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Static and Dynamic Cross-Sections:

Inferences for the Contemporary Fertility Transition*

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Concern has been expressed with the drawing of inferences on the dynamic process of the contemporary fertility transition from a static cross-section of fertility rates. The issue is directly tested in this study. A simple two equation simultaneous model for aggregate fertility change and economic growth is estimated for a cross-section of 57 developing nations. Static and dynamic versions of the sample are compared. Regression diagnostics are applied to both sets of estimations to assess the sensitivity of the results to multicollinearity and to identify outlier nations. The conclusion reached is that there are significant differences between the static and dynamic versions of the model. Thus caution is warranted with respect to purely static analyses of the contemporary fertility transition.

I. Introduction

Because time series data for adequate longitudinal analyses are rather scarce, most research on the determinants of aggregate fertility in the developing economies relies on cross-sections of Less Developed Countries (LDCs). One objection to this practice concerns the implicit assumption underlying the analysis, i.e., that the fertility transition is accurately portrayed by the experiences of

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various countries at different stages of development.[1] Critics (e.g., Schultz 1976: 106-107) argue that the estimated relationships derived from a cross-section of nations at a point in time need not correspond to the temporal experience of any one nation. Moreover, cultural differences, difficult to quantify in the best of circumstances, are far greater for a cross-section of nations than for a given nation over the course of its development (U.N. 1977: 41).

Intuitively the concern with drawing inferences about the dynamic process of the fertility transition from a static cross-section of fertility rates seems justified. The concern is directly tested here. A simple two equation model for aggregate fertility change and economic growth is estimated for a cross-section of 57 LDCs. Static and dynamic versions of the sample are compared. In the static version the dependent variables are the levels of national fertility and per capita national output in 1977. In the dynamic version the dependent variables are the changes in national fertility and per capita national output from the early 1970s to the early 1980s. The regression diagnostics of Belsley, Kuh and Welsch are applied to both sets of estimates to assess the sensitivity of the regression models to multicollinearity and to identify the "outlier" nations.

Section II sets up the regression model and briefly discusses the rationale for the selected explanatory influences on fertility change and economic growth. Section III describes the sample of

1 By the "fertility transition" is meant the process of moving from a traditional regime of high fertility to a modern regime where the average couple desires and produces no more than the approximately two births required for replacement.

Toni Richards stresses this point from the outset in her comprehensive review of the literature:

> "Much of the research has concerned the impact of modernization on fertility decline. In the rather short periods for which data are available, these variables tend to change rather slowly. However, cross-sectional differentials, either between countries or between regions within countries, tend to be rather large; these cross-sectional differentials can be thought of as the result of some long historical process. It is unlikely that the same model that accounts for changes in fertility over the period of observation will also account for differentials arising from long-term historical evolution" (p. 697).
>
> "... It can be argued that, under conditions of structural stability, where coefficients do not change with time or with different levels of development (no interactions), estimates based on within-cross-section variance represent the long term by averaging effects of several time periods. Unfortunately, hypotheses about stability of coefficients are rarely verified, and, when verification is attempted, seem unfounded" (p. 703).

LDCs used to test the model and presents the two stage least squares regression estimates. As will be shown, there are significant differences between the static and dynamic representations of the sample. Section IV concludes the study with notes on the policy implications and the value of cross-country analyses of aggregate fertility change.

II. The Regression Model

The intent here is not to provide an exhaustive survey of the literature on the determinants of fertility in developing societies. There are a number of fine reviews of the work in this area.[2] The intent rather is to set out a simple regression model of the fertility transition which can be tested with both a static and dynamic cross-section of contemporary LDC experiences. Thus only a very concise account of the hypothesized major influences on fertility change and economic growth will be given.

Fertility:

In the empirical work on the determinants of fertility in developing countries, several factors are usually represented. Broadly defined these include: infant mortality and the general health of the population, education, urbanization, income, and family planning activity.

The theory of the demograpic transition highlights the role played by falling infant mortality in reducing fertility. With economic development the survival prospects of children increase and eventually parents realize that fewer births are required to achieve a given desired family size. On the other hand, improved health conditions enhance the fecundity of the average female and, barring adjustments in contraceptive behavior, may be associated with higher fertility. The overall effect of lower infant mortality on fertility, however, is likely to be direct; although the evidence suggests that the compensation by fertility for changes in

2 For example, see Bulatao and Lee (1983b) for a useful survey of the determinants of fertility in developing countries. More directly related to the present study is Hess (forthcoming).

child mortality is less than complete.[3]

One of the strongest influences on fertility is education, especially female education beyond primary school. Secondary education can serve to delay marriage and increase economic mobility, hence the alternatives to early and frequent fertility. Basic literacy would complement the efforts of family planning programs to the extent receptiveness to change, e.g., the adoption and effective use of modern contraception, is encouraged. In some instances, however, a modest amount of primary education is associated with higher fertility. The reasons include reduced observance of traditional practices (e.g., extensive breastfeeding and significant intervals of post partum abstinence) and improved health (e.g., less secondary sterility and fetal wastage) which might have suppressed fertility.[4]

Urbanization is related to lower fertility since the net advantages to large families fall in urban areas (e.g., the costs of food and shelter are higher and the opportunities for child labor are fewer). Moreover, education, health care, family planning services, and new consumer goods tend to be more available than in rural areas.

