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CAUSAL RELATIONSHIPS BETWEEN INFANT MORTALITY AND FERTILITY IN DEVELOPED AND LESS DEVELOPED COUNTRIES

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ABSTRACT

This paper is a study of the dynamic relationships between two demographic variables--the infant mortality rate and the fertility rate--using time series methodology. I believe that I have shown that infant mortality and fertility are not independent but rather are jointly determined. Also, I believe that I have shown that a decline in infant mortality that is due to an increase in per capita real income triggers a subsequent decline in fertility. This dynamic nexus between changes in infant mortality and fertility lies at the heart of the so-called "demographic transition."

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Causal Relationships between Infant Mortality and Fertility in Developed and Less Developed Countries

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I. INTRODUCTION

"Fertility reduction seems to be a nearly universal feature of the development of modern secular societies,..."[1,2] The lagged response of fertility to reductions in mortality (manifested in the lack of coordinated fertility control programs) have historically resulted in high growth rates of population in the less developed countries, e.g., Latin American countries (Arriaga 1970).[3]

Over the past two decades, the causal relationships between infant mortality and fertility have been a controversial issue (Heer 1983 and Scrimshaw 1978). Since the direction of this causality is not established on empirical grounds, many existing estimates of fertility demand functions and infant survival production and demand functions are marred by simultaneous equation bias. The purpose of this study is to examine the dynamic relationships between infant mortality and fertility by applying time series techniques to the annual data on these variables for economically developed countries and for economically less developed countries.

First, I examine causal relationships within a two-variable model--infant mortality and fertility rates--for a sample of economically developed countries, including the Western European countries of Denmark, Finland, France, Norway, Portugal, Switzerland, and the United Kingdom (the U.K.), and the United States

(U.S.A.). The time periods studied are: 1939-74 for most of the European countries, 1942-75 and 1944-75 for the U.K., and 1923-77 for U.S.A.[4]

Second, I examine dynamic responses within a larger-scale dynamic system that includes per capita real income, total mortality rate, infant mortality rate, and birth rate, for three Latin American countries, Uruguay, Chile, and Costa Rica.[5] Each of these three countries experienced some economic development before World War II. While Uruguay has now, essentially, passed through its demographic transition, Chile is still in the midst of its era of transition having entered it in the early 1960s. Costa Rica, on the other hand, has just begun its era of fertility decline (Oechsli and Kirk 1975). In addition, Uruguay and Chile have been heavily affected by European migration. These similarities and differences should be useful in illuminating the nature of the dynamic relationship between infant mortality and fertility.

According to the theory of demographic transition, mortality decline occurs along with an increase in industrialization and urbanization, a diffusion of medical technology, and rises in literacy and living standards (Davis 1945 and Pitchford 1974). With some time lag, the reduction in mortality triggers a subsequent fall in fertility. The positive association between the length of post-partum amenorrhea and the duration of breast feeding are the biological and physiological causal effects of a decline in infant mortality that reduces fertility (Chen et al.

1974, Ginneken 1974, and Potter 1963).[6] The prolonged lactation due to the reduction in infant mortality has an important fertility reducing effect. For the behavioral responses of fertility behavior, Chowdhury et al. (1976) in their study for Pakistan and Bangladesh as well as May and Heer (1968) for India support the child survival hypothesis, while Olsen (1980) finds the child replacement effect for Colombia.[7] Heer (1983) argues that the magnitude of the responses of couples' fertility behavior will depend on their preference for the lost child's sex and the surviving children's sexes and number as well as the perceived monetary and psychic costs of birth controls. For example, Coombs and Sun (1978) and Heer and Wu (1975) find that in Taiwan, births that follow previous child deaths are higher when the losses are male and the surviving children are female, because of the strong preference for sons.

