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Age at Marriage, Divorce, Fertility and Labor Force Participation of Women: a Time Series Perspective

H. Naci Mocan

University of Colorado at Denver and National Bureau of Economic Research, USA*

Abstract
This paper uses vector-autoregressions to gain insights into the dynamic relationships between age at marriage, divorce, fertility, and labor force participation of women. The use of vector-autoregressions let us circumvent the statistical problems faced by previous studies. Age at marriage, fertility, the divorce rate, and the labor force participation rate are permitted to depend on the past values of each other. The impulse response simulations allowed us to observe the short-run reactions of the variables to the unexpected perturbations in the system. Contrary to the evidence presented by cross-sectional analyses, no significant influence of young marriages on the divorce rate is found: A positive shock to the proportion of young marriages did not generate an increase in the divorce rate. On the other hand, young marriages and the divorce rate simultaneously increased or decreased when there were increases in the fertility or the labor force participation rates. This outcome implied that the inverse association between age at marriage and divorce is not a causal relationship; rather divorces and marriages co-vary due to changes in labor force participation and fertility. The results hold when we use the unemployment rate for women as the labor market variable.

I. INTRODUCTION

During the last few decades several socio-economic variables in the United States demonstrated significant changes. The labor force participation of women increased from 35 percent in the 1950s to more than 55 percent in the late 1980s. Fertility declined continuously after late 1950s and the divorce rate exhibited an increasing trend during the same period. These trends evoked economists' and sociologists' attentions, and a large body of literature emerged analyzing the reasons and the consequences of these changes.

Economic theory suggests that in order for the labor force participation rate to rise there must be changes in the value of market or non-market time, or tastes. The change in the value of time can be due to exogenous factors, e.g. a technological progress, or it can be realized due

*University of Colorado at Denver, Department of Economics, Campus Box 181, P.O. Box 173364, Denver, Colorado 80217-3364, USA.

to increased productivity which may be a result of increased human capital. The change in tastes represents changes in social and psychological attitudes like changing sex roles, life styles and family structures. On the other hand, as the labor force participation reacts to these changes, it also influences them. For example, as higher school attainment, decreased fertility and higher marital dissolution affect labor force participation of women, the changing labor force participation behavior in turn alter the attitudes towards education, family formation and fertility decisions.

Traditionally, the examination of the trend in the divorce behavior relied on such variables as the employment opportunities for females, fertility rates, age at marriage, and the availability of government programs like child care. One expects an increase in the divorce rate as the labor force participation of women goes up, as fertility and age at marriage go down, and as the provision of government programs which support single parents expands. As is the case with the analysis of labor force participation, however, we notice mutual causalities in the investigation of the divorce behavior. As the divorce rate is expected to be influenced by labor force participation of women and fertility, it also influences them: A rise in the divorce rate is expected to increase the female labor force participation and decrease fertility. The statistical problems that emerge due to failure to account for these mutual causalities are discussed below.

Using a relatively new time-series technique this paper investigates the dynamic interrelations among labor force participation, divorce, fertility and age at marriage. Our main focus is the relationship between age at marriage and divorce behavior. The existence of an inverse relationship between age at marriage and probability of marital disruption is one of the strongest stylized facts in the sociology and family economics literature. This relationship has been repeatedly documented by a number of empirical studies [Burchinal and Chancellor (1963), Burchinal (1965), Bauman (1967), Parke and Glick (1967), Carter and Glick (1970), Glick and Norton (1971), Bumpass and Sweet (1972), Weed (1974), Shoen (1975), Lee (1977), Booth and Edwards (1985), Becker et al. (1977)].

Some mechanisms have been suggested to explain this relationship. One is that, people who marry young are unprepared in emotional, psychological, and instrumental ways for the process of selecting a mate and/or for the adequate performance of marital roles. This would result in relatively low marital satisfaction, and consequently, in an increased probability of marital dissolution (Bartz and Nye, 1970).

Empirical studies which consistently pointed out the inverse association between age at marriage and divorce face some methodological problems. Studies, which focused *only* on the relationship between age at marriage and divorce suffer from an *omitted variable bias* as the failure to take into account possible confounding factors creates biased coefficients. Among these factors are the fertility behavior, labor force participation and income level. Therefore, in these studies the relation between age at marriage and probability of divorce may be spurious due to factors which influence both age at marriage and divorce.

Studies, which investigated the relationship between age at marriage and divorce by controlling other factors typically involved estimating a probability of divorce equation in a certain interval of time as a function of relevant explanatory variables. For example, Becker *et al.* (1977) estimated the effects on the probability of divorce for age at marriage, schooling, income, and children, and found an inverse relation between age at marriage and the probability of divorce. The major shortcoming of these single equation multivariate techniques is that some explanatory variables of the estimating equation might not be *exogenous*. The obvious example is the age at marriage variable. There has been theoretical and empirical work pertaining to the determinants of age at marriage.[1] A simultaneous equation bias is created by treating the variables like age at marriage and fertility exogenous, when in fact they are determined within the system.

An ideal estimation procedure, therefore, would be a simultaneous equations system, where all the endogenous variables are estimated jointly. A plausible system, for instance, would consist of age at marriage, probability of divorce, fertility, labor force participation, duration of marriage, and religious affiliation, where age at marriage, probability of divorce, labor force participation, duration of marriage and fertility are treated as endogenous variables. However, since many of the variables are determined within the system, estimation of this simultaneous equations model is possible only if one puts some identification restrictions. Put differently, even if one starts with the premise that there are mutual causalities between labor force participation of women, age at marriage, fertility and divorce, and therefore they must be estimated jointly within a simultaneous equations system framework, the estimation can only be realized if one eliminates some of the variables from some equations to be able to identify the system. This procedure assumes that the excluded variables have no influence (or zero influence) on the particular dependent variable, hence these restrictions are sometimes called "zero restrictions".

