The Spatio-temporal Dynamics of Japanese Birth Rates: Empirical Analyses Using the Expansion Method

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Abstract

This paper investigates the spatio-temporal dynamics of Japan's birth rates in the post-World War II period. The results of our analyses suggest that the spatial manifestations of the tail end of the demographic transition in Japan have been influenced by cyclical fluctuations, with a boom which produced a reversal of the traditional rural-urban birth rate differentials. Our analyses implement the research philosophy and the techniques of the Expansion Methodology.

Key words: post-demographic transition, Easterlin's theory, Expansion Method, spatio-temporal analysis, rural-urban birth rate differentials, the second baby boom.

I. INTRODUCTION

Japan's post-war fertility dynamics reflected the tail end of demographic transition and a variant of the fertility cycles (Ohbuchi, 1982; Ogawa and Mason, 1986) that characterized virtually all developed countries worldwide (Easterlin and Condran, 1976; Butz and Ward, 1979). Namely, they involved the tendency of fertility to approach a lower level and, simultaneously, to oscillate around that level.

Easterlin (1968, 1980) has suggested a theory based on an income effect on fertility, and interaction between economic circumstances and childbearing. These relationships result in a self-generating cycle. Prior to Easterlin, Kuznets (1958) found a 15–25 year coincident cycles in birth rate, migration, and economic growth. Hypotheses such as these, developed in the United States, can be examined using Japanese data at a regional as well as a national scale. We question the extent to which these hypotheses can be applied to the analysis of regional variations in cyclical fertility, variations which are more complicated than those at a national scale.

This paper thus investigates spatial variations in the cyclical trend in the post-demographic transition phase in Japan. Regional differences in the cyclical birth rate trend are examined by testing a drift in the birth rate trend over time and over space. Spatial drift is further investigated in terms of drift across a geographically significant contextual variable, in this case, the level of urbanization. It is a common presupposition that traditional rural-urban fertility differentials persist even in the post-demographic transition phase: high rates in rural areas versus low rates in urban areas. We test whether or not the rural-urban differentials hold over time.

This paper is based on the 'Expansion Method' approach. The Expansion Method combines orderly routines for the investigation of parametric drift with a research philosophy that suggests questioning the contextual stability of models and relationships. Here the Expansion methodology is employed to model the spatial variability of temporal trends in birth rate, and to question the temporal stability of the relationship between birth rate and urbanism.

In the following sections, we first develop the background themes of the research, and relate them to pertinent theories and literatures. A
presentation of the methodology used and of the empirical analyses in which it is implemented follows. We end with some conclusions.

II. JAPAN’S POSTWAR FERTILITY TREND AND CYCLE

The literature has long recognized the relationship between fertility and business cycles (for example, Silver, 1966; Simon, 1969). Pro-cyclical fertility trends were recognized as ‘Kuznets cycles’ (Kuznets, 1958), which encompass matching migration cycles. This linkage is usually explained in terms of the notion that since children may be regarded as consumer goods, more affluent households have more children, when economic circumstances are more favorable. In Easterlin’s formulations, a variant of this income-fertility relationship has been coupled with a second relationship predicated upon the notion that past ‘baby’ boomers will flood the labor market, depress young people’s wages and reduce fertility when the baby boomers come of age (Easterlin, 1968, 1980; Easterlin and Condran, 1976). These processes lead to a self-generating cycle. Easterlin’s hypotheses stress a causal relationship between population growth and income, with a time lag of 20–30 years.

More recently, the suggestion has been made by Butz and Ward (1979) that counter-cyclical fertility surges may have begun to appear as a result of the increased participation of women in the labor force. According to their theory, women work and postpone childbearing in great numbers during an upswing in the business cycle. In the downswing, they are more likely to lose their jobs and to take advantage of this forced absence from the labor force to fulfill their reproductive goals. A number of tests of this counter-cyclical theory of fertility have been carried out for developed countries including Japan (for example, Ermich, 1979; Ogawa and Mason, 1986). Compared with the positive effect of male income on fertility, any negative effect of rising female wages in Japan, however, was less significant, at least until the late 1970s.

Japan’s demographic transition entered its declining phases in the 1920s, and population growth reached a level comparable with western developed countries by the middle 1950s (Tachi, 1960; Harris, 1982). A precipitous decline was set in motion after 1949. Japan’s strikingly rapid fertility decline in the early post-war period was unprecedented and unmatched by the other developed countries.

