0.13018	0.36080
1970–1975	10	4	−0.25000	0.14063	0.37500
		2	−0.25000	0.15000	0.38730

Table 4. 2 Mean, variance and standard deviation of α for the trace of the position of cohort by age group

A. Center of population

Period	n	k	$\bar{W}$	V_W	s_W
1965–1970	14	4	0.07143	0.04624	0.21503
		2	0.14286	0.07781	0.27894
1970–1975	14	4	0.05357	0.05740	0.23958
		2	0.14286	0.15561	0.39448

B. Population center

Period	n	k	$\bar{W}$	V_W	s_W
1965–1970	14	4	0.01786	0.05102	0.22588
		2	0.03571	0.09694	0.31135
1970–1975	14	4	−0.08929	0.16837	0.41033
		2	−0.10714	0.15816	0.39770

Table 5 Confidence interval mean direction of the populations of the traces of the position of cohort by birth year group and age group

(a) The trace of the position of cohort by birth year group

(a–1) Center of population

Period	$\bar{\omega}$		δ
1965–1970	−4°56′	(−4.93°)	21°
1970–1975	−51°11′	(−51.18°)	21°

(a–2) Population center

Period	$\bar{\omega}$		δ
1965–1970	−70°40′	(−70.67°)	38°
1970–1975	−26° 3′	(−26.05°)	70°

(b) The trace of the position of cohort by age group

(b–1) Center of population

Period	$\bar{\omega}$		δ
1965–1970	23°12′	(23.20°)	17°
1970–1975	9°18′	(9.30°)	24°

(b–2) Population center

Period	$\bar{\omega}$		δ
1965–1970	37°38′	(37.63°)	22°
1970–1975	−11°42′	(−11.70°)	42°

Notes: The values in this table are calculated by the data for the case that $k=4$. The confidence interval of the mean direction of population μ_0 is obtained by

$$\bar{\omega}-\delta<\mu_0<\bar{\omega}+\delta$$

Figure 7 shows the trace of the position of cohort by age group during the periods from 1965 to 1970 and from 1970 to 1975, namely the courses of the movement of the position of the central points of cohorts which have given years of age (x) in 1965 and 1970 ($C_{1965}{}^{(x)}$ and $C_{1970}{}^{(x)}$) and in 1970 and 1975 ($C_{1970}{}^{(x)}$ and $C_{1975}{}^{(x)}$).

When we compare the shapes of the two traces, the trace of the position of cohort by birth year group and the trace of the position of cohort by age group, we can find the difference between their lengths. Most of the lengths of the traces of the position of cohort by age group are longer, while most of the lengths of the traces of the position of cohort by birth year group are shorter. The reasons why most of the lengths of the traces of the position of cohort by age group are longer than those of the traces of the position of cohort by birth year group are as follows:

(1) The positions of the central points of the cohorts whose years of age are larger than 25 lie in the order of age. The position of the central point of the cohort which has years of age from

65 to 70 is farthest from the central point of net product, and the position of the point of cohort which has years of age from 25 to 30 is nearest to the central point of net product, and

(2) the central points do not move widely during the period observed.

For example, if the positions of central points of the cohorts $C_{1965}{}^{(30)}$ and $C_{1965}{}^{(35)}$ were at the spots $P_{1965}{}^{(30)}$ and $P_{1965}{}^{(35)}$ in 1965, and the distance of the movements of the central points of the cohorts $C_{1965}{}^{(30)}$ and $C_{1965}{}^{(35)}$ during the period from 1965 to 1970 were short, the positions of the central points of the cohorts $C_{1970}{}^{(35)}$ and $C_{1970}{}^{(40)}$, $P_{1970}{}^{(35)}$ and $P_{1970}{}^{(40)}$ will be near the spots $P_{1965}{}^{(30)}$ and $P_{1965}{}^{(35)}$, respectively as shown in Figure 10. Therefore, the length of the trace of the position of cohort by age group for the age group from 35 to 40 which is the distance between the spots $P_{1965}{}^{(35)}$ and $P_{1970}{}^{(35)}$ is longer than the lengths of the traces of the position of cohort by birth year group for the cohorts $C_{1965}{}^{(30)}$ and $C_{1965}{}^{(35)}$ which are the distances between the sports $P_{1965}{}^{(30)}$ and $P_{1970}{}^{(35)}$ and between spots $P_{1965}{}^{(35)}$ and $P_{1970}{}^{(40)}$.

From this example, we can see that even if the length of the trace of the position of cohort by birth year is short, that of the trace of the position of cohort by age group can be longer.