Moreover, in a static model one assumes that all interaction among variables occur simultaneously. There is reason, however, to believe that the variables of this system can have lagged effects on each other. In other words, it takes time for changes in one variable to affect the others. For example, the change in the divorce rate today might not be very closely related to the change in the labor force participation today. More realistically, today's divorce rate depends on what has been happening to the labor force participation in the past. What happens to the labor force participation today affects what is going to happen to divorce in the future. Thus, an accurate representation of the system should be the one that takes into account the dynamic nature of the interdependence of the variables.

This paper uses vector-autoregressions (VAR) to describe the dynamic interrelations between age at marriage, divorce, fertility, and labor force participation of women. The use of VAR lets us circumvent the above mentioned empirical problems. The findings do not confirm the often reported inverse relation between age at marriage and divorce behavior. We find that the inverse association between age at marriage and divorce is not a causal relationship; rather young marriage and divorce co-vary due to the changes in labor force participation and fertility.

Section II describes the estimation methodology, Section III reports the results, Section IV is the conclusion.

II. METHODOLOGY

Previous empirical research on the relationship between age at marriage and divorce behavior has several weaknesses. They are either based on very limited specifications, where many relevant variables are not included in the estimation, or they did not take into account the inherent simultaneity of the variables. More precisely, to estimate a probability of divorce equation as a function of only age at marriage would potentially yield spurious results, since at least fertility and labor force participation should be included as additional regressors. A multivariate regression of divorce on age at marriage, labor force participation and fertility is not reliable either, since fertility, labor force participation, and age at marriage are not exogenous variables that are determined outside the system. On the other hand, a simultaneous equations system can be estimated only if one puts some a priori restrictions on the model which are hard to justify theoretically. Also, the dynamic nature of some potential mutually causal relationships (like the ones between the labor force participation of women and age at marriage, age at marriage and fertility, fertility and divorce, and divorce and labor force participation) is difficult to model using ordinary regression techniques.

Noticing the empirical problems encountered in traditional cross-sectional estimations, Michael (1985) estimated bi-variate vector-autoregressions between labor force participation and divorce, labor force participation and fertility, labor force participation and age at marriage, using aggregate United States data. This paper differs from his in two ways. First, we use monthly data as opposed to yearly, which yields much more information about the dynamics of the system. More importantly, the results obtained from bi-variate vector-autoregressions do not necessarily hold when one includes additional variables to the model (For theoretical and empirical discussions of this issue see Lütkepohl 1982, Mocan 1990).

This paper is the first to attempt to investigate the dynamic interrelations between age at marriage, divorce, fertility and labor force participation of women in a multivariate context using vector-autoregressions (VAR). The application of VAR enables us to consider labor force participation, fertility, divorce and age at marriage as endogenous variables, and to observe the dynamic influence of each of them on the others. A VAR can be interpreted as the reduced form relationship that arises from a dynamic stochastic structural model, the underlying parameters of which are based on the utility functions and the constraints (Eckstein *et al.* 1985). Since VAR is essentially a reduced form estimation, it does not yield information about the structural relationships between variables. For example, we are not able to tell whether early marriage leads to higher fertility which in turn leads to higher divorce rates, or early marriage leads to higher labor force participation, thus lower fertility and higher divorce rates. However, we do not consider this as a major drawback, because as mentioned above, even with a very rich micro data one can only estimate a quasi-structural system. The advantage of our technique is its ability to estimate the whole system without imposing any restrictions on the behavioral patterns, and perhaps more importantly, to uncover the dynamic interactions among the variables.

In a VAR system, each variable is regressed on its own lagged values, lagged values of the other endogenous variables as well as lagged values of the relevant exogenous variables. Thus a VAR does not put a priori restrictions on the system, and allows all the variables to be explained by the dynamics of all other variables. Because the right-hand side variables in each equation consist of past values, they are all predetermined. Thus, the system can be consistently estimated using ordinary least squares (OLS). Furthermore, estimating each equation separately using OLS produces asymptotically efficient estimates, provided the right-hand side variables are the same in every equation (Hakkio and Morris 1984). Thus, the VAR methodology has the potential to uncover causal time-series.

This study employs monthly U.S. data which cover the time period 1963–1982.[2] Fertility (FERT) is measured as the number of births per 1000 women between the ages of 16 and 44. The variable LFPR stands for the labor force participation rate for women who are 16 years of age and over. YOUNGMAR measures the proportion of brides between ages 16 and 24 in their first marriages to the number of women in the same age group and shows the tendency to marry early. The divorce rate (DIVORCE) is measured as the number of divorces per 1000 married women who are 18 years of age and over. The ratio of males to females in population (SEXRATIO) is a proxy for the available alternatives to women. This fifth and the only exogenous variable is expected to have an influence on the timing of marriage as well as on divorce, and therefore on the whole system.

One should note that the theoretical framework is based on individual-level observations: Labor force participation, marriage, divorce and fertility are individual decisions. Therefore, the appropriate empirical analysis should be based on individual-level micro data. However, the use of micro data, although theoretically more relevant, does not let us circumvent the statistical problems as outlined above. Since the variables of the model are all interdependent, studies based on micro data inevitably will suffer either from a simultaneous equation bias, or an omitted variable bias. Moreover, even with the richest micro data one cannot capture the dynamic interdependence of the variables. Because of the above mentioned limitations of the individual data, other individual actions, like criminal conduct, have been extensively analyzed using aggregate data (Ehrlich 1975, Cook and Zarkin 1985, Corman *et al.* 1987, Cover and Thistle 1988, Corman and Joyce 1990). Another example is the relationship between the consumption of health inputs such as prenatal care and nutrition and its impact on health outcomes measured by birthweight, which is well documented at the individual level. Researchers also investigated whether the relationship holds at the aggregate level (Corman and Grossman 1985, Corman *et al.* 1987).