Figure 1 shows the trends in crude birth rate

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Figure 1. Japan: crude birth rate and standardized birth rate.
The Spatio-temporal Dynamics of Japanese Birth Rates

Figure 2. Labor market of Japan.

(CBR) and standardized birth rate (SBR) over a time spanning from 1947 to 1985. The latter is standardized by the age composition of 1930, but the former remains heavily affected by variations in the age structure. The crude birth rate is, therefore, indeed an inaccurate measure of fertility, but it is the most popular measure of fertility as well as that of population growth. We focus on both indices in our analyses.

The CBR and SBR trends show an overall fertility decline in the post-war period, as the 'demographic transition' theory postulates. However, the tail end of the demographic transition involves not only a monotonic decline in fertility, but rather a decline combined with cyclical fluctuations. In fact, Japan experienced two baby booms in the post-war period. The first one started immediately after the end of the World War II and lasted until 1949. The 'second baby boom' occurred in 1965-1974, during Japan's economic expansion. The moderate upsurge in fertility in the second baby boom, and the subsequent decline, suggest not only the lower 'asymptotic' level in the stage of a mature society, as portrayed in the demographic transition theory but also the emergence of the fertility cycles that characterize in this stage.

The cyclical fluctuations in fertility are related to economic fluctuations. Figure 2 shows unemployment rate and the 'active openings ratio' (ratios of 'job-offers' to 'job-seekers') in the period 1947–1985. Unemployment is low, and job offers outstrip job seekers when the economy is 'overheating' and labor market conditions are especially favorable to job seekers. It is clear that the second baby boom occurred when workers enjoyed such especially favorable conditions. It is doubtful whether this applies to the same extent with respect to the first baby boom. It was instead due to the postponement of childbearing from wartime to the years immediately following the cessation of the hostilities.

The increase in both series during the second baby boom followed by their decline, strongly suggests that the second baby boom was caused not only by an echo effect of the first baby boom, as has been widely acknowledged, but was also an effect of rising income of young people. Indeed, Ohbuchi (1981) in evaluating the applicability of Easterlin's hypothesis to Japan, found a strong correlation between relative wage (of a young generation to that of their fathers's generation) and total fertility rate.

Easterlin's theory highlights the frequently ignored, but important, interactions between
the fertility cycle and the national economy through a closed national labor market, in which the effect of the fertility cycle on the future labor market is lagged. This perspective is relevant at the regional as well as the national scale. Regional variations in population growth by child births remain, about 20 years later, as variations in each region's labor supply. These labor supply variations probably induce spatial adjustment through labor migration. The birth rate therefore constitutes a fundamental factor underlying regional economic dynamics. An analysis of such regional variations in birth rate as a system in regional development is, therefore, critical (ALONSO, 1980).

Migration as another dimension of population growth should also clearly be included. In fact, up to the 1920s, when the U.S. labor market was open to immigrants from the Old World, Kuznets cycles (of 15-25 years duration) were found in the economy, in international migration, and in the birth rate (KUZNETS, 1958). This suggests that the fertility and population migration trends are closely related and intertwined temporally, as both are affected by business cycles.

To compare the trends in birth rates, the economy, and internal migration, we examine the net migration trend in Japan's core regions from 1954 to 1985 (Fig. 3). We define the core as made up of the following ten prefectures: Tokyo, Kanagawa, Saitama, Chiba, Aichi, Mie, Gifu, Osaka, Hyogo, and Nara. Massive rural-urban migration occurred in the 1950s and 1960s. Net migration in the core regions peaked in 1961. Net in-migration in the core regions dropped substantially after the oil crisis of 1973, and was followed by net out-migration in the late 1970s. In the 1980s the net migration began to surge again, reflecting the relative economic recovery of the core from the recession of the mid to late 1970s. It was reported that net migration in the core regions has been almost synchronized temporally with regional income inequality (GAUTHIER, TANAKA AND SMITH, 1992).

We found, as a long run trend, a correlation between economic growth and rural-urban migration, but not between either of these variables and birth rates: economic growth (the active opening ratio) and rural-urban migration peaked in 1961, but the birth rate remained low. After around 1965, however, the three indices, in the long run, seemingly coincided temporally at least until about 1980.
The hypotheses or models of fertility cycles, discussed above, are not fully applicable to Japan. Moreover, their application to the regional dimension is more complicated. To examine the regional variations in birth rates and their spatio-temporal interaction with the regional economy in the post-demographic transition phase, we focus, in this paper, on changes in rural-urban differentials in birth rate.

