FERTILITY CHOICE AND ECONOMIC GROWTH: THEORY AND EVIDENCE

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Abstract—This paper examines a growth model with endogenous consumption, labor–leisure, and fertility. A fertility choice variable capturing both the quality and quantity of the family size enters the utility function positively, but it also generates time costs. Theoretical comparative dynamic results are derived for changes in exogenous production and utility parameters. Employing post-World War II United States data, we estimated the model using a structural VAR with imposed long-run restrictions based on the theoretical predictions. The empirical results lend support to the endogeneity of fertility choice and present dynamic responses of each endogenous variable to employment, fertility, and output shocks.

"*Growth economists, to the extent that they have dealt with fertility, have featured the gross economic effects of population growth, leaving to biologists, sociologists, and demographers the task of explaining the increases in the size of the human population. This concentration on such gross effects is understandable in view of the fact that the factors determining population growth have been a major unsettled part of economic theory. The concept of an optimal population has not been fruitful.*" (Schultz (1974, p. 5)).

I. Introduction

RECENTLY, growth theory has undergone a renaissance of sorts. The rebirth of this field has appropriately led researchers to reexamine the underlying driving forces of economic growth and their implications for business cycles. In particular, there is a call for an integration of family economics (such as endogenous fertility) with growth theory and macroeconomics (e.g., see Becker (1988)). In the eighteenth century, the debate between Thomas Malthus and neoclassical economists already highlighted a crucial linkage between population/fertility growth and economic growth. Nevertheless, modern growth theorists in the Solow-Swan tradition have assumed that child-bearing decisions are unaffected by income, employment or any other macroeconomic variables.[1] The new wisdom, essential to understanding long-term growth, recognizes that much economic investment is made by human beings as well as in physical capital and that fertility itself is shaped in important ways by economic considerations. These insights have led to renewed interest in studying fertility and economic growth (see Barro and Becker (1989) and Becker, Murphy and Tamura (1990)).

Independent of the growth literature, the study of fertility has long been a tradition of demography and family economics research (e.g., see selected readings by Spengler and Duncan (1956), and references in the presidential addresses by Lee (1987) and Becker (1988)). These studies have focused on predicting fertility or birth rates (based on extrapolations adjusted for changes in the age–sex–marital composition of the population) or on examining differential fertility (using abundant cross-sectional data). Their inability to predict the sharp fertility decline in the 1930s and the sharp rise in the 1950s initiated a call for a "fuller analysis" of fertility behavior (see Kuznets (1958), Becker (1960) and particularly, Easterlin (1968)). However, as Becker (1988) pointed out, there is only a small literature considering the implications of fertility decisions for other parts of economics, especially, macroeconomics and growth theory.

The present work builds on the new wisdom of Barro and Becker (1989) and Becker, Murphy and Tamura (1990) to emphasize the importance of examining how families and the macroeconomy interact in the process of economic development. On the one hand, the household's child-bearing decision depends crucially on economic conditions. The fertility decision, on the other hand, feeds back into the economy, influencing

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[1] Exceptions are Razin and Ben-Zion (1975) and Nerlove, Razin and Sadka (1987), although they emphasize fertility and distribution issues rather than the process of economic growth.

labor and capital accumulation decisions. In contrast to their studies, our paper allows for the dynamic interactions between labor–leisure and fertility choice. This is especially crucial when there are substantial time costs involved in raising children. Moreover, our model also permits us to examine a structural fertility preference shock, which can capture some important biological and sociological factors emphasized by demographers.

While the theoretical literature pertaining to endogenous fertility is burgeoning, surprisingly little empirical work has been conducted within an optimizing dynamic macroeconomic framework. As a consequence, the existing findings on the causes of short- and long-run fertility fluctuations and on the interactions between fertility and macroeconomic variables remain a matter of conjecture or speculation.[2] In this paper we attempt two goals. First, we develop a dynamic general equilibrium model that provides a complete characterization of the short-run dynamics and the long-run steady-state of fertility and other macroeconomic aggregates.[3] Second, our analytical construct is empirically implementable; it helps to econometrically identify fundamental economic disturbances to the system, which is, to the best of our knowledge, the first attempt at such an endeavor in the area of endogenous fertility and economic growth. Using U.S. time series data, we investigate the relevance of endogenous fertility choice, and estimate the dynamic responses of fertility to structural shocks. The study thus provides insights into understanding the dynamics of the post-WWII baby boom, the prolonged fertility decline afterward, and the baby boom echo occurring in the late seventies.

The theoretical model, on the one hand, predicts that a shift of preferences away from leisure and toward fertility generally has ambiguous effects on steady-state quantities. This is due to the presence of two opposing effects on savings: a contemporaneous substitution effect and an intertemporal substitution effect. The former works through the change in desired capital accumulation, and the latter through the change in labor supply. On the other hand, an improvement in labor productivity (e.g., an increase in the human capital of the average worker), increases the steady-state consumption, but its impact on other quantities is generally ambiguous due to the opposing substitution effects.

Based on a recently developed structural VAR methodology (see Blanchard and Quah (1989) and Ahmed, Ickes, Wang and Yoo (1993)), we are able to econometrically identify three unobservable structural disturbances, including an employment shock, a fertility disturbance equivalent to our theoretical preference shift, and an output disturbance represented by a Harrod-neutral productivity shock. These fundamental disturbances capture traditionally used economic factors (such as income, wages/employment and prices) as well as other non-economic factors. The long-run restrictions used to retrieve these structural shocks from the estimated reduced form are derived from the choice-theoretical model, and are generally less controversial than any imposed on the short-run dynamics. The empirical results support our contention that fertility choice should not be considered exogenous to the labor market or to the growth process. In particular, employment shocks are responsible for explaining a significant portion of the variance of the forecast error for the fertility rate. The employment shock causes a reallocation of time away from child-rearing and toward labor effort, thus retarding fertility growth; moreover, fertility changes feed back into employment and output movements. Finally, we decompose the fertility series to show how it has responded historically to the three fundamental disturbances.