In our case, VAR is the most appropriate estimation technique since it allows us to avoid the simultaneous equation biases and to capture the dynamic relationships among variables. The technique dictates the need for time series data with a large number of observations. Consequently, we employ monthly time series data described above.

All variables are expressed in logarithms and linear and quadratic trend variables are included in each equation. Since the variables are not seasonally adjusted, each equation contains eleven dummy variables to account for monthly variation.

The estimated system has the following form:

$$(1)\quad Y_{i,t} = C_i + \sum_{k=1}^{13} \alpha_{i,k} D_{i,k,t} + \sum_{j=1}^{5} \sum_{s=1}^{12} \beta_{i,j,s} Y_{j,t-s} + \epsilon_{i,t} \qquad i=1,..,4$$

where C_i represents the constant, and $D_{(.)}$ represents eleven seasonal dummies and the two trend terms in each equation. $Y_{(.)}$ stands for the endogenous variables, $\alpha_{(.)}$ and $\beta_{(.)}$ are the coefficients. Since twelve lags of SEXRATIO are included in each equation as exogenous variable, j goes from 1 to 5.

If the VAR model in (1) is correctly specified, the errors of each equation ($\epsilon_{i,t}$) should be a white noise. In other words, if our system does not omit any relevant variables and if the lag structure captures the dynamics correctly, there should not be additional information contained in the error terms; hence the errors should behave randomly. To check the specification of the system, several tests were performed. All of these tests demonstrated the white noise properties of the errors (See the Appendix).

III. IMPULSE RESPONSE FUNCTIONS

A very appealing aspect of the VAR framework is that it permits a random shock to one variable to move across all the equations and allows for a rich set of dynamic interactions. Consider, for example, the simple VAR model below which consists of the divorce rate, the labor force participation rate, and age at marriage. For ease of demonstration each variable enters with one lag only.

$$AM_t = \alpha_1 + \beta_1 AM_{t-1} + \gamma_1 DIV_{t-1} + \delta_1 LFPR_{t-1} + \epsilon_t$$

$$DIV_t = \alpha_2 + \beta_2 AM_{t-1} + \gamma_2 DIV_{t-1} + \delta_2 LFPR_{t-1} + u_t$$

$$LFPR_t = \alpha_3 + \beta_3 AM_{t-1} + \gamma_3 DIV_{t-1} + \delta_3 LFPR_{t-1} + v_t.$$

A one standard deviation shock in the labor force participation rate σ_v (the standard deviation of v_t) at time t will change the future values of divorce, age at marriage and labor force participation itself. At time t the labor force participation rate will rise by the amount of the perturbation, σ_v. In period t + 1 the divorce rate will change by $\delta_2\sigma_v$, age at marriage will change by $\delta_1\sigma_v$, and the labor force participation will change by $\delta_3\sigma_v$. In period t + 2 the divorce rate will change by $(\beta_2\delta_1 + \gamma_2\delta_2 + \delta_2\delta_3)\sigma_v$, age at marriage will change by $(\beta_1\delta_1 + \gamma_1\delta_2 + \delta_1\delta_3)\sigma_v$, and labor force participation will change by $(\beta_3\delta_1 + \gamma_3\delta_2 + \delta_3^2)\sigma_v$. This example illustrates how a VAR framework allows for dynamic interactions among variables. The change in the divorce rate at time t + 2 for example, depends on the lagged effects of age at marriage on divorce (β_2), of the labor force participation on age at marriage (δ_1), of the labor force participation on divorce (δ_2), as well as the own dynamics of the labor force participation (δ_3) and the divorce rate (γ_2), and the magnitude of the initial shock (σ_v).

In this section we will report these dynamic simulations of the model (Impulse Response Functions in the VAR terminology). Mapping out the responses of the variables to unanticipated shocks in one of the variables will allow us to gain insights into their dynamic interactions.[3]

As long as the errors of the variables are contemporaneously correlated (the off-diagonal elements of the variance-co-variance matrix is nonzero), changes in errors occur simultaneously, hence a change in a variable can not be attributed to the innovation in that variable alone. Therefore an orthogonalization of the errors is needed, which is obtained by triangularization of the variance-covariance matrix of residuals, to create a block recursive system among errors.[4] The transformation imposes a causal ordering among the contemporaneous errors. The impulse response functions presented below is based upon the following causal ordering: LFPR, FERT, YOUNGMAR, DIVORCE.[5]

To make the impulse responses comparable, the response of each variable is expressed as a proportion of its standard deviation. The first characteristic of the system is its stability. The figures indicate that the responses to shocks in the system tend to dampen, with variables converging to the initial values within five years.

Figure 1 presents the dynamic responses of the proportion of young marriages and the divorce rate following a shock in the labor force participation rate of women. After the increase in the labor force participation rate, the proportion of young marriages increases for 30 periods. During the same interval, the divorce rate rises as well. After the third year, the proportion of young marriages declines and returns to its initial level; and so does the divorce rate.