There is much evidence to support the presupposition that, over the course of the demographic transition, lower fertility spreads from urban centers into rural hinterlands. Such spread effects are considered a spatial expression of the diffusion of 'modernization'. The hypothesis of the spatial spread of lower birth rates from urban centers to their primarily rural hinterlands was tested and validated for the USSR (Casetti and Demko, 1973; Demko and Casetti, 1970), and for Europe between 1860 and 1913 (Casetti and King, 1975).

Certainly, the tendency for fertility to be lowest in core regions and increasingly higher with distance from these regions was a significant and consistent feature of Japan's demography (Kawabe, 1979; Ogasawara, 1973, 1974). Today's developing countries experiencing the demographic transition demonstrate the declining fertility of rural-urban immigrants as they assimilate the low fertility norms of urban areas (for example, Lee and Farber, 1984). Thus, we presuppose that the intermediate to terminal phases of demographic transitions tend to be accompanied by spatial spread of lower fertility from the centers to hinterlands.

Based on this presupposition, a negative relationship between fertility and urbanization is normally expected. However, a few exceptions have been noted. For example, the Netherlands during the middle nineteenth century had higher urban than rural fertility (Petersen, 1960). Here, rising incomes during the urbanization and industrialization processes appear to have had a positive effect on fertility. In the long run, there is a negative relationship between income and fertility, as the demographic transition theory postulates. In the short run, however, a positive relationship between income and fertility has sometimes shown up in the past, as pro-cyclical fertility theories, such as those of the Kuznets and Easterlin cycles, have proposed. In this case, it is possible that rising income in urban areas will lead to a reversal of rural-urban fertility differentials.

In the following sections we report an analysis of the changes in the spatial distribution of Japan's crude birth rates (CBRs) and standardized birth rates (SBRs). The results of this analysis suggest a reversal of rural-urban differentials in CBRs and to lessor extent SBRs. To confirm this trend, the first analysis led to a second analysis to test for drift in the parameters associated with CBRs and SBRs across the rural-urban continuum.

III. SPATIO-TEMPORAL ANALYSIS

The Expansion Method (Casetti, 1972, 1982) is research philosophy and a technique for generating or modifying models by a sequence of well defined logical steps. As a technique, it involves the following:

(a) an 'initial' model in which some or all of the parameters in letter form are selected;
(b) some or all of its letter parameters are 'expanded' by expansion equations that redefine them as functions of variables and/or of random variables that may or may not appear in the initial model;
(c) a 'terminal' model is generated by replacing the expanded parameters into the initial model.

As a research philosophy the Expansion Method stresses the usefulness of relating models to contexts by the expansion of initial formulations in terms of contextual variables. Applications of the Expansion Method have included demographic analyses (Casetti and Demko, 1973; Demko and Casetti, 1970; Casetti, 1973), spatial diffusion studies (Casetti and Gauthier, 1977), investigations of polarized growth (Kraakover, 1983, 1984), and policy evaluations (Thrall, 1979; Jones and Kodras, 1986). Reviews of applications of the Expansion Method are contained in Casetti (1986) and Casetti and Jones (1987).

A number of applications have been concerned with 'trend surface expansions' (Casetti and Jones, 1983; Jones, 1983; Brown and Jones, 1985) and others with temporal parametric
drift (Malecki, 1975, 1980; Pandit, 1986). Both
trend surface expansions and temporal expan-
sion are employed in the analyses that follow.

Our first objective was to investigate the
spatio-temporal trends of Japan’s CBRs and
SBRs during the 1950 to 1985 period. Let us
demonstrate by a simplified example how this
task can be carried out using the expansion
methodology. The relationship constituting
our starting point is between birth rate and
time. Essentially, we address the question of
whether this relationship drifts across space:
does it hold with different parameter values at
different locations in Japan? To investigate
this question, first we specify a suitable rela-
tionship between a measure of birth rate, \( F \), and
time, \( t \), as an ‘initial model’. Let us assume for
the sake of simplicity that a quadratic function
would do:

\[
F = f(t) = a_0 + a_1 t + a_2 t^2 + u
\]

where \( u \) is a well behaved error term; \( f(t) \) de-
notes a family of functions and specializes to a
specific function for given \( a \)’s.