On the other hand, in the Malthusian theory, a rise in real wages above a subsistence level reduces the average age of marriage and increases the fertility rate, which is expected to cause an increase in mortality rates with some lag. In general, high fertility rates are responsible for high risk births, e.g., births to young mothers and old mothers, fourth and higher-order births, illegitimate births, and low birth-weight births (Omran and Standley 1976 and Woodbury 1925). In some areas of Germany where breast feeding was uncommon in the 19th century, the strong positive correlation between marital fertility and infant mortality is attributed to the short intervals of births (Knodel 1968).[8]

Finally, the modern economic theory of population emphasizes an interdependency between infant mortality and fertility. Parents devote their time and provide medical care and nutritious food for their infant. The parents' decision on the allocation of resources will consequently determine the outcome of the infant's health. Therefore, the child quality, e.g., infant health status, and the number of children are jointly determined by the parents (Becker and Lewis 1973 and Willis 1973).

These three contrasting views of the causal relationships between infant mortality and fertility do not provide researchers an a priori notion of whether they should treat infant mortality and fertility rates purely exogenously or endogenously in their models. To establish the dynamic relationships between the two, it is worthwhile and natural to apply time series techniques developed by Granger (1969) and Sims (1980) to the data on infant mortality and fertility rates.

The organization of the subsequent sections is as follows: Section II describes briefly the time series techniques used to observe causal and dynamic relationships between variables in a system. Section III reports the empirical results. Finally, section IV gives a summary of this study.

II. STATISTICAL TECHNIQUES OF CAUSALITY TEST

The Granger-causality is defined as follows: A stationary stochastic time series, X, causes another stationary stochastic time series, Y, within a set of information in the universe, if the current value of Y is more accurately predicted by using the information that includes at least the own-past series of Y and the past series of X than by using the information that excludes the past series of X (Granger 1969).

To carry out the Granger-causality test, the vector autoregressive (VAR) model is estimated, e.g., in a simple two-variable model, as follows:

$$FE(t) = a_0 + \sum_{s=1}^{m} a(s)FE(t-s) + \sum_{s=1}^{m} b(s)INF(t-s) + e(t), \; \ldots.. \quad (1)$$

$$INF(t) = c_0 + \sum_{s=1}^{m} c(s)FE(t-s) + \sum_{s=1}^{m} d(s)INF(t-s) + e^*(t), \ldots.. \quad (2)$$

where $FE(\cdot)$ and $INF(\cdot)$ are stationary stochastic time series of fertility and infant mortality rates, respectively; and $e(\cdot)$ and $e^*(\cdot)$ are white-noise error terms, which are called the innovations in fertility and infant mortality rates in the VAR model, respectively.

In order to test the Granger-causality from INF to FE in the VAR model, the null hypothesis is that the set of parameters $b(s)$, $s=1,2,\ldots,m$, should be zero if there is no Granger-causality from the causal variable INF to FE. By the same manner, for the test of the Granger-causality from FE to INF in the model, the set of parameters c(s), s=1,2,...,m, should be zero if there is no Granger-causality from FE to INF.[9]

After estimating the above VAR model with appropriate lag distributions, the model is inverted to a linear combination of the innovations in FE and INF in order to compute the responses of FE (or INF) to typical random shocks in the innovations. The moving average (MAR) model is defined as follows:

$$Z(t) = \sum_{s=0}^{\infty} G(S)E(t-s), \quad ..... \quad (3)$$

where $Z(\cdot)$ is a vector of FE and INF; and $E(\cdot)$ is a vector of the innovations in FE and INF, defined as $E(t)=Z(t)-\hat{Z}(t)$ where $\hat{Z}(t)$ represents the best linear forecast of Z(t) based on its past series $Z(t-s)$, $s > 0$.[10] A particular i-th equation of Z(t), e.g., FE equation in the form of MAR representation, is expressed as follows:

$$FE(t) = \sum_{j=1}^{2} \sum_{s=0}^{k} g_j(s) e''_j(t-s), \quad ..... \quad (4)$$

where $e''(\cdot)$ are the innovations in FE and INF. The sum of $g_j(s)$ from s=0 to s=k, e.g., the j-th component of $e'' \equiv$ the innovation in INF, represents the cumulative resonses of FE in the k+1 step-ahead to random shocks in the innovation in INF.