II. Theoretical Framework

A. *The Model*

Consider a continuous-time, infinite-horizon neoclassical growth model with perfect foresight. The representative agent, being an integrated consumer–producer unit, can divide his/her time among labor effort, ℓ, leisure, χ, and child-rearing, s. We assume that s is a function of the family size, i.e., $s = s(\mu)$, where μ is the family growth rate. Specifically, s is increasing and convex in μ, i.e., $s_\mu > 0$ and $s_{\mu\mu} \geq 0$. Normalizing the periodic time endowment to unity yields the

[2] See a comment by Easterlin (1968) and Wachter (1975) as well as a recent study by Mocan (1989) on fertility and business cycles using an atheoretical econometric approach.

[3] We adopt an infinite horizon representative agent model, which implicitly accounts for altruistic parents and allows for a tractable characterization of the transitional dynamics.

time constraint

$$\chi(t) + \ell(t) + s(\mu(t)) = 1. \qquad (1)$$

The resource constraint specifies that unconsumed net output governs the evolution of the capital stock (k), given a well-behaved, constant-returns-to-scale production function, $f(k, \ell)$:

$$c(t) + \dot{k}(t) = f(k(t), \ell(t)) - \mu(t)k(t), \qquad (2)$$

where c denotes (per capita) consumption.

Therefore, our representative agent maximizes his/her lifetime utility, discounting the future by the rate of time preference, ρ:[4]

$$\int_0^{\infty} [U(c(t)) + V(\chi(t), \mu(t))] e^{-\rho t} dt$$

subject to the constraints (1) and (2). Solving the optimization problem with Pontryagin's maximum principle, we have the following first-order conditions:

$$U_c(c(t)) - \lambda(t) = 0 \qquad (3)$$

$$-V_\chi(\chi(t), \mu(t)) + \lambda(t) f_\ell(k(t), \ell(t)) = 0 \qquad (4)$$

$$-V_\chi(\chi(t), \mu(t)) s_\mu(\mu(t)) + V_\mu(\chi(t), \mu(t)) - \lambda(t)k(t) = 0 \qquad (5)$$

$$\dot{\lambda}(t)/\lambda(t) = \rho - f_k(k(t), \ell(t)) + \mu(t), \qquad (6)$$

where λ is the co-state variable associated with the resource constraint (2). Needless to say, transversality conditions and non-negativity constraints must also hold. Equations (3)–(5) are efficiency conditions for intertemporal consumption substitution, the contemporaneous labor–leisure tradeoff and the contemporaneous fertility–leisure trade-off, respectively. Equation (6) is the Euler equation governing optimal capital accumulation.

B. *Steady-State and Transitional Dynamics*

We next examine the dynamic system in the steady state, where all endogenous variables are constant (i.e., $\dot{c} = \dot{\chi} = \dot{\mu} = \dot{k} = \dot{\ell} = 0$). We will drop the time index, t, from this point forward. Using equations (3)–(6), the fundamental equations of the optimal program are

$$f_k = \rho + \mu \qquad (7)$$

$$-V_\chi + U_c f_\ell = 0 \qquad (8)$$

$$V_\mu - V_\chi s_\mu - kU_c = 0. \qquad (9)$$

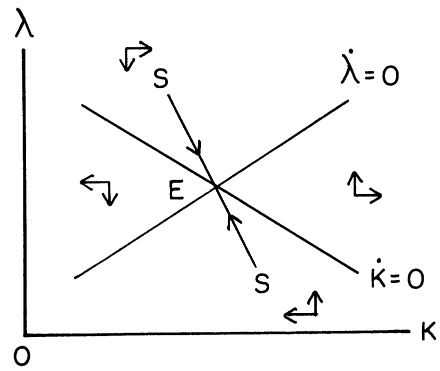
Equation (7) gives the modified golden rule for capital accumulation except that in this analysis the population growth rate is not predetermined. Equation (8) equates the marginal benefit of labor ($f_\ell U_c$) to its marginal cost (V_χ). That is, by supplying an additional unit of labor, the agent increases his/her utility by the consumption of the additional output produced; however, utility decreases due to the loss of leisure time. Finally, equation (9) equates the marginal benefit of the fertility rate (V_μ) to its marginal cost ($V_\chi s_\mu + kU_c$). A higher μ will entail a loss in leisure due to the additional time expended in raising children and a reduction in per capita consumption due to the additional saving for a larger family size.