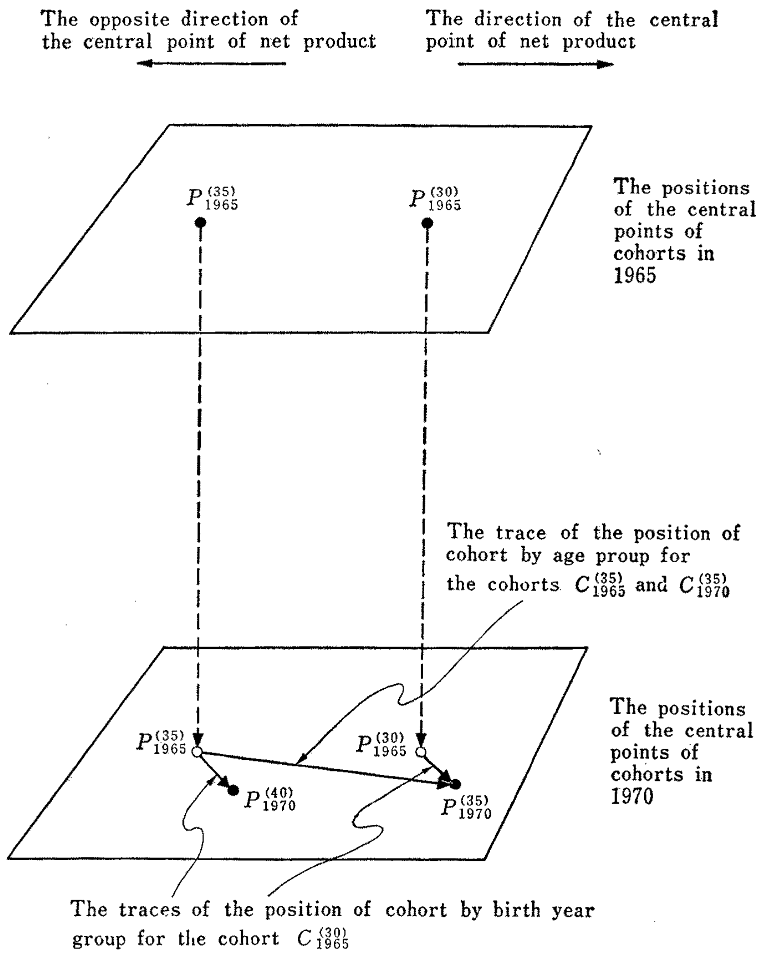


Figure 10. The mechanism of the appearance of the traces of the position of cohort by birth year group and by age group

IV Changes of the Pattern of the Distribution of Cohorts

Hoover proposed the index of population concentration Δ which is defined by the expression:[16)]

$$\Delta = \frac{1}{2}\sum_{i=1}^{n}|p_i - a_i| \tag{4.1}$$

where

p_i: the proportion of the population in the ith region ($i=1, 2, \ldots, n$) to the total population in all the regions observed

a_i: the proportion of the area of the ith region to the total area of all the regions observed

If we regard the p_i as $p_{i\ t+h}$ and a_i as $\hat{p}_{i\ t+h}$, we can obtain the following new index $\Delta_{D(t)}$.

$$\Delta_{D(t)} = \frac{1}{2}\sum_{i=1}^{n}|p_{i\ t+h} - \hat{p}_{i\ t+h}| \tag{4.2}$$

where $p_{i\ t+h}$ is actual proportion of population in the ith region to the total population in all the regions observed at time $t+h$, and $p_{i\ t+h}$ is the theoretical proportion for the $p_{i\ t+h}$ calculated by the supposition that interregional migration of population can not be found during the period from time t to time $t+h$.

The $\hat{p}_{i\ t+h}$ is calculated by the expression:

$$\hat{p}_{i\ t+h} = \frac{P_{i\ t}(1+b_{i(t)}h - d_{i(t)}h)}{P_t(1+b_{(t)}h - d_{(t)}h)} \tag{4.3}$$

because $P_{i\ t}b_{i(t)}h$ and $P_{i\ t}d_{i(t)}h$ are the number of births and deaths in the ith region during the period from time t to time $t+h$ and $P_t b_{(t)}h$ and $P_t d_{(t)}h$ are the number of births and deaths in all the regions observed during the period from time t to time $t+h$, so that the numerator of equation (4. 3) is the theoretical population of the ith region at time $t+h$ when the interregional migration is not found during the period from time t to time $t+h$ and the denominator of the equation is the theoretical population of all the regions observed at time $t+h$, where

$P_{i\ t}$: population in the ith region at time t

P_t: population in all the region observed at time t

$b_{i(t)}$: birth rate (crude birth rate) in the ith region during the period from time t to time $t+h$

$d_{i(t)}$: death rate (crude death rate) in the ith region during the period from time t to time $t+h$

$b_{(t)}$: birth rate in all the regions observed during the period from time t to time $t+h$

$d_{(t)}$: death rate in all the regions observed during the period from time t to time $t+h$

This index $\Delta_{D(t)}$ should be called " the index of the change of pattern of distribution of population" during the period from time t to time $t+h$. And this index will be able to use for measuring the degree of the change of pattern of the distribution of population since the $\Delta_{D(t)}$ will become 0 if the interregional migration of population is not found during the period from time t to time $t+h$ and $p_{i\ t+h}$ is exactly equal to $\hat{p}_{i\ t+h}$, conversely the $\Delta_{D(t)}$ will be larger than 0 if the interregional migration of population is found and $p_{i\ t+h}$ is not equal to $\hat{p}_{i\ t+h}$.[17)]

If the birth rate and death rate in each of the regions observed are exactly equal to those of all the regions observed, respectively, namely the relationships which are expressed by the equations:

$$b_{i(t)} = b_{(t)} \tag{4.4.1}$$

$$d_{i(t)} = d_{(t)} \tag{4.4.2}$$

exist, then the $\hat{p}_{i\ t+h}$ will be equal to $p_{i\ t}$ which is $P_{i\ t}/P_t$, and $\Delta_{D(t)}$ will be expressed by the formula:

$$\Delta_{D(t)} = \frac{1}{2}\sum_{i=1}^{n}|p_{i\,t+h} - p_{i\,t}| \tag{4.5}$$

According to the demographic equation, actual population in the ith region at time $t+h$, $p_{i\,t+h}$ can be expressed by the formula:[18]

$$P_{i\,t+h} = P_{i\,t}(1 + b_{i\,(t)}h - d_{i\,(t)}h + u_{i\,(t)}h - w_{i\,(t)}h) \tag{4.6}$$

where

$u_{i\,(t)}$: in-migration rate in the ith region during the period from time t to time $t+h$ (which is equal to $(U_{i\,(t)}/P_{i\,t})/h$, where $U_{i\,(t)}$ is the total number of in-migrants to the ith region during the period from time t to time $t+h$)