III. EMPIRICAL RESULTS

Granger-causality tests between infant mortality and fertility rates are performed using the annual data for the Western European countries and the United States where only data on whites were used.[11] Table 1 reports the F-statistics on the three (or five) lag coefficients of the causal variables. Table 2 presents the results of the cumulative responses of infant mortality rate (or birth rate) to random shocks in the innovation in per capita real income (or infant mortality rate) in the system which includes per capita real income, total mortality rate, infant mortality rate, and birth rate.[12]

Concerning the issue of the Granger-causality between infant mortality (INF) and fertility (FE) in Table 1, the F-statistics under infant mortality indicate that most of the results of the Granger-causality from INF to FE are statistically significant. For the results of Finland and the U.K., we find that there are significant improvements in the F-statistics from the three to five lag distributions. The F-statistics under fertility show that the Granger-causality from FE to INF for the results of Finland, France, Norway, Switzerland, the U.K., and U.S.A. are statistically significant. We note from the above results that infant mortality and fertility are not independent but causally related with each other. In particular, both are jointly determined in Finland, Norway, Switzerland, the U.K., and U.S.A.[13]

In Table 2, the cumulative responses of infant mortality rate (INF) to per capita real income (INC) are negative in Chile, Costa Rica, and Uruguay for all time horizons shown, i.e., 4, 6, and 8 years ahead. That is, an increase in per capita real income will unambiguously lead to a fall in infant mortality rate for these countries. The fall in the infant mortality rate (INF) consequently triggers a subsequent fall in the birth rate (BIR). The above dynamic associations show the nexus between changes in infant mortality and fertility that lies at the heart of the so-called "demographic transition."

TABLE 1

Granger-Causality Test[a]

F-Statistics on Causal Variable

Country	(d.f.)	Infant Mortality in Equation (1)	Fertility in Equation (2)	Time Period
Denmark	(3,26)	6.055***	1.517	1939-74
Finland	(3,26)	2.323*	1.965	1939-74
"	(5,20)	4.608***	2.192*	1941-74
France	(3,26)	1.022	3.001**	1939-74
Norway	(3,26)	2.322*	3.454**	1939-74
Portugal	(3,26)	5.268***	0.064	1939-74
Switzerland	(3,26)	2.903*	2.483*	1939-74
U.K.	(3,23)	2.208	1.548	1942-74
"	(5,18)	7.682***	2.830**	1944-74
U.S.A.	(3,45)	2.241*	5.677***	1923-77

Note. [a]Source: Yamada(1981).
* Significant at $a = 10\%$ ** Significant at $a = 5\%$
*** Significant at $a = 1\%$
(d.f.) is degrees of freedom.

TABLE 2

Cumulative Responses of Infant Mortality rate (INF) and Birth rate (BIR) in K Years Ahead

Country	K	INC→INF	INF→BIR
Chile	4	- 5.38	-0.06
	6	-15.25	3.70
	8	-25.36	7.02
Costa Rica	4	-19.12	2.00
	6	-27.26	3.03
	8	-23.01	2.98
Uruguay	4	- 7.19	-0.05
	6	- 5.46	1.44
	8	- 9.36	1.70

Note. INC→INF represents the cumulative responses of infant mortality rate in k years ahead to one standard-deviation shock in the innovation in per capita real income. Similarly, INF→BIR represents the cumulative responses of birth rate to the random shock in the innovation in infant mortality rate.

IV. SUMMARY

The aim of this study is twofold: first, it is to answer empirically the question whether infant mortality is historically one of the significant factors that influenced fertility and vice versa; and the other is to observe the dynamic responses of fertility to infant mortality.