To study the transitional dynamics of the model, we first use (3)–(5) to express consumption (c), labor (ℓ) and the fertility rate (μ) as a function of the state variable (k) and the co-state variable (λ):

$$c = c(k, \lambda); \quad \ell = \ell(k, \lambda); \quad \mu = \mu(k, \lambda), \qquad (10)$$

where $c_k = 0$, $c_\lambda < 0$, $\ell_k > 0$, $\ell_\lambda > 0$, $\mu_k < 0$ and $\mu_\lambda < 0$. These expressions can be used to characterize the transitional dynamics of the system. Assume that the net rate of real interest, $f_k - \mu$, is decreasing in k. The resulting dynamic system can be represented in (k, λ) space: the $\dot{\lambda} = 0$ locus is upward sloping, while the $\dot{k} = 0$ locus has a negative slope (see figure 1). A saddle-path equilibrium is then obtained. The capital

FIGURE 1.—SADDLE-PATH EQUILIBRIUM (E)



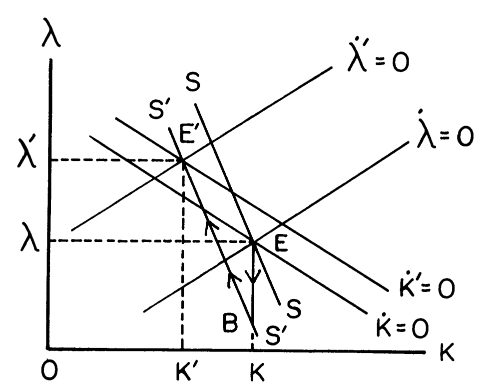
[4] It can be shown that this formulation is functionally equivalent to a model explicitly allowing for the quality of children to enter the utility function. This proof is available upon request.

TABLE 1.—SUMMARY OF COMPARATIVE STATIC RESULTS

Effect on	c	k	ℓ	μ
Increase in				
η	−	−	?	+[a]
ϵ	+	+	?	?

[a]If direct effect dominates.

FIGURE 2.—THE EFFECTS OF A PREFERENCE SHIFT TOWARDS FERTILITY (HIGHER η)



stock evolves continuously, while λ will jump instantaneously in response to perturbations.

C. *Comparative Dynamic Analysis*

In this section, we will characterize the long-run and short-run transitional responses of consumption, capital accumulation, work effort and fertility to some fundamental economic disturbances. We consider a fertility disturbance which represents a preference shift away from leisure and toward fertility, and is denoted by η. This preference shift implicitly accounts for changes in the time cost of child-rearing and the pecuniary costs of day care, the temporary postponement of fertility due to wars and education, the availability of contraceptives and any idiosyncratic alteration in attitude resulting from demographic, biological and sociological changes. We also study a Harrod-neutral productivity disturbance, denoted by ϵ (i.e., $y = f(k, \epsilon\ell)$). This productivity disturbance contains any shocks to human capital, technology and oil prices; it also includes any persistent aggregate demand shocks which are not captured by the preference shift. Table 1 summarizes the comparative static results.

1. Fertility Disturbance: The phase diagram in figure 2 demonstrates the effects of a fertility preference disturbance, η. Both the $\dot{\lambda} = 0$ and the $\dot{k} = 0$ loci shift upward.[5] On impact (from E to B), λ drops, implying that time is re-allocated toward child-rearing and away from labor effort. This contemporaneous substitution results in a higher (real) wage rate ($w = \epsilon f_\ell$), a lower (real) interest rate ($r = f_k$), and an increase in current consumption.[6] The fall in the return to savings creates an intertemporal substitution effect that retards capital accumulation while the higher wage rate increases labor effort. Therefore, in transition to the new steady state (from B to E′), the wage rate falls and the interest rate rises. Finally, the intertemporal price is higher, which, from (10), lowers consumption.

Thus, the steady-state capital stock is unambiguously reduced. If the direct contemporaneous substitution effect is dominant, one can expect that a higher steady-state fertility rate emerges. The new steady-state value of labor is ambiguous since it is not clear whether the increase in labor over the transition is sufficient to offset its instantaneous reduction. For convenience, we assume that these effects are approximately equal; this would be the outcome if the long-run labor supply curve is essentially vertical and shifted only by shocks to itself.

In this case, the new steady-state wage rate is lower and the interest rate is higher than their original values. These changes reflect the smaller level of per capita capital in the economy and lead to a lower level of per capita consumption in the new steady state.

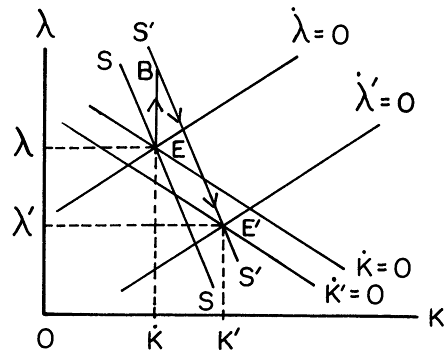
2. Output Disturbance: Figure 3 presents the dynamic adjustment of the system in response to a Harrod-neutral (labor-augmenting) technological disturbance, ϵ. Both the $\dot{\lambda} = 0$ and the $\dot{k} = 0$ loci shift downward.[7] On impact (from E to B),

[5]Notice that the $\dot{\lambda} = 0$ locus must shift up by more than the $\dot{k} = 0$ locus. Suppose not, then both k and λ will be higher at the new steady state. From (10), it follows that the steady-state fertility rate must unambiguously decline, contradicting standard beliefs.

[6]w is decreasing in ℓ and increasing in k, while r is decreasing in k and increasing in ℓ.

[7]Notice again that the downward shift of the $\dot{\lambda} = 0$ locus must dominate the downward shift of the $\dot{k} = 0$ locus in magnitude; otherwise, both k and λ will fall and the new steady-state labor will be unambiguously lower.

FIGURE 3.—THE EFFECTS OF A PRODUCTIVITY INCREASE (ξ)



time is re-allocated toward labor, reflecting its higher effective marginal product.[8] The increase in labor increases the interest rate and, via intertemporal substitution, lowers current consumption. Both the contemporaneous allocation of time toward labor and the intertemporal substitution toward the future will tend to lower the fertility rate. Along the transition path (from B to E′), capital begins to accumulate and labor effort starts to fall, thus raising the wage rate and lowering the interest rate. As capital accumulates, both output and consumption increase. However, the transitional movements of the fertility rate are ambiguous in sign. On the one hand, the fall in labor effort allows more time to be spent on child-rearing (i.e, the contemporaneous substitution effect). While on the other hand, the desire to accumulate capital (i.e., the intertemporal substitution effect) leads households to reduce their family size.