Per capita income, despite the difficulties with international comparability, is often used to indicate the level of economic development. If children are normal goods, higher income would result in higher fertility, *ceteris paribus.* The Chicago-Columbia microeconomic model of fertility, however, emphasizes the trade-off of quantity for quality of children and the rising opportunity cost of fertility with gains in economic mobility (e.g., Schultz 1976). That is, a relaxation of the budget constraint elicits not a rise in the average number of children born, but greater expenditures per child. Also higher incomes may stimulate consumption aspirations which conflict with high fertility.[5]

Family planning programs can assist the fertility transition by lowering the costs and "legitimizing" the practice of modern contraception. The general consensus is that family planning pro-

3 See Preston and Heer.

4 See Cochrane for an overview and analysis of this literature.

5 Mueller and Short provide a comprehensive review of the hypothesized effects of income on fertility.

grams work in concert with socioeconomic development, supplying the demand for birth control.[6]

In sum, fertility is written as dependent on the following factors:

$$F = f(\overset{+}{M}, \overset{-}{Y}, \overset{+}{P}, \overset{-}{S}, \overset{+}{A}, \overset{-}{FP})$$

where

F = Total Fertility Rate
M = Infant Mortality Rate
Y = Per Capita National Income
P = Primary School Enrollment Rate (i.e., the influence of basic education or literacy)
S = Secondary School Enrollment Rate for Females
A = Percentage of the Labor Force in Agriculture (i.e., a proxy for urbanization)
and FP = Family Planning Program Effort (i.e., the input of family planning programs).

The signs over the arguments indicate the hypothesized direction of each influence on the dependent variable.

Economic Growth:

Since aggregate fertility change is the main interest, only a simple equation for growth is developed. The model, however, highlights the potential influence of fertility change on economic growth.

Begin with a standard two factor aggregate production function:

$$Q = Q(K,L)$$

where Q = national output
K = capital input
L = labor input.

6 For a policy oriented discussion of family planning in developing countries, see "Family Planning as a Service" in *World Development Report 1984*.

Totally differentiating both sides and rearranging gives,

$$dQ/Q = n_k(dK/K) + n_l(dL/L)$$

where dQ/Q, dK/K, and dL/L are the growth rates of output, captital, and labor and n_k and n_l are partial output elasticities.

After subtracting the growth rate of population, dP/P, from both sides of the equation, the growth rate of per capita output, dY/Y, can be written as:

$$dY/Y = dQ/Q - dP/P = n_k(dK/K - dP/P) + n_l(dL/L - dP/P) - (1 - n_k - n_l)dP/P$$

Note that if the growth rate of labor equals the growth rate of the population, dL/L = dP/P (e.g., a stable population with full employment and constant labor force participation rates), and if the partial output elasticities sum to one (e.g., a linearly homogeneous Cobb-Douglas production function), then the growth rate of per capita output reduces to a function of the per capita growth rate of capital — a version of the simple neoclassical intensive production function. Essentially then, as modeled, the growth rate of per capita output depends on physical capital intensity and an adjustment for population growth.

For a given rate of output, *per capita* output is directly increased by lower population growth rates. Economic growth may be further enhanced by lower fertility through favorable age structure effects.[7] Reducing the traditionally high fertility found in the developing economies alleviates the large youth burdens of dependency and "frees up" resources for the human and physical capital deepening required for economic growth. Moreover, reductions in the fertility rate transitorily increase the proportion of the population in the labor force years — since there are fewer child dependents than otherwise and the size of the potential labor force will not change for at least a decade and a half. In-

[7] Ansley Coale and E.M. Hoover in the classic study first investigated the favorable age structure effects of declining fertility for economic development. The importance of the burden of dependency for savings rates and economic growth, however, is still open to question — as the exchange between Leff (1984) and Ram (1982,1984) illustrates.

deed, if lower fertility prompts increased female labor force participation rates, then the size of the labor force will be larger.[8] Therefore, for a given capital stock, reductions in the fertility rate can spur economic growth. Improved mortality conditions, however, will somewhat offset this favorable age distribution effect to the extent the increases in the survival rates are concentrated in the younger years. On the other hand, improved mortality conditions may reflect gains in the average health and productivity of the population.

Reliable data on the levels and utilization rates of physical capital in LDCs are difficult to find. Therefore energy consumption will be used to represent the input of physical capital. The total fertility rate and the infant mortality rate will be used to capture the age structure effects. The general form of the equation for national output then is:

$$Y = y(\overset{-}{F}, \overset{-}{M}, \overset{+}{E})$$

where the variables Y, F, and M are as defined above and

E = per capita energy consumption.