Figure 2 presents the reactions of the proportion of young marriages and the divorce rate to an unexpected increase in fertility. Note again that the proportion of young marriages and the divorce rate exhibit a co-movement similar to the one in Figure 1. Figures 1 and 2 demonstrate the strong interaction between the proportion of young marriages and the divorce rate, which is consistent with a priori expectations and the reports of past research. According to Figures 1 and 2, an increase (decrease) in the proportion of young marriages couples with an increase

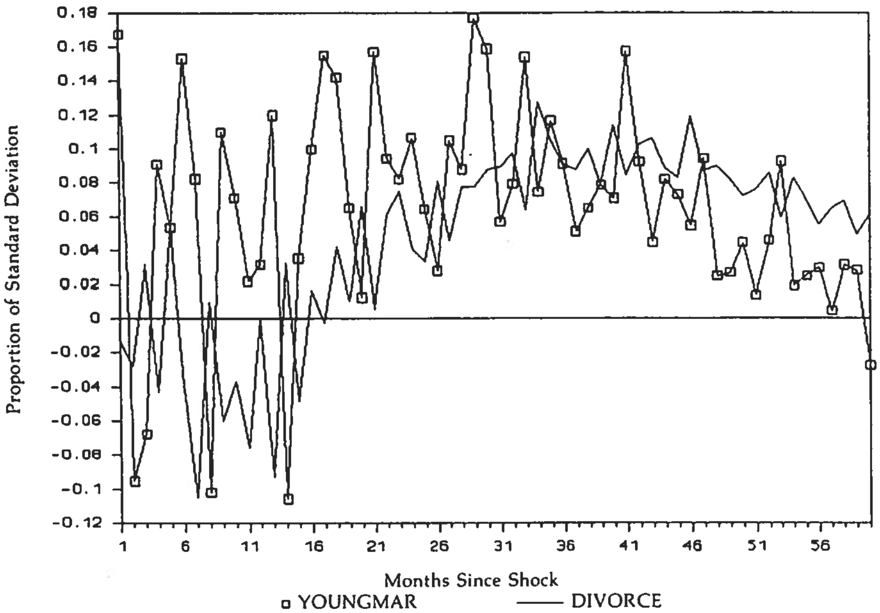

FIGURE 1 Shock to the labor force participation rate

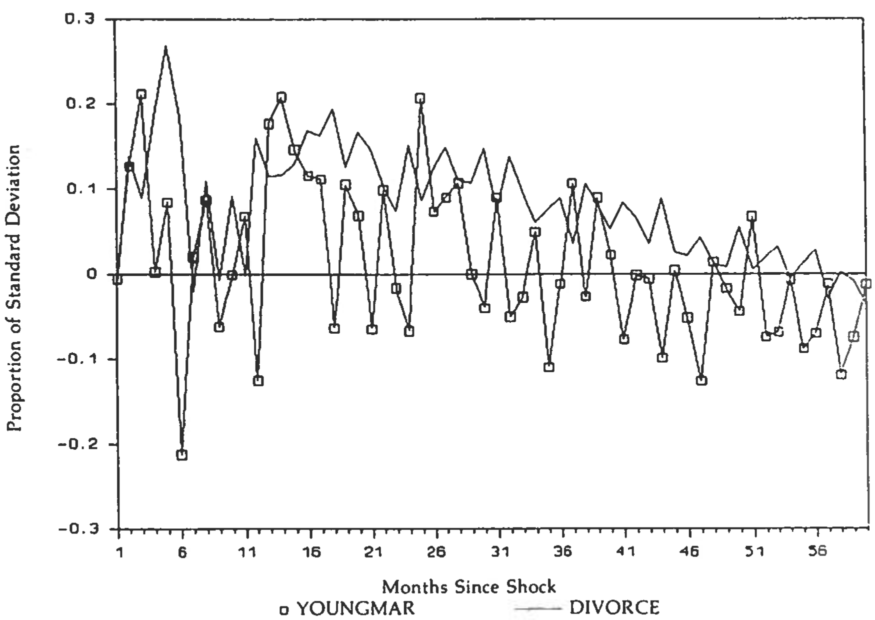

FIGURE 2 Shock to fertility

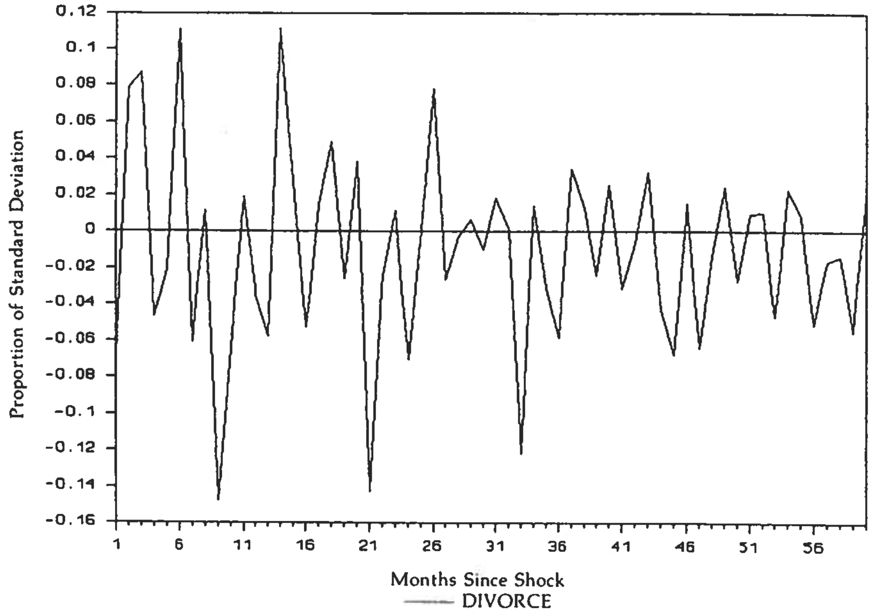

FIGURE 3 Shock to the proportion of young marriages

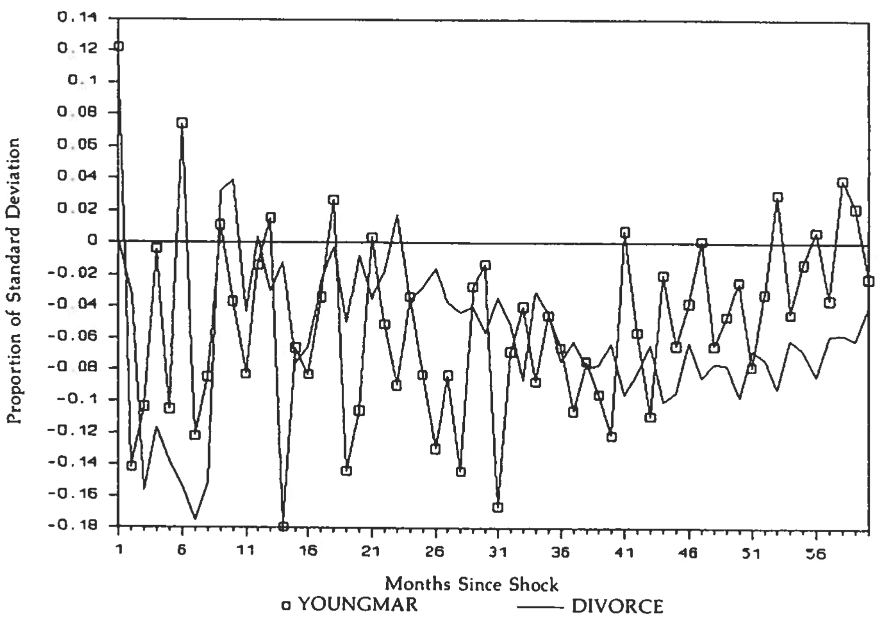

FIGURE 4 Shock to the female unemployment rate

(decrease) in the divorce. It should be noted, however, that this co-movement of the proportion of young marriages and the divorce rate is due to the unexpected increases in the labor force participation rate and fertility. Figure 3 demonstrates the response of the divorce rate to an increase in the proportion of young marriages. According to this picture, the divorce rate is not influenced in any significant way by an increase in the proportion of young marriages. The shock to the proportion of young marriages generates oscillations in the divorce rate, which lose their magnitudes after the twentyfirst month and approach the pre-shock level. The proportion of young marriages and the divorce rate co-vary due to changes in labor force participation and fertility, but the divorce rate does not react to change in the proportion of young marriages.

To check the robustness of the results, different versions of the model are estimated. First, the model is estimated using a different measure of economic activity pertaining to women. Unemployment rate for women who are 16 years of age and over substituted for the labor force participation rate. The impulse responses of this system are reported in Figures 4–6. Figures 4 and 5 illustrate the joint movement of the proportion of young marriages and the divorce rate when there are innovations in the female unemployment rate and fertility. Figure 6 shows the behavior of the divorce rate after a shock in the proportion of young marriages. These pictures are very similar to the ones reported earlier (Figures 1, 2 and 3). Once again, the proportion of young marriages and the divorce rate exhibit a co-movement due to changes in fertility or labor market activity, but an increase in the proportion of