In summary, the new steady-state level of capital is higher. However, the new level of labor effort is ambiguous since we cannot tell if its reduction over the transition path dominates its original increase. Also, since we are unable to determine the direction of change of the fertility rate over the transition, we cannot sign its comparative static result. Nevertheless, it can be seen from (10) that the lower intertemporal price must induce a higher steady-state level of consumption.

[8]Actually, there will be two effects on the (effective) wage rate. The first is a direct effect through ϵ itself and the second is through ℓ. We assume that the direct effect is dominant and thus a shock to ϵ will increase the wage rate.

III. Empirical Evidence

In this section we use a structural Vector Autoregression (VAR) model to estimate both the short- and long-run responses of the endogenous variables to the above-mentioned fertility and output disturbances, and an additional employment disturbance to the aggregate labor market. In contrast to the simultaneous equation method, this structural VAR approach focuses on the responses of the endogenous variables to unobservable structural disturbances (in lieu of observed independent variables). Our model relies only on long-run identifying restrictions based on the theoretical predictions, contrary to the Sims (1980) method (which imposes ad hoc causal orderings) and the Bernanke (1986) method (which imposes restrictions on the contemporaneous responses). The estimation will also present evidence on the relevance of fertility as an endogenous variable, based on its reaction to other economic disturbances (employment and output shocks).

The three macroeconomic aggregates considered are the growth rates of labor, fertility and output. The transformation of these endogenous variables are based upon their univariate properties to be discussed in section III.B below. The first two correspond to the theoretical choice variables, ℓ and μ, respectively, while the latter is directly related to the capital stock variable, k. To be more specific, within our theoretical framework, the steady-state capital to output ratio must be constant; our data also shows that this ratio does appear to be stationary.

A. *Methodology*

To implement the empirical study, we begin with the VAR representation of the structural form:

$$A(B)X_t = \xi_t, \tag{11}$$

where X is a (3×1) vector of the endogenous variables, the labor growth rate, the fertility growth rate and the output growth rate: $X = [\triangle \ln \ell \;\; \triangle \ln \mu \;\; \triangle \ln y]^T$; ξ_t is a (3×1) vector of independent structural shocks: $\xi = [\xi^{\ell} \xi^{\mu} \xi^{y}]^T$; B is the lag operator and $A(B)$ is a nonsingular lag matrix polynomial.

The structural form (11) can be thought of as an extension of our theoretical perfect-foresight model by allowing for stochastic exogenous disturbances. The three structural shocks considered are an employment shock (ξ^{ℓ}), a preference shift toward fertility (ξ^{μ}) and a Harrod-neutral productivity shock (ξ^{y}). Specifically, we allow our theoretical parameters η (preference) and ϵ (technology), to be stochastic. Further, by aggregating individuals' choice variables, we allow the aggregate employment level to be stochastic, analogous to Shapiro and Watson (1988). This employment shock represents changes in unemployment compensation and in the degree of labor market imperfection, and includes any labor force shifters due to demographic changes and any other alteration in labor market conditions and employment opportunities. We also note that the attachment of this shock to employment is consistent with a model that explicitly accounts for the indivisibility of labor (e.g., see Rogerson (1988)).

Assume that $A(1)$ is lower triangular and that ξ is orthogonal. Following Blanchard and Quah (1989) and Ahmed, Ickes, Wang and Yoo (1993), we can estimate the reduced form and retrieve the moving average representation of the structural form:

$$X_t = C(B)\xi_t, \tag{12}$$

where $C(B) = A^{-1}(B)$. The estimated $C(1)$, which is also lower triangular, contains the estimated long-run multipliers of the structural shocks on the endogenous variables. Thus, the identifying restrictions on $A(1)$ involve conditions on the long-run comparative static multipliers, namely, that $d\ell/d\eta$, $d\ell/d\epsilon$, and $d\mu/d\epsilon$ are all approximately zero in the long run, consistent with our theoretical results discussed in section II.C. Specifically, these identifying restrictions adopt two plausible economic relations. First, the labor supply curve is vertical in the long-run and shifted only by shocks to itself. Second, fertility choice is unaffected by Harrod-neutral productivity shocks in the long run. The latter is based on the theoretical result that along the transition path, intertemporal and contemporaneous effects of an output disturbance act on μ in opposite directions.[9] This provides the structure to the following long-run causal ordering of the system: labor growth, fertility growth, and output growth.

B. The Data and Time Series Properties

The system's three endogenous variables, labor effort (*LAB*), the fertility rate (*FERT*) and output (*Y*) are measured with total weekly hours worked by all employees, the total fertility rate and real GNP in constant 1982 dollars. Both hours and real GNP were obtained from the *Citibase* data tapes, while the fertility rate was from the *Current Population Survey*. Notably, the total fertility rate measures the number of births that 100 women would have in their lifetime, if at each year of age they experienced the age-specific fertility rate occurring in a specific calendar year. Although the total fertility rate is expressed as a hypothetical lifetime measure, it is an annual rate and is unaffected by demographic shifts in age and sex. Thus, the total fertility rate best captures the underlying fertility behavior.[10] This measure indicates a post-WWII "baby-boom" peak in 1957, followed by a prolonged fertility decline and a "baby-boom echo" starting from 1976.