Model Specification:

National fertility and national output are endogenous and simultaneously determined. The variables M, P, S, A, FP, and E are considered exogenous.[9] With the exception of energy consumption which is contemporaneous with fertility and output, the other regressors are lagged.

The functional form selected is multiplicative, i.e., of the

[8] Simply stated, the loss of potential entrants into the labor force due to lower fertility could not reduce aggregate output for 15 years (other than the marginal contribution of child labor). With the significant population momentum and labor surplus conditions facing most of the LDCs, however, the relative reduction in future labor forces would likely have no adverse impact on potential economic growth — especially if there is increased physical and human capital formation in the interim.

[9] It is worth repeating that the primary aim of this study is to test whether a static cross-section of developing nation fertility rates can be used to draw inferences for the contemporary fertility transition. Certainly more complete models of the fertility transition can be constructed (e.g., endogenizing family planning program effort); however, for the purpose at hand, the simple two equation simultaneous model serves well.

Cobb-Douglas production function variety. This permits a direct comparison of the static and dynamic versions of the model. The fertility and output equations become:

$$(1)\quad F = a_0 Y^{a_1} M^{a_2} P^{a_3} S^{a_4} A^{a_5} e^{a_6 FP}$$

$$(2)\quad Y = b_0 F^{b_1} M^{b_2} E^{b_3}$$

Note that family planning program effort in the fertility equation is modeled much like neutral technical change in the formulation of a production function. That is, the influence of family planning program effort complements the overall effect of socio-economic development on fertility.[10]

For the static version of the model, taking the natural logarithm of each side of the two equations gives:

$$\text{(S1)}\quad \ln F = \ln a_0 + a_1 \ln Y + a_2 \ln M + a_3 \ln P + a_4 \ln S + a_5 \ln A + a_6 FP$$

$$\text{(S2)}\quad \ln Y = \ln b_0 + b_1 \ln F + b_2 \ln M + b_3 \ln E$$

The interpretation of the coefficients a_i ($i = 1$ to 5) and b_j ($j = 1$ to 3) would be as partial point elasticities.

For the dynamic version, rather than instantaneous change, discrete change is represented. The discrete analogs of the two structural equations for fertility and output are:

$$\text{(D1)}\quad \dot{f} = a_0' + a_1'\dot{y} + a_2'\dot{m} + a_3'\dot{p} + a_4'\dot{s} + a_5'\dot{a} + a_6' FP$$

$$\text{(D2)}\quad \dot{y} = b_0' + b_1'\dot{f} + b_2'\dot{m} + b_3'\dot{e}$$

[10] The measures of family planning program effort used were developed by Robert Lapham and W. Parker Mauldin. The original index, based on 15 criteria designed to measure official support for family planning and the availability and effectiveness of the family planning services, was tabulated for some 94 developing nations for 1972 (See Mauldin and Berelson for the criteria and country raw scores). The maximum score possible, indicating the strongest family planning program effort, was 30 points. Then in a later study, Lapham and Mauldin (1984) presented an updated family planning program effort index for 1982 based on 30 criteria and with a maximum score of 120 points (For a comparison of the two indices, see Lapham and Mauldin (1985)).

In this case the interpretation of the coefficients a_i' ($i = 1$ to 5) and b_j' ($j = 1$ to 3) would be as partial arc elasticities.

The main difference between the static and dynamic representations of the structural equations reflects the measurements of the two sets of variables. Table 1 shows the variables used in the two version (See the appendix for more detailed descriptions of the variables and data). In the case of the static cross-section,

Table 1

VARIABLES

Static Cross-Section	Dynamic Cross-Section
F = Total Fertility Rate in 1977	$\dot{f}$ = percentage change in the Total Fertility Rate from mid-1972 to 1982
Y = Per Capita Gross National Product in 1977 (in $)	$\dot{y}$ = percentage change in Per Capita Real Gross Domestic Product from mid-1972 to 1982
M = Infant Mortality Rate in 1975	$\dot{m}$ = percentage change in the Infant Mortality Rate from 1970 to 1980
P = Primary School Enrollment Rate in 1965	$\dot{p}$ = percentage change in the Primary School Enrollment Rate from 1960 to 1970
S = Female Secondary School Enrollment Rate in 1975	$\dot{s}$ = percentage change in the Female Secondary School Enrollment Rate from 1970 to 1980
A = Percentage of the Labor Force in Agriculture in 1975	$\dot{a}$ = percentage change in the Labor Force in Agriculture from 1970 to 1980
FP = Family Planning Program Effort Index (0 to 100)	FP = Family Planning Program Effort Index (0 to 100)
E = Per Capita Energy Consumption in 1977 (in kilograms of coal equivalent)	$\dot{e}$ = percentage change in Per Capita Energy Consumption (in oil equivalent) from mid-1972 to 1982

before the logarithmic transformation, the levels of the total fertility rate, per capita gross national product, and per capita energy consumption for 1977 (the midpoint of the interval under study) are used. The infant mortality rate, percent of the labor force in agriculture, and female secondary school enrollment rate are all for 1975. The primary school enrollment rate is lagged a dozen years to allow for the longer run effects of primary education and literacy on the adult population.