$w_{i\,(t)}$: out-migration rate in the ith region during the period from time t to time $t+h$ (which is equal to $(W_{i\,(t)}/P_{i\,t})/h$ where $W_{i\,(t)}$ is the total number of out-migrants from the ith region during the period from time t to time $t+h$)

Therefore, $\Delta_{D(t)}$ is expressed by the equation:

$$\begin{aligned}\Delta_{D(t)} &= \frac{1}{2}\sum_{i=1}^{n}\left|\frac{P_{i\,t}(1+b_{i\,(t)}h - d_{i\,(t)}h + u_{i\,(t)}h - w_{i\,(t)}h)}{P_t(1+b_{(t)}h - d_{(t)}h)} - \frac{P_{i\,t}(1+b_{i\,(t)}h - d_{i\,(t)}h)}{P_t(1+b_{(t)}h - d_{(t)}h)}\right| \\ &= \frac{1}{2}\sum\left|\frac{P_{i\,t}(u_{i\,(t)}h - w_{i\,(t)}h)}{P_t(1+b_{(t)}h - d_{(t)}h)}\right| \end{aligned} \tag{4.7}$$

Consequently, it can be said that $\Delta_{D(t)}$ will be large when the number of net-migrants (which is the numerator of equation (4. 7)) in each region is large.

The similar index can be obtained for a cohort. We can define a new index $\Delta_{D(t)}$ by the following expression in which we find the theoretical value of $p_{i\,t+h}^{(x)}$, $\hat{p}_{i\,t+h}^{(x)}$ calculated by the supposition that interregional migration of population could not be found during the period from time t to time $t+h$.

$$\Delta_{D(t)}^{(x)} = \frac{1}{2}\sum_{i=1}^{n}|p_{i\,t+h}^{(x+h)} - \hat{p}_{i\,t+h}^{(x+h)}| \tag{4.8}$$

where

$p_{i\,t+h}^{(x+h)}$: proportion of population of a cohort which has years of age from $x+h$ to $x+2h-1$ in the ith region ($i=1, 2, \ldots, n$) to the total population of the cohort in all the regions observed at time $t+h$

$\hat{p}_{i\,t+h}^{(x+h)}$: theoretical proportion of population of a cohort which has years of age from $x+h$ to $x+2h-1$ in the ith region to the total population of the cohort in all the region observed at time $t+h$

This index will be able to use for measuring the degree of the change of pattern of the distribution of population of a cohort and it should be called " the index of the change of pattern of distribution of population of cohort " for a cohort which has years of age from x to $x+h-1$ at time t in the ith region during the period from time t to time $t+h$, since the $\Delta_{D(t)}^{(x)}$ will be 0 when the interregional migration of a cohort ($C_t^{(x)}$) can not be found during the period from time t to time $t+h$, and conversely the $\Delta_{D(t)}^{(x)}$ will be larger than 0 if the interregional migration is found.

The $p_{i\,t+h}^{(x)}$ in the equation (4. 8) is calculated by the equation:

$$\hat{p}_{i\,t+h}^{(x+h)} = \frac{P_{i\,t}^{(x)}(1 - a_{i\,(t)}^{(x)}h)}{P_t^{(x)}(1 - d_{(t)}^{(x)}h)} \tag{4.9}$$

where

$P_{i\,t}^{(x)}$: population of a cohort which has years of age from x to $x+h$ in the ith region at time t

$P_t^{(x)}$: population of a cohort which has years of age from x to $x+h$ in all the regions observed at time t

$d_{i(t)}^{(x)}$: death rate of a cohort which has years of age from x to $x+h$ in the ith region at time t during the period from time t to time $t+h$

$d_{(t)}^{(x)}$: death rate of a cohort which has years of age from x to $x+h$ in all the regions observed at time t during the period from time t to time $t+h$

If the birth rate and death rate of a cohort in each of the regions observed are exactly equal to those of the cohort of all the regions observed, respectively, namely the relationship which is expressed by the equation:

$$d_{i(t)}^{(x)} = d_{(t)}^{(x)} \tag{4.10}$$

exists, then the $p_{i\ t+h}^{(x+h)}$ will be equal to $p_{i\ t}^{(x)}$, which is $P_{i\ t}^{(x)}/P_t^{(x)}$ and $\Delta_{D(t)}^{(x)}$ will be expressed by the formula:

$$\Delta_{D(t)}^{(x)} = \frac{1}{2}\sum_{i=1}^{n} |p_{i\ t+h}^{(x+h)} - p_{i\ t}^{(x)}| \tag{4.11}$$