Our empirical study employs post-World War II United States annual data covering the period from 1949 to 1988.[11] To implement the structural VAR estimation, the endogenous variables in equation (11) must be stationary. The Phillips–Perron (1988) tests suggests that the logs of labor, fertility and output (*LLAB*, *LFERT* and *LY*, respectively) are stationary in first differences.[12] See table 2 which reports the test statistics with four autocorrelations in estimating the long-run

[9] It is also widely believed in the fertility literature that income has little effect on the secular movements in fertility; for example, see Easterlin (1978).

[10] There are two alternative fertility measures: the crude birth rate and the general fertility rate. The former is affected by both the age and sex distribution, while the latter depends on the age distribution.

[11] The first two years of the available data (1947–48) are truncated to avoid any possible effect from the war. Although the labor effort data are observed monthly and output data have a quarterly frequency, the fertility data are observed only annually.

[12] The null hypothesis of a second unit root in the fertility data can be rejected only at the 10% significance level; however, the power of the test is low. Moreover, using the Augmented Dickey Fuller test, the null of one unit root in the output series cannot be rejected even at the 10% level (the τ_μ statistic is -0.97 with a critical value between -3.00 and -2.93).

TABLE 2.—UNIT ROOT TEST RESULTS: $Z(t_{\tilde{\alpha}})$ AND $Z(t_{\hat{\alpha}})$ STATISTICS

Unit Root(s):		*LLAB*	*LFERT*	*LY*
One vs zero	(p = 1) $Z(t_{\tilde{\alpha}})$	−1.37	−1.82	−3.28[a]
Two vs one	(p = 0) $Z(t_{\hat{\alpha}})$	−6.01[b]	−2.72[a]	−5.47[b]

Notes: Critical values for $Z(t_{\tilde{\alpha}})$ are between −3.24 & −3.18, −3.60 & −3.50, at the 10%, 5% level, respectively.
Critical values for $Z(t_{\hat{\alpha}})$ are between −2.63 & −2.60, −3.00 & −2.93, at the 10%, 5% level, respectively.
p: order of polynomial trend (under both the null and the alternative).
[a]Significant at the 10% level.
[b]Significant at the 5%level.

TABLE 3.—SECOND STAGE COINTEGRATION TEST RESULTS: t-STATISTICS ON LAGGED LEVEL

(a) Regressions (2 variable system)		(b) Regressions (3 variable system)	
LLAB on *LFERT*	−0.79	*LLAB* on *LFERT*, *LY*	−1.68
LLAB on *LY*	−1.43	*LFERT* on *LLAB*, *LY*	−1.79
LFERT on *LLAB*	−1.36	*LY* on *LLAB*, *LFERT*	−2.78
LFERT on *LY*	−1.29		
LY on *LLAB*	−1.80		
LY on *LFERT*	−1.73		

Note: Critical values for (a) and (b) at the 5% significance level are −3.67 and −4.11, respectively (see Engle and Yoo (1987)).

variance.[13] The time-series characterization of the fertility rate could be more controversial since polynomial detrending has been a standard method in the literature of fertility and population (e.g., see Galbraith and Thomas (1941), Kirk (1960) and Lee (1987)). Simple F-tests indicate strong rejection of linear and quadratic detrending in favor of cubic polynomial detrending (with p-values less than 0.001). However, using the Ouliaris-Park-Phillips (1990) tests, we cannot reject the existence of a unit root against cubic-trend-stationarity. (The test statistic, $S_3(\hat{\alpha})$, was calculated to be −2.32 with a critical value of −4.21 at the 5% significance level.) Nevertheless, given the long tradition and fairly low power of the test (which tends to accept the null hypothesis of a unit root), we do not intend to preclude the cubic polynomial detrending method completely.

For convenience, we restrict our attention to the case that assumes that the fertility rate is integrated of order one and refer to it as the preferred "benchmark" case—this best matches with the theory and the identification outline above. We shall report empirical results from alternative specifications as sensitivity analysis in section III.C.4 below.

In addition to stationarity, the structural VAR requires that there exists no cointegrating relationships between the endogenous variables. To check for cointegration we used the two-step process proposed by Engle and Granger (1987) in both pairwise and system-wide tests. Table 3 reports the second stage results: the Augmented Dickey-Fuller tests on the residuals of the first stage regressions. All of the residuals appear to be integrated, hence the null hypothesis of no cointegration could not be rejected in any case. In summary, the structural VAR, in our benchmark case, was estimated using the logged differences of labor, the fertility rate, and output (*DLLAB*, *DLFERT*, and *DLY*) as the endogenous variable vector, X, in (11). They represent the growth rates of labor, fertility and output, respectively.

[13]We obtain the same conclusion using the Augmented Dickey-Fuller test. Moreover, all of the non-parametric unit root tests performed in the paper generate results insensitive to the number of lags (from two to six) in estimating the long-run variance.