In the dynamic cross-section the percentage changes in the total fertility rate, per capita real gross domestic product, and per capita energy consumption are for the interval from mid-1972 to 1982. The same lag structure as in the static cross-section is employed. In both versions, the influence of family planning is given by the average of the family planning program effort indices for 1972 and 1982.[11]

III. Regression Results

The structural equations for fertility change and economic growth in the simultaneous model are exactly identified and over-identified, respectively. Two stage least squares (2SLS) is the selected estimation technique. The regression diagnostics of Belsley, Kuh, and Welsch are applied to the ordinary least squares (OLS) regressions of the structural equations to assess the problem of multicollinearity and to identify the influential observations.[12]

Diagnostics:

11 There are slight differences in the actual statistics. For example, in the static version gross national product is used while in the dynamic version, gross domestic product is used. Also in the former case, energy consumption is measured in kilograms of coal equivalents; in the latter, the standard is oil equivalents. These differences are believed to be inconsequential for the regression results.

12 See David A. Belsley, Edwin Kuh, and Roy E. Welsch.

The computer software package used in the regression analysis is SAS, which incorporates, among other features, the collinearity and influence diagnostics of Belsley, Kuh, and Welsch. See *SAS User's Guide: Statistics, Version 5 Edition* (Cary, North Carolina, SAS Institute Inc. 1985) for the REG procedure and the regression diagnostics used for the ordinary least squares (OLS) estimations. These regression diagnostics are available in SAS only for the OLS estimations. For the simultaneous model and two stage least squares, the SAS procedure is SYSLIN. See *SAS/ETS User's Guide, Version 5 Edition* (Cary, North Carolina, SAS Institute Inc., 1984).

Multicollinearity (MCY) in the sample can make it difficult to distinguish among the individual effects of the explanatory variables on the dependent variable. Whether MCY is actually "damaging" to the estimated regression equation is an empirical matter. Essentially the concern is with the conditioning of the data matrix, i.e., with the sensitivity of the least squares solution to small change in the values of the predetermined and dependent variables. Belsley, Kuh, and Welsch suggest that MCY is damaging if the largest condition index, i.e., the condition number of the data matrix, exceeds 30 and at least half of the variances of two or more coefficients are associated with any condition index over 30.

Another concern in regression analysis for small samples is that the empirical results may be skewed due to the presence of outliers or influential observations. Influential observations are those which exert a "disproportionate influence" in the least squares estimation process.[13]

Along with the 2SLS regression results, the condition number and the identified influential observations for the OLS regression of the structural equation are presented. This provides additional criteria with which to compare the static and dynamic cross-sections.

Sample:

With due attention to the quality and comparability of the aggregate data, the final sample consists of 57 developing nations. Table 2 presents an overview of the sample. With respect to fer-

[13] Belsley, Kuh and Welsch list several criteria (not mutually exclusive) for identifying influential observations. For this analysis, an observation i in the data set is considered influential (in terms of external scaling) when:

1) the studentized residual associated with that observation exceeds two in absolute value, i.e.,

$$|\text{RSTUDENT}_i| > 2$$

and

2) for at least one explanatory variable X_j, the magnitude of the scaled measure of the change in the estimated regression coefficient when the ith observation is deleted (DFBETAS_{ij}) exceeds twice the reciprocal of the square root of the sample size, i.e.,

$$|\text{DFBETAS}_{ij}| > 2/(n)^{.5}$$

See Belsley, Kuh, and Welsch (Ch. 2).

Table 2

SOCIOECONOMIC MEASURES FOR THE SAMPLE OF 57 LDCs

	Sample Mean	Sample Std. Dev.	Sample Range
Total Fertility Rate:			
average of 1970 and 1975	5.93	1.18	2.6 to 8.0
1977	5.63	1.41	1.9 to 8.3
average of 1980 and 1984	5.31	1.52	1.8 to 8.2
Infant Mortality Rate:			
1970	117.4	48.4	21 to 235
1975	106.5	48.8	15 to 225
1980	96.4	47.6	12 to 211
Primary School Enrollment Rate:			
1960	59.8%	30.7	5 to 111
1965	68.9	30.7	10 to 124
1970	73.9	31.1	11 to 119
Secondary School Enrollment Rate for Females: 1970	16.2%	14.3	1 to 49
1975	21.8	17.8	1 to 62
1980	27.6	21.1	1 to 74
Percent of Labor Force in Agriculture: 1970	62.6%	22.3	4 to 94
1975	59.0	23.1	3 to 94
1980	55.3	23.8	2 to 93
Family Planning Program Effort Index (0 to 100):			
1972	23.3	26.2	0 to 86.7
1982	32.4	23.6	1.7 to 80.8
Per Capita Gross National Product: 1977	$687.3	663.9	80 to 2,820
Per Capita Energy Consumption (kilograms of coal equivalent):			
1977	795.3	1,485.0	13 to 9,000
Percentage Change in the Total Fertility Rate: (mid-1972 to 1982)	-11.9%	11.6	-35.5 to 8.7
Percentage Change in Per Capita Real Gross Domestic Product: (mid-1972 to 1982)	14.8%	26.6	-49.4 to 65.6