By using the time series techniques developed by Granger (1969) and Sims (1980), I have shown that infant mortality and fertility are not independend but jointly determined. Also, I have shown that a decline in infant mortality that is due to an increase in per capita real income triggers a subsequent decline in fertility. This dynamic nexus between changes in infant mortality and fertility lies at the heart of so-called "demographic transition."

APPENDIX

Variable	Definition
Fertility rate	The number of live births per 1,000 female population between the ages of 10-49 years in one calendar year. Source: See the United Nations in Reference (U.N.).
Fertility rate (U.S.A.)	The number of live births per 1,000 female population between the ages of 15-44 years in one calendar year. Source: See the United States of America in Reference (U.S.).
Infant Mortality rate	The number of deaths under 1 year (exclusive of fetal deaths) per 1,000 live births. Source: the U.N. and the U.S.
Total Mortality rate	The number of total deaths per 1,000 population. Source: the U.N.
Birth rate	The number of live births per 1,000 population. Source: the U.N.
Per capita real Income	Per capita Gross Domestic Product in constant dollars of 1970. Source; Wilkie and Haber (1981).

FOOTNOTES

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[1] Coale (1967), p.208.

[2] Coale (1967) points out the circumstances associated with the fertility reduction, e.g., the decline in mortality, the rising costs and diminished economic advantages of children, higher status of women, religious changes and differences, and the development of a secular, rational attitude (p.208). Similar arguments can be found in Heer (1968).

[3] Researchers such as Frederiksen (1966), Freedman (1965), and Freedman et al. (1974) emphasize the importance of effective family planning programs for the fertility reduction. This point is clearly made in the addresses by A. W. Clausen, President of the World Bank, to the National Leaders' Seminar on Population and Development in Nairobi, Kenya on July 11, 1984, and the International Population Conference in Mexico City, Mexico on August 7, 1984 (World Bank 1984).

[4] The data on infant mortality and fertility rates are annual time series. The definitions and source are listed in the appendix. The choice of the countries and the time periods were decided on the grounds of expediency. More recent data for the European countries studied were unavailable at the time when this paper was under revision.

[5] The data on the demographic and economic variables are annual time series. The appendix lists the definitions and source.

[6] Lactation is not purely biological since its duration is behaviorally determined (Taylor et al. 1976).

[7] When infant mortality is treated exogenously in a simple microeconomic model, the model predicts that the parents will reduce their desired number of births in response to a fall in infant mortality, if the demand for surviving children is price inelastic (Schultz 1976a and 1976b).

[8]Knodel and van de Walle (1967) and Wolfers and Scrimshaw (1975) also support the idea that birth or pregnancy intervals influence child survival.

[9]The Granger-causality test might be sensitive to misspecification, e.g., omitted variables or lag structure in the system. It is, however, very costly in terms of degrees of freedom to include more variables and/or more lags in the system when only a small number of time series observations are available to test the Granger-causality.

[10]If the components of E are contemporaneously correlated, it is not possible to partition the variance of Z into pieces accounted for by each innovation. An orthogonalization for E is, therefore, made after a triangularization of the system. See Gordon and King (1982), Litterman (1979), and Sims (1980) in detail.

[11]To estimate the system for each country, the VAR model is estimated in a logarithmic specification with three (or five) lag distributions. Each equation in the model includes a constant term, a linear time trend, and two dummy variables such as D1=1 for 1936-45 and D1=0 otherwise and D2=1 for 1946-50 and D2=0 otherwise. In the case of the United States, D2=1 for 1923-26 and 1946-55 and D2=0 otherwise, while D1 is similarly defined as above.

[12]The VAR model is estimated in a logarithmic specification with three lag distributions, including a constant term and a linear time trend in each equation of the model. These simulations are made based on the VAR model for the sample periods of 1951-78 for Uruguay and 1951-79 for Chile and costa Rica.

[13]Eckstein et al. (1981) finds a similar result for the Swedish data during the period 1870-1955.

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