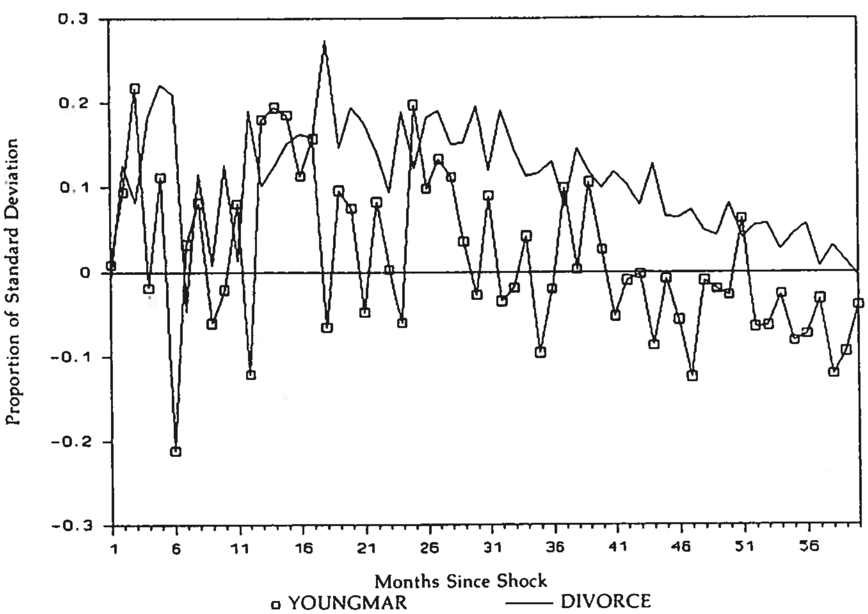

FIGURE 5 Shock to fertility

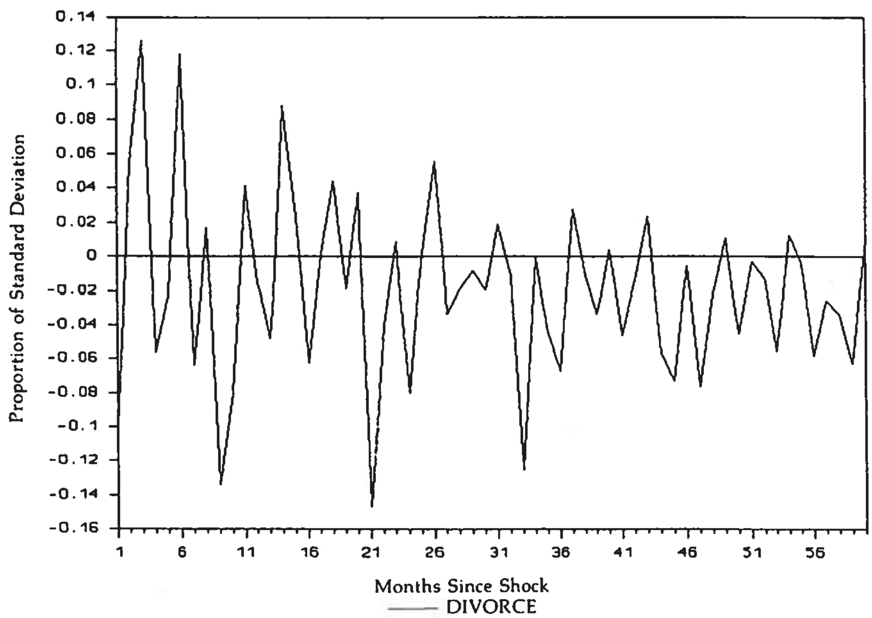

FIGURE 6 Shock to the proportion of young marriages

young marriages does not cause an increase in the divorce rate contrary to the evidence of cross-sectional analyses [e.g. Becker et al. (1977), Booth and Edwards (1985), Lee (1977), Schoen (1975), Weed (1974), Bumpass and Sweet (1972)]. This implies that it is merely a correlation between age at marriage and the divorce behavior that is observed, but there is no causality from age at marriage to divorce.

To increase the degrees of freedom, SEXRATIO is dropped from the system. The system with LFPR, FERT, YOUNGMAR, and DIVORCE generated the same results as the initial system containing SEXRATIO as an additional variable. Similarly, the exclusion of SEXRATIO from the system where unemployment variables were substituted for LFPR did not alter the results.

A Misspecified Model

A VAR consisting of YOUNGMAR, DIVORCE, SEXRATIO, the constant, seasonal dummies, and trend variables is estimated. This is a misspecified model, since it omits fertility and the labor force participation rate. In that sense it is the VAR representation of the methodology employed in previous studies. After estimating the model, a one standard deviation shock is applied to the proportion of young marriages. The behavior of the divorce rate is presented in Figure 7. In this model, as in previous studies, an increase in the proportion of young marriages generated an increase in the divorce rate. However, as is

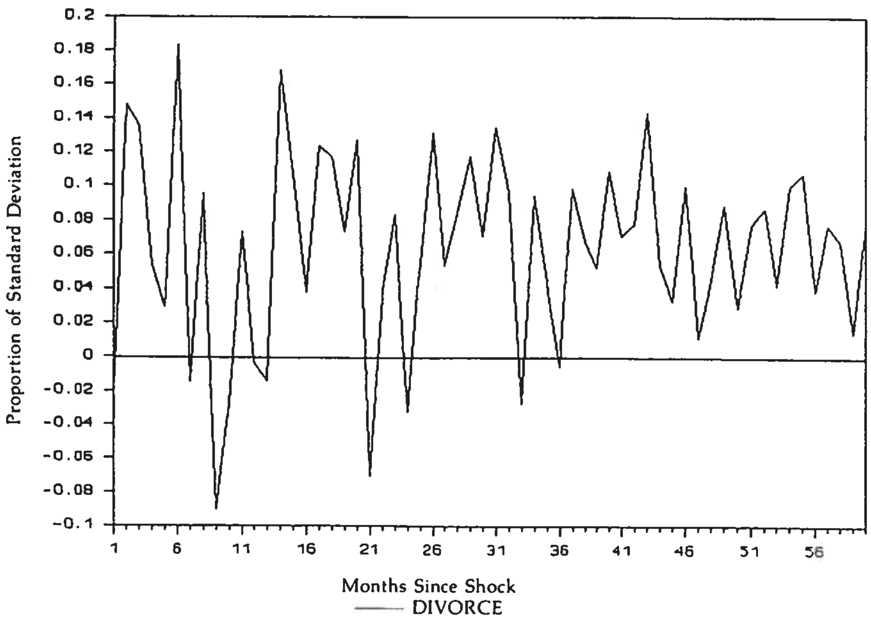

FIGURE 7 Shock to the proportion of young marriages

shown in the previous section, adding fertility and labor force participation to the system makes the observed causality from age at marriage to divorce disappear (See Figure 3). It is not the causality from age at marriage to divorce that creates the picture of joint movement between the two; rather, the intervening effects of labor force participation and fertility generate that co-movement.

IV. CONCLUSION

In this paper we used vector-autoregressions to gain insights into the dynamic relationships between age at marriage, divorce, fertility, and labor force participation of women. Since these variables are highly interdependent, standard estimation techniques suffer from a simultaneous equations bias in case of inclusion of all the variables in the estimating equation. On the other hand, it is very difficult to identify the system as a simultaneous equation model without putting a priori zero restrictions. We estimate the model without imposing any identification restrictions. Age at marriage, fertility, the divorce rate, and the labor force participation rate are permitted to depend on the past values of each other. The impulse response simulations allowed us to observe the short-run reactions of the variables to the unexpected perturbations in the system. Contrary to the evidence presented by cross-sectional analyses, no significant influence of young marriages on the divorce rate is found: A positive shock to the proportion of young marriages did not generate an increase in the divorce rate. On the other hand, young marriages and the divorce rate simultaneously increased or decreased when there were increases in the fertility or labor force participation rates. This outcome implies that the inverse association between age at marriage and divorce is not a causal relationship; rather divorces and marriages co-vary due to the intervening effects of labor force participation and fertility. This conclusion is supported by the bi-variate regression between age at marriage and the divorce rate. In that model which omits the labor force participation and fertility, an increase in age at marriage generated an increase in divorce. The results hold when we use the unemployment rate for women instead of the labor force participation rate.