tility, declines in the mean total fertility rate over the period are accompanied by increases in the sample standard deviation — which is indicative of the differential progress with the fertility transition. For the sample the average decline in the total fertility rate from mid-1972 to 1982 is 11.9%. The Pearson correlation coefficient for the 1977 total fertility rate and the percentage change in the total fertility rate over the period is .77. Thus nations with higher fertility in 1977 experienced smaller percentage declines in fertility over the encompassing ten year interval. The correlation coefficient between the 1977 per capita GNP and the percentage change in real per capita GDP from mid-1972 to 1982 is only .29. In sum, the sample of 57 LDCs is believed to be representative of the contemporary developing nations.

Fertility:

Equations (S1) and (D1) of Table 3 give the 2SLS regression results for fertility. While the static and dynamic versions are similar in terms of overall "explanatory power," and while family planning program effort and lower infant mortality are significant factors in reducing fertility in both versions; there are marked differences. With the exception of the proxy for urbanization, the estimated arc elasticities (dynamic version) exceed the estimated point elasticities (static version). In particular, the estimated arc elasticity of fertility to infant mortality in the dynamic cross-section (.30) is roughly 70% greater than the corresponding point elasticity in the static cross-section (.18); although both are consistent with only partial adjustment in fertility to changing infant mortality. The estimated arc elasticity of fertility with respect to primary school enrollment is statistically significant (if marginally so) and ten times the statistically insignificant point elasticity of the static cross-section. The positive sign supports the fertility enhancing effect of primary education found in many developing nations. The agricultural labor force variable (urbanization) is highly significant in the static model and three times the size of the statistically unimportant counterpart in the dynamic cross-section. In neither version is economic growth, by itself, important for fertility decline — although the two models show qualitatively different responses.

The OLS estimates (not shown) do not differ appreciably from the 2SLS estimates. A comparison of the condition numbers in-

Table 3

2SLS Regression Results – Fertility

	Static Cross-Section: ln F			Dynamic Cross-Section: $\dot{f}$	
	(S1)	(S1A)		(D1)	(D1A)
constant	-.265 (-.45)	.364 (.49)	constant	-.526 (-.19)	-.404 (-.14)
ln Y	.056 (.98)	.003 (.04)	$\dot{y}$	-.060 (-.83)	-.064 (-.79)
ln M	.176 (2.36)**	.113 (1.38)	$\dot{m}$	.301 (2.93)***	.238 (2.46)**
ln P	.004 (.06)	.006 (.09)	$\dot{p}$	.048 (1.90)*	.040 (1.44)
ln S	-.003 (-.09)	-.002 (-.05)	$\dot{s}$	.007 (.68)	-.049 (-1.95)*
DF·ln S		.016 (.62)	DF·$\dot{s}$		.060 (2.76)***
DS·ln S		-.025 (-1.00)	DS·$\dot{s}$		.043 (1.09)
DM·ln S		.037 (1.49)	DM·$\dot{s}$		.056 (1.94)*
ln A	.227 (3.32)***	.215 (3.03)***	$\dot{a}$	.066 (.82)	.068 (.80)
FP	-.0031 (-2.21)**	-.0024 (-1.60)	FP	-.201 (-3.61)***	-.196 (-3.38)***
$\bar{R}^2$	.75	.76		.72	.75
F	29.6***	20.8***		25.3***	19.7***
OLS cond. no.	74.3	91.7		8.5	12.0

The influential observations associated with the OLS regression of the structural equations are:

static cross-sections: underachievers: (S1)—Syria
overachieves: (S1)—Trinidad and Tobago
(S1A)—Turkey, Chile
dynamic corss-sections: underachievers: (D1) and (D1A) — Cameroon
overachievers: (D1) and (D1A)—Thiland, Burma

Notes: See Table 4.

dicates multicollinearity is a problem in the static, but not the dynamic, cross-section. In the former the collinearity diagnostics show that most of the explanatory variables (lnY, lnM, lnA, and ln P) are involved in near dependencies. Finally, different countries are influential observations in the two versions. It is interesting to note that Trinidad and Tobago is identified as a significant overachiever in the static model (i.e., her actual fertility in 1977 is less than the level predicted on the basis of the static OLS regression), but is a modest underachiever in the dynamic model (i.e., her actual fertility decline from mid-1972 to 1982 is less than what is predicted by the OLS regression for the dynamic cross-section). In contrast, Cameroon is an influential underachieve in the dynamic model, but has a negative residual in the static regression (implying overachievement in the fertility transition given the socioeconomic conditions and family planning program effort). It should be noted that none of the identified influential observations is judged to be so influential for the regression estimates as to justify deletion from the sample.