Suppose that the spatial drift of \( f(t) \) is ade-
quately represented by the following ‘expansion
equations’ that redefine the letter param-
eters of \( f(t) \) into quadratic trend surfaces:

\[
\begin{align*}
a_0 &= c_{00} + c_{01} X + c_{02} Y + c_{03} X^2 + c_{04} Y^2 + c_{05} XY \\
a_1 &= c_{10} + c_{11} X + c_{12} Y + c_{13} X^2 + c_{14} Y^2 + c_{15} XY \\
a_2 &= c_{20} + c_{21} X + c_{22} Y + c_{23} X^2 + c_{24} Y^2 + c_{25} XY
\end{align*}
\]

where \( X \) and \( Y \) are geographical coordinates of
the capitals of Japan’s prefectures with respect
to two convenient orthogonal axes.

By replacing the right hand sides of the
equation (2) through (4) for the corresponding
parameters in (1) the following ‘terminal model’ is
obtained:

\[
F = f(t) = b_0 + b_1 X + b_2 Y + b_3 X^2 + b_4 Y^2 + b_5 XY + u
\]

and the dual expansion equations

\[
\begin{align*}
b_0 &= c_{00} + c_{10} t + c_{20} t^2 \\
b_1 &= c_{01} + c_{11} t + c_{21} t^2 \\
b_2 &= c_{02} + c_{12} t + c_{22} t^2 \\
b_3 &= c_{03} + c_{13} t + c_{23} t^2 \\
b_4 &= c_{04} + c_{14} t + c_{24} t^2 \\
b_5 &= c_{05} + c_{15} t + c_{25} t^2
\end{align*}
\]

By replacing the right hand sides of (7)
through (12) for the corresponding coefficients
in (6), terminal model (5) is again obtained.

Suppose we estimate the parameters of the
terminal model (5) from empirical data, and
replace the numerical parameter estimates
obtained for the corresponding letter param-
eters of the primal and dual expansion equa-
tions. The ‘estimated expansion equations’ thus
produced are mathematical portraits of the empirically observed spatial drift of the rela-
tionship between birth rate and time repre-
seed by the primal initial model and of the
empirically observed temporal drift of the dual
initial model that expresses birth rate as an
function of geographical coordinates. Also, the
estimated primal expansion equations will
yield an estimated relationship between birth

Casetti (1986) has shown that whenever a
terminal model has been generated from a
linear initial model by linear expansion equa-
tions, there is a second linear initial model and
associated linear expansion equation(s) that
will yield the same terminal model. If a termi-
nal model is given, as soon as a ‘primal’ linear
initial model and linear expansion equations
able of producing it are defined, a second
‘dual’ linear initial model and associated linear
models and associated expansion equations
become defined.

In our example, the intrinsic duality of the
linear expansions is illustrated by the fact that
the same terminal model (5) can be arrived from
an initial model \( F = g(X, Y) \) relating the \( F \) to the
\( X \) and \( Y \) variables. To show it, assume the dual
initial model

\[
F = g(X, Y)
\]

(6) 

and the dual expansion equations

\[
\begin{align*}
b_0 &= c_{00} + c_{10} t + c_{20} t^2 \\
b_1 &= c_{01} + c_{11} t + c_{21} t^2 \\
b_2 &= c_{02} + c_{12} t + c_{22} t^2 \\
b_3 &= c_{03} + c_{13} t + c_{23} t^2 \\
b_4 &= c_{04} + c_{14} t + c_{24} t^2 \\
b_5 &= c_{05} + c_{15} t + c_{25} t^2
\end{align*}
\]

Equation (5) encompasses simultaneously a
specification of a relationship between birth
rate and time, and a specification of the spatial
variation of this relationship across Japan.

\[
F = f(t) = a_0 + a_1 t + a_2 t^2 + u
\]
rate and time for any \( X \) and \( Y \) duplet, namely, at any location in Japan. Similarly, the estimated dual expansion equations can produce an estimated birth rate trend surface at any arbitrary point in time.

However, our discussion of the results obtained focuses both (a) upon the estimated dual expansion evaluated at three points in time, that illustrate the changes in the spatial distribution of Japan's birth rates, and (b) upon the estimated primal expansion equations evaluated at selected locations, to illustrate the differences in birth rate trends across space.