C. *Estimation*

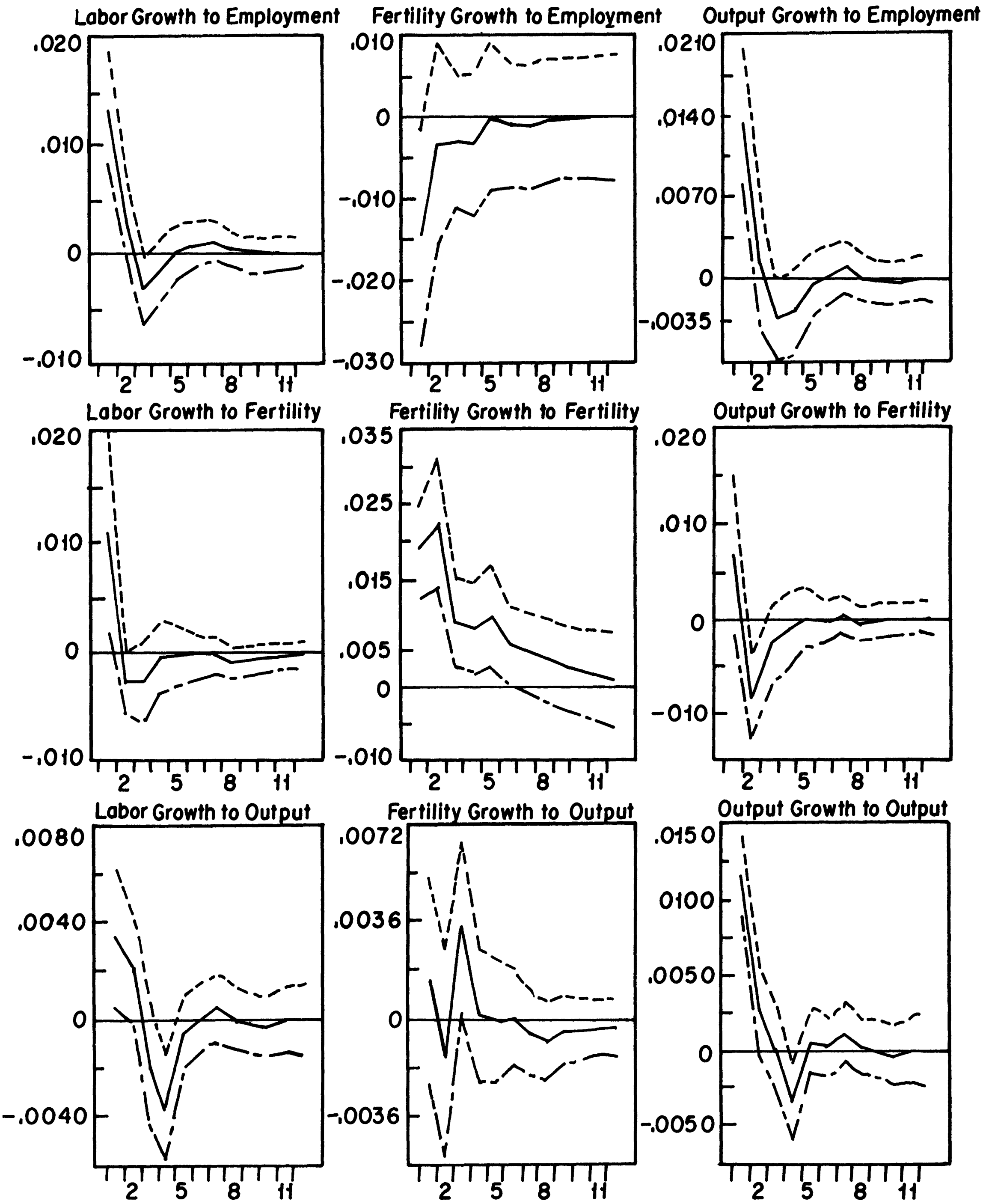
Based on Akaike information criterion, we find that three lags are the best to represent the dynamic structure of the system. For brevity, the estimated $C(1)$ is not reported in the text. Instead, we focus on the short-run dynamic effects of these structural disturbances by performing impulse response and variance decomposition analyses.

1. Impulse Response Analysis: The impulse response functions show how the three endogenous variables respond, over a twelve-year horizon, to each one-standard-deviation shock.[14] Figure 4 plots the responses of labor growth, fertility growth and output growth, respectively, to the employment, fertility, and output shocks. The solid lines give the point estimates while the dotted lines show the one standard error bands (standard errors were generated by computer simulation based on 1000 replications).

As shown in the left-hand panel in figure 4, labor effort responds to an employment shock in a fashion similar to Shapiro and Watson's (1988)

[14]The sizes of the employment, fertility, and output shocks are 0.0156, 0.0225, and 0.0152, respectively.

FIGURE 4.—RESPONSES OF LABOR GROWTH, FERTILITY GROWTH AND OUTPUT GROWTH TO EMPLOYMENT, FERTILITY AND OUTPUT SHOCKS



results: labor increases in the short run, then levels out after approximately eight years. The impulse responses to a preference shock support the theoretical prediction about transitional dynamics: after the first year labor effort is decreasing, thereafter, labor rises and eventually returns to its original level. In response to an output disturbance, labor effort increases for two years and then decreases back to its original level. This "hump-shaped" response is analogous to the findings of Shapiro and Watson (1988) and is consistent with our theoretical conclusion as well as the notion of a long-run vertical labor supply curve.

The impulse responses of fertility to each structural shock are plotted in the middle panel of figure 4. If fertility is exogenous, it should not respond to output or employment disturbances. However, our estimation shows that fertility does respond to employment shocks. As expected, an employment shock decreases fertility on impact since time is re-allocated toward labor, and such an effect diminishes after four years to approach the long-run steady-state. Our results show that the short-run negative response of fertility to an employment shock is especially significant on impact, whereas the effect of output disturbances on fertility is found to be rather weak at all horizons.

Finally, the output responses are depicted in the right-hand panel in figure 4. Output responses to employment and technology shocks are again similar to Shapiro and Watson's (1988) results: output increases sharply on impact, then declines and approaches a permanently higher level gradually. In response to a technology shock, output adjusts much more slowly. A fertility disturbance should, theoretically, retard capital accumulation and decrease labor on impact; hence, output is expected to fall in the short run. Our estimated results indicate that such a response is in particular significant for the second year following the perturbation.