Economic Growth:

As equations (S2) and (D2) of Table 4 illustrate, much more of the variation in economic growth is accounted for by the static model.[14] Energy consumption is statistically a very important determinant of national output in both models, however, the estimated elasticity in the static version is double that for the dynamic version. That is, in the former, the indicated marginal capital-output ratio is 2 to 1 (or an increase of 1% in per capita energy consumption would result in a gain of .5% in per capita gross national product, *ceteris paribus*). In the dynamic cross-

14 In the dynamic cross-section 33% of the variation in economic growth is accounted for by regression model — compared to 81% in the static cross-section. This is not surprising since it is more difficult to explain actual changes than levels of national output. In contrast, for fertility the static and dynamic cross-sections have roughly the same explanatory power. There is evidence that once the fertility transition begins, i.e., with the diffusion of discretionary control over fertility, a certain momentum builds and the initial declines in national fertility are sustained (see Hess, forthcoming). Economic growth, on the other hand, is more variable. In the turbulent decade of the 1970s (e.g., the breakdown of the Bretton Woods international monetary system, oil price shocks, and stagflation in the developed economies), many developing nations experienced slower growth. In fact nearly a quarter of the 57 LDCs in this sample experienced negative growth in real per capita output over this period.

Table 4

2SLS Regression Results – Economic Growth

	Static Cross-Section: ln Y			Dynamic Cross-Section: $\dot{y}$	
	(S2)	(S2A)		(D2)	(D2A)
constant	4.410	4.419	constant	-.776	-2.623
	(5.50)***	(5.43)***		(-.10)	(-.36)
ln F	.279	.549	$\dot{f}$	-1.746	-1.344
	(.49)	(1.02)		(-3.20)***	(-2.70)***
ln M	-.351	-.453	$\dot{m}$	.541	.249
	(-1.37)	(-1.86)*		(1.14)	(.57)
ln E	.495	.498	$\dot{e}$	.233	.245
	(9.47)***	(9.39)***		(3.29)***	(3.57)***
$\bar{R}^2$	.81	.81		.33	.31
F	81.9***	79.9***		10.1***	9.5***
OLS cond. no.	41.1	41.1		6.8	6.8

The influential observations associated with the OLS regression of the structural equations are:

static cross-section: underachievers: India, Sri Lanka
overachievers: none
dynamic cross-section: underachievers: Jamaica, Nicaragua
overachievers: Sudan

Notes: t statistics are in parentheses below the estimated coefficients.
* = significant at the .10 level
** = significant at the .05 level
*** = significant at the .01 level

section the estimated marginal capital-output ratio is closer to 4 to 1. There are no other statistically significant explanatory influences in the static equation. In contrast, the importance of declining fertility for economic growth is evident in the dynamic cross-section. The size of the estimated arc elasticity (-1.7) suggests that in addition to the reduced population growth rates that lower fertility brings, there are considerable advantages from the changing age distribution.

The only difference of significance between the results for the 2SLS regressions and OLS regressions (not shown) for economic growth is the doubling of the estimated coefficient for fertility change with the simultaneous model. Again the condition number associated with the OLS regression of the structural equation is much higher in the static model. And again the influential observations differ between the two versions. Discrepancies appear here too: Sri Lanka qualifies as an economic underachiever in the static regression, i.e., based on her 1977 per capita GNP, but in the dynamic cross-section she is a modest overachiever, i.e., her actual growth in real per capita GDP from mid-1972 to 1982 exceeded her predicted growth. For Nicaragua the reverse is true. She is an economic underachiever in the dynamic version (over the seventies she experienced severe economic decline), but in the static cross-section the residual for economic growth is positive.

Extending the Model:

Cultural differences may modify the effects of socioeconomic development and family planning activity on fertility. The influence of culture, which may reflect fundamental religious beliefs or customs that have evolved in a particular society over time, is pervasive and difficult to quantify. It may be manifested, among other ways, in marriage patterns, in the status of women, and in kinship relations. For example, the effects of gains in female education on fertility may vary across cultures.[15] To test this the structural equation for fertility is modified to allow for regional variation in the response of fertility to secondary school enrollments for females. Four regions are identified: Latin America and the Caribbean (primarily Catholic), the Middle East and North Africa (primarily Muslim), sub-Saharan Africa, and Asia. In these last two regions, no one religion is dominant. The fertility structural equation becomes:

static model:

$$\ln F = \ln a_0 + a_1 \ln Y + \cdots + a_4 \ln S + a_{4f} DF \cdot \ln S + a_{4s} DS \cdot \ln S + a_{4m} DM \cdot \ln S + \cdots$$

[15] See Hess (forthcoming) for a more complete discussion of the influence of culture on fertility, and in particular, for the empirical justification for modeling regional variation in the response of fertility to female secondary school enrollment.

dynamic model:

$$\dot{f} = a_0' + a_1\dot{y} + \cdots + a_4'\cdot\dot{s} + a_{4f}'DF\cdot\dot{s} + a_{4s}'DS\cdot\dot{s} + a_{4m}'DM\cdot\dot{s} + \cdots$$

where DF = 1 (0 otherwise) for sub-Saharan African nations
DS = 1 (0 otherwise) for Asian nations
DM = 1 (0 otherwise) for North African and Middle Eastern nations.