In our illustrative example we assumed that the appropriate initial model is a quadratic in time, and the appropriate expansions equations are two dimensional second degree polynomials in \( X \) and \( Y \). In the actual empirical analyses, however, no a priori specification of these functions is warranted. The approach we followed can be described as follows. We started from a first degree polynomial in time expanded into quadratics in \( X \) and \( Y \), and then we augmented it sequentially by blocks of terms alternatively corresponding to higher degree polynomials in time and to higher degree trend surfaces. At each step, therefore, for every block of terms added, an F test was carried out to determine whether the terms added were significant and the process was stopped when the last block of terms was not significant at the 1 percent level.

Our procedure is best clarified through comments on the entries in Table 1. The 12 lines in the table refer to the twelve steps by which the procedure was implemented. Each line/step refers to the regression estimate of a terminal model generated by expanding a polynomial in time of the degree specified in column 2. The R-square for the regression is given in column 4. The degrees of freedom in column 5 refer to the F values in column 6. These F's test for significance the block of terms 'added' at a given step. Take for instance line 4: the regression reported in it is based on a 4th degree polynomial in time expanded into 2nd degree trend surfaces. The F statistic in line 4 tests whether the block of terms added to the regression reported in line 3 (third degree polynomial in time expanded into second degree trend surfaces) are associated with coefficients significantly different from zero. Asterisks indicate significance at the 1% level.

Table 1 shows that first we kept increasing the degree of the polynomial in time, then the degree of the trend surfaces, and finally, again the degree of the polynomial in time. The procedure produced a terminal model corresponding to a fourth degree polynomial in \( t, X, \) and \( Y \) that is not significantly improved by increasing the degree of the initial model or of the expansion equations and that represents a significant improvement with respect to terminal models or lower degree expansion equations. Consequently, we selected it as the end product of this analysis.

In the analysis reported in Table 1, CBR is a dependent variable. We could have implemented the same procedure for the analyses with SBR as a dependent variable, but decided against it. Since our objective was to compare the spatial patterns of CBRs and SBRs, it seemed useful to employ the same model specification in both analyses, and therefore, the model arrived at by the sequence of steps documented in Table 1 in the CBR analysis was
also employed in the SBR analysis.

Estimated primal and dual expansion equations were obtained by replacing the letter parameters in the expansion equations by their numerical counterparts appearing in the estimated terminal model. These estimated expansion equations are mathematical portraits of the spatial variation of the birth rate time relationship and of the temporal variation of the birth rate coordinates relationship. Let us focus first on the estimated dual expansions. These equations were used to produce estimated trend surfaces of both CBR and SBR for the years 1950, 1970, and 1985. These trend surfaces are portrayed in Fig. 4.

In 1950 the spatial patterns of both CBR and SBR were similar and by and large, high throughout the country, ranging from about 25 to about 31 births per 1,000 persons for CBR and from 24 to 28 for SBR. The highest rates of both birth rates were observed in northern Honshu and southern Kyushu. The overall spatial patterns support the notion that urban regions had lower fertility than the rural ones, as expected.

The lowest values gravitated in the eastern part of Japan; generally, the farther the distance from Osaka, the higher the CBR and SBR tended to be. The lowest rate was near Osaka, while the prefectures surrounding Tokyo retained relatively high rates. It means, at that time, the former was more urbanized than the latter in terms of fertility behavior, reflecting the former’s historically leading role in development. In fact, it is well known that the western part of Japan (excluding Kyushu) was socioeconomically more advanced long before World War II.

Essentially, the spatial pattern characterized by lower fertility in the core regions basically had not changed since 1920 (Tsubouchi, 1970), despite an overall decline of birth rates since then.

By 1970 the CBRs and SBRs had declined dramatically. The spatial patterns of both CBRs and SBRs no longer shared a similar pattern, and they were strikingly different from the one prevailing in 1950. In 1970 the Tokaido Megalopolis, which includes Tokyo, Nagoya, and Osaka, showed the highest CBRs, in excess of 18, while the lowest rates prevailed in eastern Tohoku and southern Kyushu. The contrast between high CBRs in the Tokaido Megalopolis and low CBRs in the rest of the country is a reversal of the traditional rural-urban differentials.