2. *Variance Decomposition Analysis:* The variance decompositions show how much of the forecast error variance for each endogenous variable can be explained by each disturbance. As tables 4a–c indicate, employment shocks are important for explaining labor and output variations, corroborating with results in Shapiro and Watson (1988). Although output shocks account for about one-third of output variation, they appear to be not very influential on labor even in shorter horizons, which is consistent with the notion of a long-run vertical labor supply curve. Notably, fertility shocks have unomitable impacts on labor and output growth, significantly (within one standard error bands) explaining, approximately one-third and one-quarter of their variations, respectively, after the first year. Moreover, at one year ahead, about 37% of the variance of fertility can be explained by employment shocks, and the point estimate is significant. Further out, employment effects become slightly less influential, while at all horizons, output shocks are of little importance. The results are consistent with the impulse response analysis. The evidence supports the hypothesis that there are important dynamic interactions between labor and fertility decisions, and that fertility is endogenous and should be explicitly modelled, as related to developments in the labor market.

TABLE 4.—VARIANCE DECOMPOSITION OF FORECAST ERRORS: BENCHMARK MODEL

Horizon (Yrs)	Employment Shock	Fertility Shock	Output Shock
Table 4a: Decomposition of Variance of Labor Growth			
1	59.20 (30.63)	37.11 (31.02)	3.69 (7.31)
2	58.08 (26.32)	37.00 (26.61)	4.92 (6.80)
8	55.66 (22.52)	35.29 (22.72)	9.04 (8.60)
∞	55.49 (22.16)	35.46 (22.25)	9.05 (9.72)
Table 4b: Decomposition of Variance of Fertility Growth			
1	37.28 (31.63)	62.39 (31.91)	0.33 (4.20)
2	20.63 (25.94)	79.02 (26.15)	0.34 (3.42)
8	16.98 (24.21)	81.86 (23.87)	1.16 (3.37)
∞	16.76 (24.88)	82.05 (24.21)	1.19 (4.77)
Table 4c: Decomposition of Variance of Output Growth			
1	51.70 (22.10)	12.66 (21.24)	35.64 (15.11)
2	42.95 (15.91)	26.07 (15.86)	30.98 (12.10)
8	43.06 (14.70)	25.93 (15.15)	31.02 (11.77)
∞	43.07 (15.33)	25.92 (15.46)	31.01 (12.75)

Note: Standard errors in parentheses, ∞ taken to be 40 years.

3. *Historical Decompositions:* We next decompose historically the major changes in the rate of fertility into changes due to each of the disturbances (see table 5). This exercise enables us to understand short-run fluctuations as well as some secular movements in fertility which may correspond to the Kuznets (1958) or Easterlin (1968) cycles.

TABLE 5.—MAJOR CHANGES IN FERTILITY GROWTH BY SOURCE

	Employment Shock	Fertility Shock	Output Shock
Increases	1956–64, 1982	1952–57, 1977–88	—
Decreases	1965–69, 1971–72 1977–78, 1980–81	1958–68, 1971–75	—

First, we study major fertility changes arising from an employment shock. From 1956 to 1964 fertility experienced a nine year period of positive growth due to labor market conditions. During this time, husbands' incomes were high relative to their parents so there was little need to supplement earnings with wives' salaries. Therefore, young women did not enter the work-force en masse and the fertility rate rose, corroborating with Easterlin's (1968) hypothesis. Afterwards (1965–69), baby-boom mothers were completing their child-bearing years and beginning to return to the work force, and hence fertility declined. In 1970 output growth fell and in the mid-1970s the economy suffered a severe recession due to the first oil crisis. After each slowdown (1971–72 and 1977–78), as the economy recovered and the opportunities for employment increased, women re-entered the work force and fertility decreased. The time period from 1980 to 1981 experienced high inflation due to the second oil crisis. As households sought to maintain their standard of living in face of the uneven and volatile rise in prices, the incidence of "dual income" families rose. This "added worker effect" enlarged the labor pool and, thus, lowered fertility. Apparently, in 1982 the "added worker effect" was reversed, as inflation stabilized.

Second, we investigate the essential movements in fertility arising from a preference shift. The baby-boom years are evident in the rise in fertility growth from 1952 to 1957. Another prolonged rise in fertility growth occurs in 1976, which seems to be a result of a baby boom echo in conjunction with a series of child care legislation initiated by the federal government during this time (see a historical survey by Robins (1990)). The legislation included a tax credit for child care, the community services block (which subsidizes child care centers), and the accelerated cost recovery system (which makes business-provided child care centers eligible for accelerated depreciation). Also, during this time, attitudes regarding the acceptability of out-of-home child care may have begun to change. In the 1960s, women began to have children at a later age, reflecting a preference shift away from child-bearing after the post World War II baby-boom. The postponement, which also may have occurred due to the increased availability of contraception, caused the decline in fertility growth from 1958 to 1968. In addition, a notable fertility decline from 1971 to 1975 deserves comment: it reflected the adverse effect of higher opportunity costs of child-rearing due to education desires.

Finally, we note that the historical decomposition of fertility due to output shocks only displays relatively unimportant movements.

4. *Sensitivity Analysis:* In this section we investigate the robustness of the above results to the alternative time-series specifications of the fertility variable. First, we re-estimated the system under the same long-run dynamic structure as our benchmark case but with cubic-detrended fertility. When output is last and fertility is second we are assuming that income effects on the secular movements in fertility are negligible. Moreover, with fertility characterized as trend stationary no disturbances will have permanent effects on the deterministic fertility growth rate. However, because of the irreversibility of the child-bearing decision, fertility preference shocks are permitted to have long-lasting effects on output. Second, in conforming with Blanchard and Quah's (1989) implementation, we place the trend-stationary fertility variable last in the system. This allows the deviations of fertility away from trend to be affected by all disturbances, thereby allowing us to test the importance of the income effect on short-run fertility fluctuations. However, in so doing we do not allow output to respond to fertility preference shocks in the long run.