APPENDIX

SPECIFICATION TESTS

First, to see if the lag specification adequately captures the dynamics of the model, the estimated system with 12 lags of each variable was tested as a restriction on systems with 15 and 17 lags. The null hypotheses of no difference was accepted in both cases. The χ^2 statistics was 81.97 with 60 degrees of freedom in the former, and 128.3 with 100 degrees of freedom in the latter.[6] Secondly, a Sims exogeneity test (Sims 1972), coupled with the a priori knowledge as to the exogeneity of SEXRATIO, enabled us to perform a specification test of the model. For illustrative purposes suppose the following simple VAR model represents the correct specification:

$$X_t = \alpha_1 X_{t-1} + \alpha_2 X_{t-2} + \alpha_3 Y_{t-1} + \alpha_4 Y_{t-2} + \alpha_5 E_{t-1} + \alpha_6 E_{t-2} + \epsilon_t$$

$$Y_t = \beta_1 X_{t-1} + \beta_2 X_{t-2} + \beta_3 Y_{t-1} + \beta_4 Y_{t-2} + \beta_5 E_{t-1} + \beta_6 E_{t-2} + u_t$$

$$E_{t-1} = \tau E_{t-2} + \mu_t,$$

where X and Y are the endogenous variables. E is the exogenous variable, and therefore explained by its dynamics only. If one estimates the equation

$$X_t = \delta_t X_{t-1} + \delta_2 X_{t-2} + \delta_3 E_{t-1} + \delta_4 E_{t-2} + \delta_5 E_{t+1} = v_t,$$

omitting the lagged values of Y, but including the future value of the exogenous variable, the chain of correlation between E_{t+1} and Y_t may give rise to a significant estimate of $\delta_5 \neq 0$, which represents the specification error of the model, since the future values of the exogenous variable is not expected to influence the current value of the endogenous variable.

The first row of Table 1 reports the F-statistics for the 12 leads of SEXRATIO in each of the four equations of the system. They are not significantly different from zero, implying the rejection of the hypothesis that there is a specification error of the model.

Lastly, a Lagrange Multiplier (LM) test was applied to the residuals.[7]

The LM statistic provides a general test for autocorrelation of errors, and is valid when the set of regressors includes lagged dependent variables. The tests were based on additional regressions, in which each dependent variable is regressed on the same set of variables plus the set of lagged residuals. One rejects the null hypothesis of no autocorrelation (white noise errors) if the set of lagged residuals are different from zero.

The last five rows of Table 1 show the χ^2 statistics for the coefficient of lagged errors in each equation for 1, 2, 4, 6 and 12 lags of the errors. As is evident, the χ^2 values are small, leading us to the acceptance of the hypothesis that the errors of the estimated system are white noise, hence the system is well specified.

TABLE 1

SPECIFICATION TESTS

TEST STATISTIC	EQUATION LFPR	FERT	YOUNGMAR	DIVORCE
F-statistic for twelve leads of SEXRATIO[a]	1.323 (.213)	.688 (.760)	.962 (.488)	1.778 (.581)
LM-test, Chi-square[b]				
H_0: $\rho_1 = 0$	3.303	3.284	.442	1.691
H_0: $\rho_1 = \rho_2 = 0$	2.600	4.116	.622	3.900
H_0: $\rho_1 = \ldots = \rho_4 = 0$	5.065	6.288	2.760	6.716
H_0: $\rho_1 = \ldots = \rho_6 = 0$	7.818	6.630	3.450	8.766
H_0: $\rho_1 = \ldots = \rho_{12} = 0$	13.584	20.400	18.600	9.192

[a]The numbers in parentheses are the marginal significance levels.
[b]The residuals are regressed on the same right-hand side variables and a set of lagged residuals. An F-statistic is computed for the coefficients on the lagged residuals. Multiplying F by the number of autocorrelations in the null hypothesis yields the χ^2 statistic, where the number of autocorrelations in the null hypothesis is the degrees of freedom. The critical values for χ^2 at the .05 level for 1, 2, 4, 6, and 12 degrees of freedom are 3.841, 5.991, 9.488, 12.592, and 21.026 respectively.

BIBLIOGRAPHY

Bartz, Karen and Nye Ivan (1970), "Early Marriage: A Propositional Formulation," *Journal of Marriage and the Family*, **32**: 258–68.

Bauman, Karl E. (1967), "The Relationship Between Age at First Marriage, Schooldropout and Marital Instability: An Analysis of the Glick Effect," *Journal of Marriage and the Family*, Nov 1967, **29**: 672–80.

Becker, Garry (1973), "A Theory of Marriage. Part I," *Journal of Political Economy*, **81**: 813–46.

Becker, Garry, (1973) "A Theory of Marriage. Part II," *Journal of Political Economy*, **82**: S11–S26.

Becker, Gary, Landes Elisabeth and Michael Robert, (1977) "An Economic Analysis of Marital Instability," *Journal of Political Economy*, **85**: 1141–87.

Breush, T.S. (1978) "Testing for Autocorrelation in Dynamic Linear Models." *Australian Economic Papers*, **17**: 334–55.

Bumpass, Larry, L., Sweet, James, A. (1972), "Differentials in Marital Instability: 1970," *American Sociological Review*, Dec, **37**: 754-66.

Carter, Hugh, and Glick Paul C. (1970), *Marriage and Divorce: A Social and Economic Study*, Cambridge: Harvard University Press.

Corman, Hope and Grossman, Michael, (1985) "Determinants of Neonatal Mortality Rates in the U.S." *Journal of Health Economics* **4**: 213–36.

Corman, Hope, Theodore Joyce and Grossman, Michael (1987), "Birth Outcome Production Function in the United States", *Journal of Human Resources*. **22**: 339–60.

Corman, Hope, Joyce Theodore, and Lovitch, Norman (1987), "Crime, Deterrence and the Business Cycle in New York City: A VAR Approach," *Review of Economics and Statistics*. **69**: 695–700.

Corman, Hope and Joyce, Ted (1990) "Urban Crime Control: Violent Crimes in New York City," *Social Science Quarterly*, September 1990.