Again, in this place, we can rewrite the formula of the definition of $\Delta_{D(t)}^{(x)}$ as follows:

$$\Delta_{D(t)}^{(x)} = \frac{1}{2}\sum_{i=1}^{n}\left|\frac{P_{i\ t}^{(x)}(u_{i(t)}^{(x)}h - w_{i(t)}^{(x)}h)}{P_t^{(x)}(1-d_{(t)}^{(x)}h)}\right| \tag{4.12}$$

because the actual proportion of population of a cohort $p_{i\ t+h}^{(x)}$ can be expressed by the equation:

$$p_{i\ t+h}^{(x)} = \frac{P_{i\ t}^{(x)}(1-d_{i(t)}^{(x)}h + u_{i(t)}^{(x)}h - w_{i(t)}^{(x)}h)}{P_t^{(x)}(1-d_{(t)}^{(x)}h)} \tag{4.13}$$

and $\Delta_{D(t)}^{(x)}$ can be written by

$$\Delta_{D(t)}^{(x)} = \frac{1}{2}\sum_{i=1}^{n}\left|\frac{P_{i\ t}^{(x)}(1-d_{i(t)}^{(x)}h + u_{i(t)}^{(x)}h - w_{i(t)}^{(x)}h)}{P_t^{(x)}(1-d_{(t)}^{(x)}h)} - \frac{P_{i\ t}^{(x)}(1-d_{i(t)}^{(x)}h)}{P_t^{(x)}(1-d_{(t)}^{(x)}h)}\right| \tag{4.14}$$

where

$u_{i(t)}^{(x)}$: in-migration rate of a cohort which has years of age from x to $x+h$ at time t, $C_t^{(x)}$ in the ith region during the period from time t to time $t+h$ (which is equal to $(U_{i(t)}^{(x)}/P_{i\ t}^{(x)})/h$, where $U_{i(t)}^{(x)}$ is the total number of in-migrants of a cohort $C_t^{(x)}$ to the ith region during the period from time t to time $t+h$)

$w_{i(t)}^{(x)}$: out-migration rate of a cohort which has years of age from x to $x+h$ at time t, $C_t^{(x)}$ in the ith region during the period from time t to time $t+h$ (which is equal to $(W_{i(t)}^{(x)}/P_{i\ t}^{(x)})/h$, where $W_{i(t)}^{(x)}$ is the total number of out-migrants of a cohort $C_t^{(x)}$ from the ith region during the period from time t to time $t+h$)

The value $\Delta_{D(t)}^{(x)}$ ($x=0, 5, \ldots, 65$) for the periods from 1965 to 1970 and from 1970 to 1975 are shown in Table 6.[19] The values of $\Delta_{D(t)}^{(x)}$'s in Table 6 are calculated by equations (4. 11) and (4. 5) based on the assumptions which are expressed by equation (4. 10) and equations (4. 4. 1) and (4. 4. 2) and by using the data obtained from the population censuses in 1965, 1970 and 1975.[20]

Figure 11 shows very clearly the relationship between age and the value of $\Delta_{D(t)}^{(x)}$. According to the graphs in Figure 11, the value of $\Delta_{D(t)}^{(x)}$ becomes very high at age groups from 10 to 15 and from 15 to 20, for the two periods from 1965 to 1970 and from 1970 to 1975. This result shows that the populations of the cohorts which have years of age from 10 to 15 and from 15 to 20 move actively for entering school and getting employment. The value of $\Delta_{D(t)}^{(x)}$ for the cohort which has years of age from 25 to 29 is very low. This means that the main part of the people of this cohort work without migration. It is very interesting to find the fact that the value of $\Delta_{D(t)}^{(0)}$ is almost as large as that of $\Delta_{D(t)}^{(30)}$ for the two periods observed. From this fact, we can say that the cohort $C_t^{(0)}$ (t=1965, 1970) has a close relationship to the cohort $C_t^{(30)}$ (t=1965, 1970). The cohort $C_t^{(0)}$ will be the sons or the daughters of the $C_t^{(30)}$ and consequently the former will move with the latter.

Table 6 The values of $\Delta_{D(t)}^{(x)}$

(a) The values for the period from 1965 to 1970

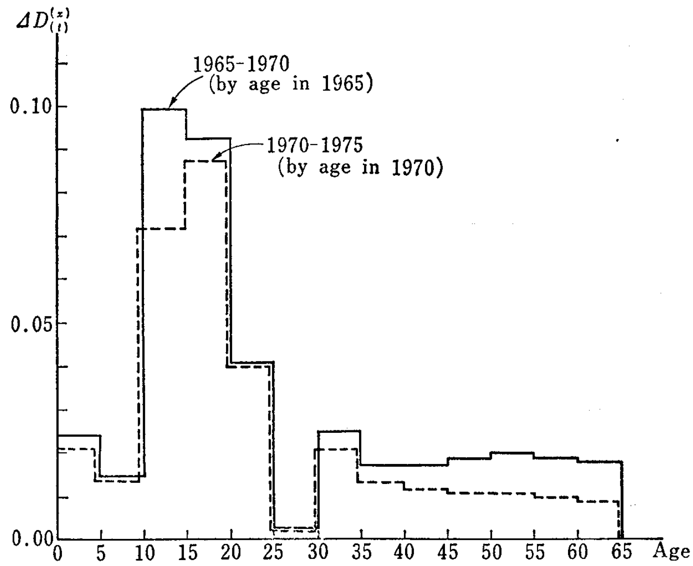
Age group (year)	$\Delta_{D(t)}^{(x)}$
0– 4	.02429780
5– 9	.01488730
10–14	.09970153
15–19	.09274821
20–24	.04066923
25–29	.00072275
30–34	.02430147
35–39	.01596856
40–44	.01591936
45–49	.01766117
50–54	.01902852
55–59	.01804334
60–64	.01690947
Total	.03051605

Note: The years of age of the age group in this table are those in 1965.