The differences between these cases and the benchmark case are minor (see tables 6 and 7 relative to table 4). First, in the alternative specifications, employment (fertility) shocks explain about 26% more (less) of the variance of labor growth in the first period and about 16% more (less) thereafter. Nevertheless, in the two alternative cases, the contribution of fertility shocks to labor growth is still important (accounting for

TABLE 6.—VARIANCE DECOMPOSITION OF FORECAST ERRORS: ALTERNATIVE SPECIFICATION, FERTILITY SECOND

Horizon (Yrs)	Employment Shock	Fertility Shock	Output Shock
Table 6a: Decomposition of Variance of Labor Growth			
1	84.51 (19.45)	8.56 (17.56)	6.93 (9.82)
2	75.63 (16.37)	17.34 (14.52)	7.03 (8.52)
8	70.08 (14.81)	18.46 (12.34)	11.46 (9.76)
∞	70.08 (15.66)	18.46 (13.47)	11.48 (10.62)
Table 6b: Decomposition of Variance of Fertility Growth			
1	27.78 (23.06)	71.94 (23.71)	0.28 (5.05)
2	16.29 (19.29)	83.57 (20.35)	0.14 (4.15)
8	20.21 (21.66)	79.20 (21.65)	0.59 (4.47)
∞	20.75 (21.82)	78.68 (21.96)	0.56 (5.78)
Table 6c: Decomposition of Variance of Output Growth			
1	55.18 (19.08)	0.92 (10.28)	43.90 (17.60)
2	45.87 (15.81)	16.71 (10.98)	37.42 (14.43)
8	45.54 (13.95)	19.13 (10.30)	35.33 (13.06)
∞	45.41 (14.08)	19.42 (11.69)	35.17 (13.50)

Note: Standard errors are in parentheses, ∞ taken to be 40 years.

TABLE 7.—VARIANCE DECOMPOSITION OF FORECAST ERRORS: ALTERNATIVE SPECIFICATION, FERTILITY LAST

Horizon (Yrs)	Employment Shock	Fertility Shock	Output Shock
Table 7a: Decomposition of Variance of Labor Growth			
1	84.51 (19.36)	9.00 (16.23)	6.49 (11.88)
2	75.63 (15.68)	17.52 (13.26)	6.85 (10.12)
8	70.08 (14.24)	18.61 (11.54)	11.31 (10.20)
∞	70.07 (15.50)	18.60 (13.31)	11.33 (10.56)
Table 7b: Decomposition of Variance of Fertility Growth			
1	27.78 (22.99)	72.14 (23.34)	0.08 (10.53)
2	16.29 (19.69)	83.68 (20.79)	0.03 (10.34)
8	20.21 (21.29)	79.38 (21.37)	0.41 (10.16)
∞	20.75 (21.47)	78.85 (21.54)	0.39 (10.25)
Table 7c: Decomposition of Variance of Output Growth			
1	55.18 (19.04)	1.31 (12.10)	43.51 (19.52)
2	45.87 (15.21)	16.79 (11.32)	37.34 (15.35)
8	45.54 (13.54)	19.17 (10.70)	35.29 (13.16)
∞	45.41 (14.24)	19.46 (13.40)	35.13 (13.71)

Note: Standard errors in parentheses, ∞ taken to be 40 years.

about 18%) after the first period. Second, on impact, employment shocks account for approximately 10% less and preference shocks about 10% more of the variance of the forecast error for fertility in the alternative specification. However, after one year, the variance decompositions of fertility are very similar in all three cases. Third, the variance decomposition of output growth is not very sensitive to different specifications. Fourth, the results of the two alternative specifications are almost identical indicating that the ordering of the last two variables, cubic-detrended fertility and output growth, does not matter. This also indicates that, even in the short run, output shocks have little effect on fertility variations. Finally, the impulse response functions and the historical decompositions are qualitatively similar under all specifications. In summary, although we have some quantitative differences between various specifications, our main conclusions remain unchanged.

IV. Concluding Remarks

Our empirical evidence shows that the dynamics of labor supply, output growth and fertility are consistent with a model which explicitly accounts for the endogeneity of fertility decisions. The historical decompositions of fertility indicate that shocks to employment and preferences are important in explaining movements in the fertility rate. Therefore, models with a predetermined fertility-leisure choice may mis-specify the structural disturbances as well as their dynamic effects.

The endogeneity of fertility has policy implications which are usually over looked by macroeconomists and policymakers alike. For example, a tax on labor acting similarly to a negative employment shock will also affect fertility, which will in turn alter the influence of the tax on labor supply. Policies which tax or subsidize raising children (such as day care provisions, public education, tax incentives, etc.) can act analogously to the preference shock and have effects on labor supply and capital accumulation.

Finally, empirical evidence on the co-movements between the growth rates of per capita income and population growth have been inconclusive (e.g., see Kuznets (1967) and Kormendi and Meguire (1985)). Both our theoretical and empirical results can help explain the controversy. The sign of the correlation depends crucially on which shock initiates the motion and on the relative reactions of the labor and capital stock inputs. The impulse response functions show that the correlation between the paths of output growth and fertility is negative in response to a labor or a fertility preference shock. However, these two variables appear to be positively correlated given an output shock. Therefore, the previous empirical ambiguity stems from the absence of a plausible causal ordering in a multivariate system where structural shocks have not been explicitly retrieved.

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