The spatial pattern of the 1970 SBRs was somewhat different and more complicated. It tended to show somewhat higher rates in core regions. Eastern Tohoku and Kanto had relatively high rates, but most of central Honshu had ‘average’ rates. Low rates appeared in eastern Tohoku and southwestern Japan.

By 1985, both CBRs and SBRs had declined to substantially low levels. At the same time, regional differences had become minor. In terms of CBRs, eastern Tohoku and southwestern Kyushu had relatively higher rates, while a zone stretching from Hokuriku to Shikoku had low rates. Similarly, the regional differences in SBRs became very small.

These spatial patterns in CBRs and SBRs suggest that very interesting shifts in rural-urban differentials occurred over the time horizon covered by our investigation. In 1950 CBRs and SBRs tended to be lower in predominantly urban areas and higher in predominantly rural areas. This was consistent with the results of most empirical studies. However, the 1970 CBR map shows an unprecedented reversal of the traditional rural-urban differentials. The 1970 SBR map does not show this reversal as clearly as the CBR’s, but some urban prefectures exceeded the average rate.

By 1980, the inverse relationship between rural and urban CBRs has disappeared, and a tendency to lower rates in urban environments reappears. This tendency is even more apparent as regards the SBRs. In 1985 the rural-urban differentials in SBRs are back to normal, with the lowest rates in the Tokyo Metropolitan areas. In fact, our analyses show that birth rate trends of the demographic transition type were still underway in peripheral environments, while birth rate cycles were in full swing in urban environments in core regions.

In order to show why this is the case let us focus on the primal estimated expansion equations, and reconsider the logical structure of our
Figure 4. Trend surfaces for CBR and SBR.
analyses. Our initial model is a relationship between birth rate and time. The coefficients of this relationship are redefined by expansion equations into functions of spatial coordinates (specifically, trend surfaces). The terminal model is estimated, and the numerical coefficients obtained are replaced into the expansion equations to produce an estimated primal expansion of the initial model’s coefficients. The coefficients can be used to associate any location in Japan with a realization of the initial model, namely, with a location specific relation between birth rate and time. Consequently, if the coordinates of locations typically urban and typically rural and peripheral are entered into the estimated primal expansion equations, we obtain estimated birth rate trends that are typical of these environments.

The birth rate trends obtained by entering into the estimated expansion equations the spatial coordinates for two points in or near the core regions and for two points in the periphery (Fig. 5), were calculated and graphed (Fig. 6). CBRs for rural locations are characterized by birth rate trends of the ‘tail end of the demographic transition’ type, while the urban core locations display a cycle with a maximum at circa 1970. The second baby boom was pronounced in the urban areas in contrast to no apparent upsurge for the rural areas.

The changes in rural-urban differentials in birth rate suggested by the spatio-temporal analyses is investigated and tested in the analysis that follows.

IV. BIRTH RATE AND URBANIZATION ANALYSIS

The analysis reported in this portion of the paper investigates the temporal drift of the relationship between both CBRs and SBRs and ‘urbanization.’ Urbanization is hereby operationally defined as the percentage of population in urban areas. Our approach involves defining a birth rate urbanization relationship and then investigating whether this relationship drifts significantly over time in a manner that is consistent with the changes in rural-urban differentials suggested by our previous analysis.

Let our primal initial model be a simple linear relation between birth rate (CBR or SBR), $F$, and urbanization, $U$:

$$F = a_0 + a_1 U + u$$

where $u$ is an error term. It should be noted that the $a$, $b$, and $c$ coefficients appearing here and hereafter are unrelated to those in the previous analysis.

The $a_1$ parameter in equation (13) determines whether the relationship between fertility and urbanization exists, and whether a high urbanization level, or its opposite, is associated with higher fertility. Specifically, if $a_1$ is zero, there is no relation between fertility and urbanization. If $a_1$ is negative, the fertility urbanization relationship is of the conventional type; if it is positive, the relationship is of the alternative type.