(b) The values for the period from 1970 to 1975

Age group (year)	$\Delta_{D(t)}^{(x)}$
0– 4	.02066558
5– 9	.01343049
10–14	.07115476
15–19	.08705726
20–24	.03989688
25–29	.00059036
30–34	.02092822
35–39	.01345682
40–44	.01148586
45–49	.01063496
50–54	.01040454
55–59	.00979024
60–64	.00800260
Total	.02221990

Note: The years of age of the age group in this table are those in 1970.



Note: The years of age are expressed by those at the beginning of the period observed.

Figure 11 The relationship between age and the value of $\Delta_{D(t)}^{(x)}$ for the periods from 1965 to 1970 and from 1970 to 1975

V Conclusion

In the previous study which is regarded as the preliminary study of this paper, I could find that the strength of the reaction of people to the level of regional income depends upon the age of cohort, and young cohorts react strongly to the level of regional income and flow into regions of higher income level.

In this place, I examined the characteristics of the migration of cohorts: the movements of the locations of the central points of the distribution of cohorts and the change of the patterns of the distributions of cohorts in Japan.

According to the results of the examination, I could find that (1) the directions of the main streams of migration of cohorts which are the streams of migration of cohorts which have years of age from 10 to 14 and from 15 to 20 are the direction of the central point of net product and (2) the cohorts which have years of age from 10 to 14 and from 15 to 19 move actively for entering school and getting employment and the pattern of the distribution of population of this cohort changed drastically. These results are not inconsistent with those obtained by the previous study.

When I examined the characteristics of the migration of cohorts, I proposed to define some new methods to analyse the characteristics. To make the change of the location of the central point of population of cohort clear, I defined two kinds of traces; trace of the position of cohort by birth year group and trace of the position of cohort by age group and proposed to use the frequency distribution of the direction of the traces, and to measure the degree of the change of the pattern of the distribution of population of cohort clearly, I proposed to define the index of the change of pattern of distribution of population of a cohort $\Delta_{D(t)}{}^{(x)}$.

By this analysis, we can say that main part of the migration of population which consists of the streams of migration of population of young cohorts which have years of age from 10 to 14 and from 15 to 19[21] is influenced very strongly by economic factors,[22] even though it is discussed that migration of population is influenced by social and economic factors and we must consider the influence from these factors when we analyze the interregional migration of population.[23]

Notes

* A part of this study was done under the joint study with Professor Toshio Kuroda of Nihon University titled " A Study of Effects of the Change of Population Structure on Socio-economic Activities of a Country," and supported by the Grant in aid for the Joint Study of Economic Science Research Institute of Nihon University, 1977.

And I am indebted to Mr. Taizō Hamana and Mr. Kouji Kaba of FUJIMIC (Fuji Management Information Center) for their technical assistance of computation by the electronic computer.

Some parts of this study were presented to the 47th conference of the Japan Statistical Society, July 23–25, 1979 at Takamatsu and the 6th Pacific Regional Science Conference, August 13–14, 1979 at Seoul, Korea.

I wish to express my great gratitude to Dr. Masaharu Tanemura of the Institute of Statistical Mathematics, Ministry of Education for his valuable suggestions about the test for the samples from von Mises distribution.

1) Urban population in Table 1 is the population in the regions which are called " shi."
2) In general, the logistic curve is expressed by the expression:

$$y_\tau = \frac{K}{1+me^{-r\tau}} \qquad (1)$$

where y_τ is the value questioned y (in this paper, it is the proportion p_U) at time τ, and K, m and r are parameters.

When we use the least square method, the parameters K and r are obtained, as is well known, by the relationship between the value y and the increase rate of the y, R which is expressed by the regression equation:

$$R = a + by \qquad (2)$$

where a and b are parameters. The parameter r is a, and K is $-a/b$. And the parameter m is obtained by the expression:

$$m = \left(\frac{K}{y_\tau} - 1\right)e^{r\tau} \qquad (3)$$

(Suzuki, Keisuke: *Introduction to Modern Statistics*: *The Theories and Methods for Analyzing Data*, Tokyo, Kotsu Nihon Sha, 1971, pp. 224–227.)

Equation (1. 1) was obtained by using the data from 1920 to 1940 and from 1955 to 1975, by the least square method.

The curve was successfully applied and the fitness of the curve for the actual data was surprisingly good.

The relationship between the proportion p_U and the increase rate of the p_U for 5 years R (which is equal to the increment of p_U during 5 years devided by p_U and is necessary for calculating the values of parameters of the logistic curve by the least square method) was expressed by the regression equation:

$$R = 0.28275 - 0.003146\, p_U \qquad (4)$$

(see Figure A and Table A)