Note that this modeling sets Latin America as the standard response for fertility with respect to female secondary school enrollment. The 2SLS regression results for the revised simultaneous model are presented as equations (S1A) and (D1A) in Table 3 and equations (S2A) and (D2A) in Table 4.

For the static cross-section for fertility (see equations (SIA)), the ill effects of multicollinearity are compounded. The condition number associated with the OLS regression increases from 74.3 to 91.7. The only robust regressor is the percentage of the labor force in agriculture. The estimated coefficients and t-ratios for infant mortality and family planning program effort fall so that these two influences are no longer statistically signigicant. New countries qualify as influential observations.

For the dynamic cross-section (equation (D1A)), the regression estimates in the revised model are comparatively stable. The estimated coefficients for the infant mortality and primary school enrollment variables do fall, and only the former remains statistically significant. Family planning program effort, on the other hand, is virtually unchanged with respect to the impact on fertility change. In the simpler model, change in the secondary school enrollment rate for females is inconsequential for fertility change. Allowing for regional variation, however, substantially alters this. The estimated arc elasticities are significantly different for three of the four regions. Furthermore, for the Middle East/North African and sub-Saharan African regions, gains in female secondary school enrollment rates are associated, *ceteris paribus,* with higher fertility over the decade of the seventies. Only in Latin America is the response negatively significant. In the static model, differential responses of fertility to female secondary education are statistically insignificant.

The condition number associated with the OLS regression of the structural equation for fertility change in the dynamic cross-section does increase slightly, with the collinearity occurring among the secondary school enrollment variable group. The identified influential observations are the same as in the simpler model.

For the 2SLS regressions for economic growth, the results parallel the earlier findings. Again the estimated influences of fertility and mortality on output differ between the two cross-sections. In the static version reductions in infant mortality are associated with significantly more growth in per capita output (the productivity effect). While in the dynamic cross-section there is a drop of about 25% in the estimated elasticity, fertility change remains a statistically significant determinant of economic growth, and as before, the magnitude of its estimated influence increases in moving from the OLS to the 2SLS regressions.

IV. Conclusions

One of the most damaging problems confronting purely cross-sectional studies on the determinants of aggregate fertility in the contemporary developing economies is multicollinearity. It follows that regression diagnostics like those of Belsey, Kuh, and Welsch should accompany such empirical work.

The dynamic cross-section tested here (i.e., two points in time for 57 LDCs) should not be confused with a dynamic model of the fertility transition. Nevertheless, the regression results strongly suggest that the concerns expressed over the use of simple static cross-sections of fertility rates for drawing inferences on the dynamic process of fertility change are justified. Thus, whenever possible, a cross-section of time series should be used.

The possibility of misleading policy implications from static cross-sectional analysis exists. This is not the place to undertake a lengthy discussion of the appropriate policies to assist the developing nations through their fertility transitions. It is enough to point out the discrepancies based on the two empirical models presented here. In the static version the only robust influence on fertility is the percentage of the labor force in agriculture. Given the explosive growth of urban populations and the accompanying proliferation of shanty towns in the developing nations, accelerated shifts out of agriculture do not appear feasible — as either development strategies or population policies. The implications derived from the dynamic cross-section, however, are that lower infant mortality and strong family planning program efforts are the keys to reducing fertility. Concern with the pronatalist impact of a few years of primary education (e.g., reduced breastfeeding) may also be warranted. Furthermore, regional (cultural) differences can be important, as the various responses of fertility to female secondary school enrollments indicate. Reducing infant and child mortality and promoting family planning can also be supported with the simpler version of the static model (S1). The severe multicollinearity, however, understates the significance of these factors and further masks the regional variation in the response of fertility to female secondary education in the extended model.

With respect to economic growth, reliance on the static cross-section would downplay the gains from reducing fertility. One of the primary contentions of the United States at the International Conference on Population in Mexico City in 1984, "First and most important, population growth is, of itself, a neutral phenomenon," receives support in the regression analysis from the static, but not the dynamic, cross-section.[16]

In sum, the stronger and more reliable insights into the contemporary fertility transition are provided by the dynamic cross-section, where the actual experiences of the developing nations over time are used.

Finally, cross-sectional aggregate studies of the fertility transition complement micro level studies of fertility behavior.[17] One of the advantages of cross-country studies where the nation is the

16 See United States. It should be noted that in the OLS regression for the structural equation for fertility in the dynamic cross-section of the extended model the estimated coefficient for economic growth is -.063 and statistically significant at the .10 level. Moving to the simultaneous model and 2SLS (equation D1A) sharply reduces the significance of this estimate and suggests that the causality runs from fertility change to economic growth.