The primal expansion equations redefine $a_0$ and $a_1$ into polynomials in time. Assume for the sake of simplicity that cubic polynomials portray adequately the temporal changes of $a_0$ and $a_1$. The expansion equations are:

$$a_0 = c_{00} + c_{01} t + c_{02} t^2 + c_{03} t^3$$

$$a_1 = c_{10} + c_{11} t + c_{12} t^2 + c_{13} t^3$$

By substituting the right hand sides of (14) and (15) into (13), we obtain the terminal model:

$$F = c_{00} + c_{01} t + c_{02} t^2 + c_{03} t^3$$
$$+ c_{10} U + c_{11} t U + c_{12} t^2 U + c_{13} t^3 U + u$$

Figure 5. Locations: core (B, C); periphery (A, D).
Upon estimation from empirical data, equation (16) can examine the changes in rural-urban differentials. In fact, if the statistically-significant estimate for the corresponding letter parameters in equation (15) and the resulting estimated expansion equation produces the requisite sign change in c₁₀, c₁₁, c₁₂, and c₁₃, if these are substituted for the corresponding letter parameters in equation (15), and if the resulting estimated expansion equation produces the requisite sign changes in a₁, then the reversal of these differentials may be regarded as proven.

The terminal model (16) can be also produced by the dual initial model (17) and expansion equations (18) through (20).

(17) \[ F = b_0 + b_1 t + b_2 t^2 + b_3 t^3 + u \]
(18) \[ b_0 = c_{00} + c_{10} U \]
(19) \[ b_2 = c_{01} + c_{11} U \]
(20) \[ b_3 = c_{02} + c_{12} U \]

The dual initial model is a birth rate time relationship. The estimated dual expansion equation can associate any arbitrary level of
urbanization with a realization of this dual initial model. Consequently, different urbanization levels may produce birth rate trends with or without the surge between 1965 and 1975 observed in the national data and in some of the results produced by the previous analyses.

The empirical analysis presented in the paragraphs that follow was again carried out separately for CBRs and SBRs and was based on the previous birth rate data complemented by data on the percentage of urban population by prefecture for the same years. In this second analysis our primal initial model was assumed on a priori grounds. However, we had no basis for selecting the degree of the polynomial in time appearing in the primal expansion equations, in the terminal model, and in the dual initial model. The estimation approach we followed is similar to the one applied for the previous set of variables. A terminal model based on expansion equations defined as linear functions of time was estimated first. Then we added the terms required by quadratic expansions, by cubic expansions, and so on. At each step the terms added were tested as a block using $F$ statistics to determine whether we could reject the null hypothesis that their parameters were not significantly different from zero. The polynomials selected are the highest degree for which the null hypothesis could be rejected at the 1% level.

Table 2 documents this search and shows that fourth degree polynomial expansions generated the terminal model selected. As in the previous analysis, this search was not carried out for the SBR analysis in order to use the same model specification arrived at for the CBRs. This decision was again motivated by our intention to compare and contrast the results of the CBR and SBR analyses.

Let us focus on the expansion equation for the slope, $a_1$, of the primal initial model, $F = a_0 + a_1U$. The slope parameter reflects the 'effect' of urbanization on birth rates. Figure 7a shows that $a_1$ of CBR was negative in the 1950s, but rapidly came close to zero in the mid-1950s, and by 1960 it became positive, attaining a maximum between 1965 and 1970. By 1980 $a_1$ became negative again, thus initiating a return to the traditional negative effect of urbanization.

Figure 7b portrays the temporal trends of the slope parameters in the SBR model. This slope parameter was negative throughout the 1950-1985 period; however, it became very close to zero in the 1965-1975 subinterval, and declined thereafter. This means that the effect of urbanization on SBRs remained negative throughout the period under study, while the rural-urban differentials became almost negligible during the second baby boom.

The estimated dual initial model at three levels of urbanization is plotted in Fig. 8. The plots show a pattern very similar to the one suggested by the previous analysis. Namely, the second baby boom materializes in urban but not in rural environments. More specifically, rural CBR trends involve a monotomic decline over time, while urban CBR trends display the upswing between 1965 and 1975 noted earlier. On the other hand, such reversal or rural-urban differences was less visible in SBRs, but the rural-urban differentials in SBRs were substantially reduced in 1970. In other words, rural SBR trends declined over time, but urban SBR trends were cyclical. Thus, a complete reversal of rural-urban differentials did not occur in SBRs, but the effect of the second baby boom was more pronounced in urban SBRs.

Our findings are contrary to the well accepted trends in rural-urban fertility differentials. The unusual reversal of rural-urban differentials in CBRs, and the lack of those in SBRs occurred in the second baby boom period. Indeed, the reversal of natural increase rates between rural and urban areas took place in the late 1960s.