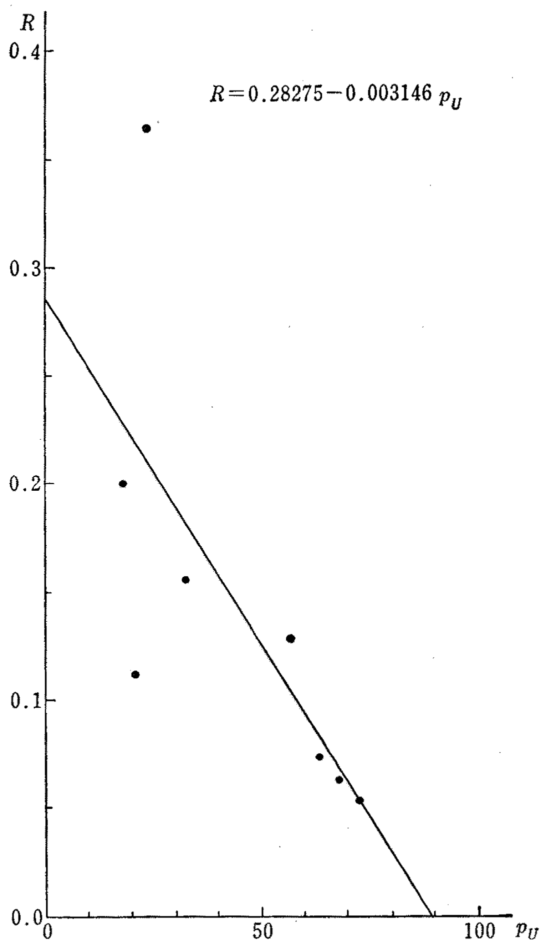


Figure A The relationship between the proportion p_U and the rate R

Table A The proportion p_U and the increase rate of the p_U, R which is used for the calculation of the parameters

Period	p_U*	R
1920–'25	18.0	0.200
1925–'30	21.6	0.111
1930–'35	24.0	0.363
1935–'40	32.7	0.153
1955–'60	56.1	0.128
1960–'65	63.3	0.073
1965–'70	67.9	0.062
1970–'75	72.1	0.053

* The value of this column is the value of the p_U at the beginning of the period, and it was obtained from Table 1.

Table B The actual and the calculated values of p_U

Year	The value of p_U	
	Actual	Calculated
1920	18.0	17.45
1925	21.6	21.78
1930	24.0	26.77
1935	32.7	32.36
1940	37.7	38.42
1945	27.8	44.73
1950	37.3	51.04
1955	56.1	57.12
1960	63.3	62.75
1965	67.9	67.80
1970	72.1	72.15
1975	75.9	75.84

And the value of the parameter m found in the denominator of the right side of the expression of the definition of the logistic curve expressed by equation (1) was obtained from the data from 1935 to 1940 and from 1955 to 1970.

In Table B, the calculated value of p_U is shown.

According to the logistic curve shown by equation (1. 1), in future, the proportion p_U will approach to 89.88%, which is shown by the parameter K.

Incidentally, the gaps between the actual and calculated values found from 1945 to 1955 were occurred by the effect of the Second World War. In this period of time, the people in Japan were dispersed (this dispersal of the people was called " sokai (疎開) " in Japanese), and a part of the people in urban regions moved to rural regions.

3) Suzuki, Keisuke and Masahiko Nakayama: Measuring the effects of difference of regional income on interprefectural migration of population by age and sex, *Bulletin of the Population Association of Japan*, No. 9, 1975, pp. 22–24.

4) Suzuki, Keisuke and Masahiko Nakayama: *ibid.*

5) The $m\ (s, x, h)$ for the ith prefecture $m_i\ (s, x, h)$ is defined by

$$m_i(s, x, h) = \frac{M_i(s, x, h)_{(t)}}{P_i(s, x, h)_t} \times 100$$

where $M_i\ (s, x, h)_{(t)}$ is the net migration of a cohort which has years of age from x to $x+h-1$ during the period of time from year t to year $t+h$ by sex of the ith prefecture, $P_i\ (s, x, h)_t$ is the population of a cohort which has years of age from x to $x+h-1$ by sex in year t.

6) The y for the ith prefecture during h years from year t to year $t+h-1$ is defined by the following expression:

$$y_i = \sum_{s=0}^{h-1} \left(\frac{Y_{i\ t+s} - \bar{Y}_{t+s}}{\bar{Y}_{t+s}} \right) \times 1000$$

where $Y_{i\ t+s}$ is the per capita personal income of the ith prefecture in year $t+s$ ($s=0, 1, 2, \ldots$), and $\bar{Y}_{t+s}$ is the average per capita personal income of all the prefectures in Japan.

7) Economic Planning Board: *Statistics of Income by Prefecture, The Third Report* (*1955–1971*), Tokyo, Shiseido, 1974, pp. 336–341.

Bureau of Statistics, Office of the Prime Minister: *1955 Population Census of Japan*, Vol. 3, *Whole Japan*, Part 1, Tokyo, Bureau of Statistics, 1959, pp. 50–69.

Bureau of Statistics, Office of the Prime Minister: *1960 Population Census of Japan*, Vol. 3, *Whole Japan*, Part 1, Tokyo, Bureau of Statistics, 1964, pp. 18–93.

Bureau of the Census, Office of the Prime Minister: *1965 Population Census of Japan*, Vol. 3, *Whole Japan*, Part 1, Tokyo, Bureau of Statistics, 1967, pp. 2–77.

Bureau of the Census, Office of the Prime Minister: *1970 Population Census of Japan*, Vol. 2, *Whole Japan* (*Results of Basic Tabulation*), Tokyo, Bureau of Statistics, 1972, pp. 6–51.

8) If the parameter b is positive, the net migration rate $m\ (s, x, h)$ must be higher when the income level y becomes higher. Therefore, when the parameter b is positive, we can say that migrants flow into the regions of higher income level from the other regions.