17 For example, Schultz (1973) and Hermalin have investigated the comparability of static and dynamic cross-sections for fertility in Taiwan in the late sixties. Their findings (using regional level fertility rates in Taiwan) are consistent with the implications of the

unit of analysis is the ability to identify outliers. Such global investigations provide a backdrop for more intensive country-specific analyses — analyses that can be better designed to determine which factors are responsible for the extraordinary performances. For example, on the basis of such research, common development strategies or policy initiatives might be identified for the demographic overachievers or those LDCs with greater than expected fertility declines. As shown in this study, the identified national outliers differ between the static and dynamic versions of the regression models. This is yet another reason to be wary of purely static analysis of the contemporary fertility transition.

Appendix

The sources for the data used in this study are:
World Tables, Third Edition, Vol. II (Social Data), 1983 for:
- Total Fertility Rates in 1970, 1975, 1977 and 1980
- Infant Mortality Rates in 1970, 1975 and 1980
- Secondary School Enrollment Rates for Females in 1970, 1975 and 1980
- Primary School Enrollment Rates in 1960, 1965 and 1970
- Percent of Labor Force in Agriculture in 1970, 1975 and 1980
- Energy Consumption per Capita (kilograms of coal equivalent) in 1977

World Tables, Second Edition, 1980 for:
- Gross National Product per Capita ($) in 1977 (Table 11: 430-33)

World Development Report 1986 for:
- Total Fertility Rate in 1984 (Table 26: 230-31)

present study (using aggregate data at the national level). As Schultz (1973: 269) concludes:

> "...estimates based on a single cross-section are seriously biased. Slowly changing constraints in the parents' environment, such as the regime of child mortality, agricultural composition, and male schooling, are attributed, in a cross-section, an exaggerated and distorted role in affecting birth rates."

World Development Report 1985 for:

- Average Annual Growth Rate Gross Domestic Product 1973-1983 (Table 2: 176-77)
- Average Annual Growth Rate in Energy Consumption (oil equivalents) 1973-1983 (Table 8: 188-89)
- Average Annual Growth Rate in Population 1973-1983 (Table 19: 210-11)

The Family Planning Program Effort Scores for 1972 are from Mauldin and Berelson. The Family Planning Program Effect Scores for 1982 are from Lapham and Mauldin (1984).

In addition, in several instances gaps in the data reported in the above sources had to be filled in with data from the *World Development Reports* for 1978, 1983, and 1984, and in one case, from the wall chart, "The World's Youth: A Profile (Population Reference Bureau, 1985)." The specific instances are available from the author upon request.

Variables:
The Total Fertility Rate is the average number of children born to a hypothetical female over the total span of childbearig years if subject to the current age specific fertility rates.

The Percentage Change in the Total Fertility Rate from mid-1972 to 1982 ($\dot{f}$) is calculated as the percentage change from the average Total Fertility Rate for 1984 and 1980 to the average Total Fertility Rate for 1975 and 1970.

The Infant Mortality Rate is the number of deaths to infants less than one year old per thousand live births.

The Primary School Enrollment Rate refers to the ratio of students in primary school to the population of children of primary school age (normally 6 to 11 years old).

The Female Secondary School Enrollment Rate refers to the ratio of females in secondary school to the population of females of secondary school age (normally 12 to 17 years old).

The Percentage of the Labor Force in Agriculture refers to the ratio of the number in the labor force in agricultural activities (farming, forestry, hunting, and fishing) to the total labor force.

The Family Planning Program Effort Index is calculated as the average of the family planning program effort scores for 1972 and 1982 (after the raw scores are coverted to a common base of 100).

The Percentage Change in Per Capita Real GDP ($\dot{y}$) is calculated as the difference between the average annual growth rates in real Gross Domestic Product and Population for 1973 to 1983 multiplied by 9.5 (where 9.5 is the number of years in the interval for fertility change).

The Percentage Change in Per Capita Energy Consumption ($\dot{e}$) is calculated as the difference between the average annual growth rates in energy consumption and population for 1973 to 1983 multiplied by 9.5.

The nations in the sample are:

sub-Saharan Africa: (n = 21)
Mali, Zaire, Upper Volta (Burkina Faso), Rwanda, Burundi, Tanzania, Niger, Togo, Ghana, Kenya, Sierra Leone, Sudan, Liberia, Senegal, Zambia, Cameroon, Ivory Coast, Mauritania, Somalia, Central African Republic, Guinea

North Africa and the Middle East: (n = 6)
Egypt, Morocco, Turkey, Tunisia, Syria, Algeria

Asia: (n = 13)
India, Sri Lanka, Pakistan, Indonesia, Philippines, Thailand, Malaysia, South Korea, Bangladesh, Nepal, Burma, Hong Kong, Singapore

Latin America and the Caribbean: (n = 17)
Bolivia, Honduras, El Salvador, Nicaragua, Peru, Dominican Republic, Jamaica, Ecuador, Colombia, Paraguay, Chile, Brazil, Mexico, Trinidad and Tobago, Costa Rica, Venezuela

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