Table 2. Regression results from fertility urbanization analyses, dependent variable: CBRs.

<table>
<thead>
<tr>
<th>$t$ (1)</th>
<th>$R^2$ (2)</th>
<th>Degrees of freedom (3)</th>
<th>$F$ (4)</th>
</tr>
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* Significant at the 1% level.
The rural-urban reversal in CBRs is clearly attributable to the postwar rural-urban migration which increased the urban share of people of child bearing years, but questions remain concerning SBRs. Unfortunately rural-urban or regional differentials in fertility cycles have not been widely examined. To our knowledge, there is a similar example reported in the United States, in which, during the post-war baby boom, an increase in fertility was more pronounced in urban areas than in rural areas (Rindfuss and Sweet, 1977). Why was urban fertility more affected by a baby boom?

The explanation for the remarkably diminished rural-urban differentials in SBRs in the second baby boom is still speculative, but we can invoke the Kuznets (1956) and Easterlin (1980) cycle theories. These theories attribute a baby boom to the rising income or economic prosperity of young people. Urban areas with rapid job creation and high income attracted a large number of young people from rural areas, and their economic prosperity probably affected urban young couples in such a way as to generate rising urban fertility. Therefore, there is admittedly the long-run negative effect of income on fertility, as the demographic transi-
Figure 8. Dual initial model $F = b_0 + b_1t + b_2t^2 + b_3t^3$ evaluated at three levels of urbanization: CBR(a) and SBR(b).

...tion theory postulates—thus, temporally declining, and spatially lower urban fertility—, but the short-run positive effect of income on fertility as well as migration in the second baby boom resulted in the reversal in the traditional spatio-temporal patterns of CBR, and a geographical variation in the manifestation of the baby boom which was more noticeable in urban than rural areas, even in terms of SBR.

V. CONCLUSIONS

This paper investigates the spatial temporal patterns of Japan's CBRs and SBRs between 1950 and 1985. We test spatio-temporal drift in CBR and SBR trends, and drift in both across the rural-urban continuum.

Our analysis shows that a considerably unique phenomenon occurred during the second baby boom: the reversal of the rural-urban differentials in terms of CBR, and the
shift to almost negligible rural-urban differentials in terms of SBR. We also found that second baby boom was an predominantly urban phenomenon; urban birth rate trends display a cycle with a maximum at circa 1970, while rural counterparts show the tail end of the demographic transition.

The rise in urban CBRs can be related to the massive postwar migration from rural to urban areas. The rise in urban SBRs and the diminished rural-urban differentials during the second baby boom constituted a distinctive spatial patterning of the fertility cycle in the post-demographic transition stage. Our analyses reveal such impressive changes in the spatio-temporal trends, but, to reinforce our argument, it would be desirable to investigate these further by using the total fertility rate, a more adequate measure of fertility than the SBR.

Unfortunately rural-urban differentials or regional differentials in fertility cycles have not been fully examined in terms of the fertility cycle theory. In this paper, we speculate on the extension of the pro-cyclical models, such as Easterlin model, to the regional level.

The approach of this paper is of great importance, as regional birth rate cycles have great impacts on future local labor markets and migration. For example, the distorted spatial pattern of birth rates generated during the second baby boom has obviously affected, first, the local school system, subsequently the local labor market, and, in turn, interregional labor migration after the mid-1980s. Such sets of processes are often ignored, but indeed relevant in the analysis of regional dynamics. The interactions between regional birth rates and economic growth should be investigated further, theoretically and empirically.

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戦後日本の出生率の時・空間変動
——エックスパンション法を使用した実証分析——

田中恭子*・E. カセッティ**

人口転換理論の最終段階における出生率の低下は、周期的な変動をすることに特徴が見られる。欧米先進諸国と同様に、日本でも周期的変動がみられたが、空間的側面の変動については余り研究が行われていない。本研究は1950年から1985年の間における日本の出生率の空間的変動、及びその都市化レベルとの関係の変遷について分析を行った。分析方法はエックスパンション法に基づき、パラメーターの変化を検証した。その結果、第二次ベビー・ブームは、伝統的な都市・農村間の出生率差の逆転をまねく、特異な空間的パターンを出現させ、また上昇・下昇のサイクルは特に都市において激しかったことが明らかとなった。

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