And when the parameter b is positive, the correlation coefficient r becomes positive. Therefore, when the correlation coefficient r is positive, we can obtain the same conclusion mentioned above.

9) Flaskämper, Paul: *Bevölkerungsstatistik*, Hamburg, Felix Meiner, 1962, p. 112.

10) Kuhn, Harold W. and Robert E. Kuenne: An Efficient Algorithm for the Numerical Solution of the Generalized Weber Problem in Spatial Economics, *Journal of Regional Science*, Vol. 4, No. 2, Winter, 1962, pp. 21–33.

11) Bureau of Statistics, Office of the Prime Minister: *1965 Population Census of Japan*, Vol. 2, *One Percent Sample Tabulation Results*, Part 1, *Age, Sex, Marital Status and Legal Nationality*, Tokyo, Bureau of Statistics, 1967, pp. 10–18.

Bureau of Statistics, Office of the Prime Minister: *1970 Population Census of Japan*, Vol. 2, *Whole Japan* (*Results of Basic Tabulation*), Tokyo, Census of Statistics, 1972, pp. 6–39.

Bureau of Statistics, Office of the Prime Minister: *1975 Population Census of Japan*, Vol. 5, *Results of Detailed Tabulation* (*Twenty Percent Sample Tabulation*), Part 1, *Whole Japan*, Division 1, Tokyo, Bureau of Statistics, 1978, pp. 6–39.

Bureau of Statistics, Office of the Prime Minister: *Japan Statistical Yearbook*, 20th edition, Tokyo, Japan Statistical Association, 1970, p. 490.

12) People moves not only for getting job or employment, but also for entering school. Therefore, we must also consider the distribution of educational facilities. However, in Japan, we can find many educational facilities in the regions whose net products are higher, and we can say that the pattern of the distribution of educational institutes is similar to the distribution of net product. Consequently, the tendency of the concentration to the regions whose net products are higher will be strengthened.

13) Bureau of Statistics, Office of the Prime Minister: *Japan Statistical Yearbook*, 20th edition (1969), Tokyo, Japan Statistical Association, 1970, p. 496.

14) We can identify a direction of the trace as precisely as we need by increasing the number of k.

15) In general, we can calculate the confidence interval for the mean direction of population μ_0 with confidence coefficient equal to $(1-\alpha)\times 100$ percent, δ, by the α, sample size n and $\bar{R}$, assuming that the un-

derlying distribution of direction ω is the von Mises distribution $M(\mu_0, \kappa)$ with probability function $f(\omega)$, where $f(\omega)$ is defined by

$$f(\omega) = \{2\pi I_0(\kappa)\}^{-1} \exp \{\kappa \cos (\omega - \mu_0)\}$$
$$0 < \omega \leqq 2, \quad \kappa > 0$$

and in this expression $I_0(\kappa)$ is a constant which is determined by a paramerter κ, namely,

$$I_0(\kappa) = \sum_{r=0}^{\infty} \frac{1}{r!^2} \left(\frac{1}{2}\kappa\right)^{2r}$$

$\bar{R}$ is defined by

$$\bar{R} = (\bar{C}^2 + \bar{S}^2)^{1/2}$$

where

$$\bar{C} = \frac{1}{n} \sum_{i=1}^{n} \cos \omega_i, \qquad \bar{S} = \frac{1}{n} \sum_{i=1}^{n} \sin \omega_i$$

when we denote the angle of the ith direction measured from a standard direction in counterclockwise direction by ω_i.

The confidence interval of the mean direction of population μ_0 is expressed by

$$\bar{\omega} - \delta < \mu_0 < \bar{\omega} + \delta$$

where $\bar{\omega}$ is calculated by

$$\bar{\omega} = \cos^{-1} \frac{\bar{C}}{\bar{R}}$$

or

$$\bar{\omega} = \sin^{-1} \frac{\bar{S}}{\bar{R}}$$

(Mardia, K. V.: *Statistics of Directional Data*, London, Academic Press, 1972, pp. 20–23, 57.)

In this paper, the angle is measured by W whose value appears from -1 to $+1$. But, we can easily apply the method of the examination of the confidence interval mentioned above to the distribution of W, by the following formula for $\bar{C}$ and $\bar{S}$.

$$\bar{C} = \frac{1}{n}\left(\sum_{p=1}^{n^+} \cos W^+{}_p \times 180° + \sum_{q=1}^{n^-} \cos W^-{}_q \times 180°\right)$$

$$\bar{S} = \frac{1}{n}\left(\sum_{p=1}^{n^+} \sin W^+{}_p \times 180° + \sum_{q=1}^{n^-} \sin W^-{}_q \times 180°\right)$$

where $W^+{}_p$ is the pth observation ($p=1, 2, \ldots, n^+$) of angle of direction whose value is positive, $W^-{}_q$ is the qth observation ($q=1, 2, \ldots, n^-$) of angle of direction whose value is negative, and $n^+ + n^-$ is n which is the total number of observations.

16) Hoover, E. M.: Interstate redistribution of population 1850–1940, *Journal of Economic History*, Vol. 1, 1951, pp. 199–205.

Hoover, E. M.: Internal mobility and the location of industry, Williamson, H. F. (ed.): *The Growth of the American Economy*, Englewood Cliffs, New Jersey, Prentice Hall, 1951.