Cook, Philip, and Zarkin, Gary, (1985), "Crime and the Business Cycle," *Journal of Legal Studies*, **14**: 115–28.

Cover, James and Thistle, Paul (1988), "Time Series, Homicide, and the Deterrent Effect of Capital Punishment," *Southern Economic Journal*, **54**: 615–22.

Eckstein, Z., Schultz, T.P. and Wolpin, K.I. (1985), "Short-run Fluctuations in Fertility and Mortality in pre-industrial Sweden," *European Economic Review* **26**: 295–317.

Ehrlich, Isaac (1975), "The Deterrent Effect of Capital Punishment: A Question of Life and Death," *American Economic Review*, **65**: 397–417.

Glick, Paul, C., and Norton, Arthur, J. (1971), "Frequency, Duration, and Probability of Marriage and Divorce," *Journal of Marriage and Family*, May 1971, **33**: 307–17.

Godfrey, L.G. (1978) "Testing for Higher Order Serial Correlation in Regression Equations When the Regressors Include Lagged Dependent Variables." *Econometrica*, **46**: 1303-10.

Gordon, R.J. and King. S.R. (1982) "The Output Cost of Disinflation in Traditional and Vector Autoregressive Models." *Brookings Papers on Economic Activity*, **1**: 205–42.

Hakkio, Craig, S., and Morris, Charles, S. (1984), "Vector Autoregressions: A User's Guide," *Federal Reserve Bank of Kansas City Research Working Paper*, November 1984, RWP 84–10.

Keeley, Michael, (1977) "The Economics of Family Formation: An Investigation of the Age at first Marriage, *Economic Inquiry*, 238–50.

Keeley, Michael, (1979) "An Analysis of Age Pattern of First Marriage," *International Economic Review*, **20**: 527–44.

Lee, Garry R. (1977), "Age at Marriage and Marital Satisfaction: A Multivariate Analysis with Implications for Marital Stability," *Journal of Marriage and the Family*, August 1977.

Litterman, Robert, B. (1979) "Techniques of Forecasting Using Vector Autoregressions," Working Paper No. 115, Federal Reserve Bank of Minneapolis.

Lütkepohl, Helmut (1982), "Non-causality due to Omitted Variables," *Journal of Econometrics*, **19**: 367–78.

Mocan, Naci, H., (1990), "Business Cycles and Fertility Dynamics in the United States: A Vector Autoregressive Model," *Journal of Population Economics*, Vol. 3: 125–46.

Michael, Robert, T., (1985), "Consequences of the Rise in Female Labor Force Participation Rates: Questions and Probes," *Journal of Labor Economics*, Vol. 3: S117–146.

Schoen, Robert, (1975), "California Divorce Rates by Age at First Marriage and Duration of first Marriage," *Journal of Marriages and the Family*, **37**: 548–55.

Sims, Christopher, A. (1981), "An Autoregressive Index Model for the U.S., 1948–1975," in J. Kmenta and J.B. Ramsey eds., *Large Scale Macro-Economic Models*, New York: North-Holland.

Sims, Christopher, A. (1972), "Money, Income and Causality," *American Economic Review*, 540–52.

Sims, Christopher, A. (1980), "Macroeconomics and Reality." *Econometrica*, **48**: 1-48.

Weed, James, A. (1974), "Age at Marriage as a Factor in State Divorce Rate Differentials," *Demography*, **11**: 361–75.

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FOOTNOTES

[1]See for instance Keeley (1977, 1979), where household production theory and search theory are incorporated to explain the incentives to marry and the determinants of age at first marriage.

[2]The data are obtained from various issues of *National Center for Health Statistics Monthly Vital Statistics Report, Vital Statistics of the U.S., Department of Health, Education and Welfare, Statistical Abstract of the United States* and the Citibase.

[3]We chose not to report the estimated coefficients. The model contains 296 coefficients (74 in each equation). Therefore, it is very difficult to make inferences by them. Also, the individual coefficients may not be very informative due to collinearity in this kind of heavily parameterized model (Corman et al.). The outputs of model (1), however, are available from the author upon request. After estimating the VAR model in (1), it is converted into a linear combination of the innovations. The impulse responses are based upon the moving average representation of the following form:

$$Y_{i,t} = \sum_{j=1}^{4} \sum_{s=0}^{\infty} \theta_{i,j,s}\, u_{j,t-s}, \quad i = 1, \ldots, 4,$$

where $u_{(\cdot)}$ stands for the error term and $\theta_{(\cdot)}$ represents the moving average coefficients.

[4]For details, see Gordon and King (1982), Sims (1980), and Litterman (1979).

[5]The imposition of a causal ordering among the contemporaneous innovations only matters when their correlations are substantial. Consider Fisher's z-transformation. $z = \ln[(1+r)/(1-r)]$, where r is the sample correlation. The statistic $n^{1/2}z$ is distributed approximately N(0,1) in large samples, where n is the degrees of freedom for the least squares residuals. In our case with n = 190, a correlation must exceed .07 in absolute value to be significantly different from zero. This was only the case with the correlations between YOUNGMAR and FERT, and YOUNGMAR and DIVORCE, where the correlations were –.17 and –.09 respectively. The alternative causal orderings for these variables did not change the results in any significant way; neither quantitatively, nor qualitatively. In particular, no ordering did generate different results from the one without a causal ordering.

[6]This is the modified Chi-square proposed by Sims (1980, footnote 18).

[7]The Durbin-Watson statistic is not appropriate when the specification includes a lagged dependent variable; nor strictly speaking is the Box-Pierce Q-statistic. The LM statistic provides a general test for autocorrelation of errors, when regressors include lagged dependent variables (Breush 1978, Godfrey 1978).