Duncan, Otis Dudley, Ray P. Cuzzort, and Beverly Duncan : *Statistical Geography*, Illinois, The Free Press of Glenco, 1961, p. 83.

17) From the definition of $\Delta_{D(t)}$, it can be said that the value of $\Delta_{D(t)}$ appears between 0 and 1.

18) Tachi, Minoru: *Formal Demography*, Tokyo, Kokon Shoin, 1960, pp. 146–149.

19) The population of Okinawa is not contained for the calculation of the value $\Delta_{D(t)}{}^{(x)}$.

20) Bureau of Statistics, Office of the Prime Minister: *op. cit.* (1965).
Bureau of Statistics, Office of the Prime Minister: *op. cit.* (1972).
Bureau of Statistics, Office of the Prime Minister: *op. cit.* (1978).

21) According to the study by Rogers, in the United States of America, the cohort which have years of age from 20 to 29 move most actively between regions. (Rogers Andrei: *Introduction to Multiregional Mathematical Demography*, New York, John Wiley, 1975, pp. 177–185.)

22) I have already found the influence of the economic factors to the migration of population quantitatively by the statistical or econometric analysis of the variation of the regional population in Japan. (Suzuki, Keisuke: Statistical examination of models of regional variation of population in Japan, *Journal of Japan Statistical Society*, Vol. 6, No. 1, 1976, pp. 1–20. Suzuki, Keisuke: Geographical redistribution of population in Japan, *Annals of the Association of Economic Geographers*, Vol. 21, No. 2, 1975, pp. 1–21.)

23) As a matter of fact, some of the movements of cohorts other than the main movements might be explained by non-economic factors although I did not consider here, because in this paper, I especially endeavered to depict the fact about the main streams of migration.

要　旨

わが国の地域的人口分布は，少なくとも，この国に国勢調査がおこなわれるようになって以来，着実に変化し続けて来た。実際，都市人口の総人口に占める割合を測定してみると第2次世界大戦中の「疎開」による一時的人口分散があったにもかかわらず，その割合は，1920年以来，今日に至るまで一本のロジスティック曲線に沿って変化して来たことが見いだされた。

他方，わが国の人口移動の特徴として挙げられることは，若年層，特に，10歳から20歳までの年齢層の人びとがはげしく移動することである。筆者は，これまでに，共同研究者と共に年齢別人口移動と地域的所得水準との関係を解析し，特に，上記の年齢層の人びとが地域的所得水準に敏感に反応することを見いだした。この結果を見いだした共同研究においては，地域別性別年齢別純移動率 $m(s, x, h)$ と地域的所得水準 y との間に，

$$m(s, x, h) = a + by$$

という関係があることを前提として，この回帰方程式の b——これは，$m(s, x, h)$ の y に対する敏感度の指標とみなされる——ならびに相関係数 r——これは，$m(s, x, h)$ の y に対する反応の大きさの確実性の指標とみなされる——と年齢との関係を観察し，b と r とが，それぞれ10歳から19歳までの年齢階級において大きくなるという結果を得た。

ここでは，さらに，わが国の年齢別人口移動の特性を明らかにするために，年齢別人口中心(これは，年齢別人口重心 (center of population) および人口中心点 (population center) によってとらえた)の時間的動き，ならびに年齢別人口分布のパターン(分布様式)の時間的変化を測定してみた。

年齢別人口中心の時間的動きを測定する場合には，『「同一出生年のコーホート」別人口中心の軌跡 (trace of the position of cohort by birth year group)』および『「同一年齢のコーホート」別人口中心の軌跡 (trace of the position of cohort by age group)』と名づけた2種のコーホート別人口中心の軌跡を用いた。前者は，ある1時点 t におけるある年齢階級 (x 歳から $x+h-1$ 歳までの年齢階級) のコーホートの人口中心と，その後のある1時点 $t+h$ におけるそのコーホート(したがって，そのコーホートは，時点 $t+h$ において，$x+h$ 歳から $x+2h-1$ 歳までのコーホートとなっている)の人口中心とを結んだ直線であり，後者は，ある1時点 t とその後のある1時点 $t+h$ における同一の年齢階級のコーホートの人口中心を結んだ直線である。

また，年齢別人口分布のパターンの変化を測定する場合には，フーバー (Hoover) の提唱した人口集中指標 (index of population concentration) を変形して得た『コーホート別人口分布変化指標 (index of the change of pattern of distribution of population of cohort)』を用いた。

このような測定方法を用いて，わが国の年齢別人口分布の変化を1965年から1970年まで，ならびに1970年から1975年までの2つの期間について測定したところ，以下のような点が明らかになった。

（1） 5年間の各測定期間の初期において，10歳から14歳まで，ならびに，15歳から19歳までの年齢をもつ年齢階級の人びとは分布の中心の位置ならびに分布様式を顕著に変化させ，わが国の人口移動の主要な流れを形成している。

（2） それらの人びとの移動の方向は，わが国の純生産の中心に向う。

こうした解析結果から，わが国の人口移動の主要な流れの主な原因は，その流れを形成している10歳かな14歳まで，ならびに15歳から19歳までの人口集団の行動の特性から判断して，就学および就業であるとみなされる（また，特に，15歳から19歳までの年齢階級の人びとの移動が経済活動と密接な関係をもっているといえよう）。

人口の地域間移動は，一般に社会的経済的要因によると考えられているが，最近におけるわが国の主要な人口移動の流れに対しては，経済的要因が大きく影響を及ぼしているといえよう。