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CAUSATION AMONG SOCIOECONOMIC TIME SERIES

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ABSTRACT

Using annual U. S. time series data from 1950-1974, formal tests of causation are performed among three socioeconomic phenomena: women's labor force participation rates, fertility rates, and divorce rates. Box-Jenkins and other techniques are employed with Granger-Sims type definition of causation based on leads and lags.

Women's labor force participation appears to be causally prior to both fertility and divorce; the direction of effect on fertility is negative and on divorce, positive. Additional tests with alternative definitions of variables and a longer (1924-1974) time span also exhibit causal influence from fertility to divorce (with no feedback). When per capita income is also tested for causal influence, it, too, appears causally prior to fertility and divorce.

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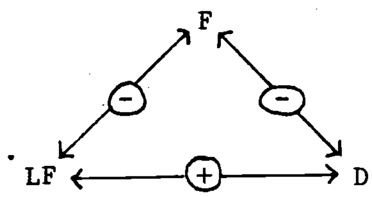
This paper addresses the question of causation among three socio-economic phenomena, fertility, divorce and women's labor force participation, in the U.S. during the post-World War II era. Section I discusses the hypothesized relationships among the three; Section II discusses the notion of causation and recently developed macro-economic time series techniques for identifying causation using rather sophisticated methods of studying leads and lags. Section III reports findings using these techniques, and Section IV extends the investigation to include the causal relationships between these three socioeconomic variables and income. Section V is a brief summary.

I. Behavioral Patterns

Over the past thirty years in the U.S. profound changes have occurred in several dimensions of family life including fertility, divorce, and women's labor force behavior. These interrelated changes are discussed in several disciplines that offer broadly similar explanations, and these explanations accord with the layman's armchair analysis.[1] Thus from an analytical point of view the decline in fertility since the late 1950's, the rise in women's LFPR, and the rise in divorce rates in recent years seem to fit together rather well. If one of these series was justifiably viewed as causally prior, it would be relatively easy to understand why the others behaved as they did. But which might be the prime mover?

The existing literature suggests considerable simultaneous causation among these three aspects of socioeconomic behavior. Relying on a single recent volume of papers (Schultz (1974)). plus one article on divorce behavior (Becker, Landes, Michael (1977)), we are told that:



That is, fertility (F) and women's labor force participation rates (LF) are expected to be mutually causal and negatively related, F and divorce rates (D) are expected to be mutually causal and negatively related, while LF and D are also expected to be mutually causal and positively related. In empirical studies, however, one finds few attempts to investigate interdependence among these three dimensions of behavior. Some researchers select one as a dependent variable using others as "exogenous" influences, while other researchers employ the same basic variables with causal links assumed to be reversed. Indeed, the list of those who have themselves "run the regression" both ways is not unimpressive.

The best strategy for studying these interrelated phenomena is debatable. One strategy would be to estimate a system of simultaneous equations representing quasi-structural relationships. There are many fundamental causes of the change in fertility, women's labor force and divorce behavior suggested in the literature, including improved labor market opportunities for women due in part to a shift toward services in the composition of output; rise in real income; growth of social (i.e. governmental) provision of various services including old age insurance, medical care, child care, et cetera; growing acceptance of personal freedoms including sexual freedom (prompted in part by medical technology in fertility control); et cetera. These and other social and technical forces have surely affected socioeconomic behavior, but research on several of these separate structural equations has not progressed very far as yet, so this strategy does not appear most fruitful at this time. Development of rigorous life cycle models of these interdependent socio-economic decisions represent another research strategy, but these models of so many decisions become practically intractable.

Consequently, the strategy adopted here is a less demanding one. Using techniques developed recently for use in judging causation among macro-economic series (e.g., see Sims (1972)), pairwise tests of causation are performed among several post-war annual time series. Regarding these tests, recent literature suggests that there has developed general agreement about an appropriate definition of causality which can be implemented empirically, but that there is less consensus about the appropriate procedure for making it operational (see the Pierce-Granger-Sims JASA Exchange, 1977, and see Hsiao (1977)). This is the first attempt of which I am aware to apply these time series techniques to the area of economics of human behavior.

II. The Notion of Causation

The concept of causation used here is that proposed by Granger (1969) and Sims (1972) and essentially involves predictability: given two time series X_t and Y_t, Y is said to cause X if the prediction of X_t conditional on X_{t-i} is improved by using information about Y_{t-i}.

Sims (1972) has shown that causation can be inferred, using a linear prediction equation, by regressing a suitably transformed (stationary) series of X on the past and future values of a stationary series of Y. If future values of Y, Y_{t+i}, are as a group statistically related to X_t (as judged by a partial F-test on the set of Y_{t+i}, $i=1\cdots n$) then X is said to cause Y. This evidence of feedback causation from X to Y is based on the logic that future values of Y could not have caused a change in current values of X. (Of course, it is possible that expectations of Y_{t+i} based on information available at time t but not yet incorporated in Y_t itself have affected X_t.)

This procedure for establishing causation is essentially definitional. If lead-values of Y are statistically related to X in a regression on a detrended, covariance stationary series with no serial correlation in the regression's residuals, then X causes Y. The causation test from X to Y using feedback from X_t to Y_{t+i} involves the logic of inferring causation from the sequence of leads and lags. Concluding from these tests that X causes Y does not imply X is the sole cause of Y or even that it has a quantitatively large influence on Y; it implies only that evidence is observed of a statistically significant causal link from X to Y.

Procedurally the issue becomes how best to produce stationary series in X and Y that yield linear regressions with no serial correlation in the residual. One relatively extreme procedure employs the time series techniques of Box-Jenkins (1976) applied to each series separately. That is, assume the series X is generated by a discrete linear stochastic process which, when estimated, can be removed from the series X yielding a series X^s which is a white noise series (i.e. a series of identically and independently distributed random variables with mean zero and variance σ^2). The series X is

$$X_t = k + \sum_{i=1}^{n} \phi_i X_{t-i} + X_t^s. \tag{1}$$

So in principle, by estimating k and ϕ_i, the series of random--unanticipated or unpredicted--shocks X^s can be calculated. Box-Jenkins procedures employ maximum likelihood estimators of ϕ_i. The same type of relationships can be estimated, independently, for the series Y, yielding Y^s. Using the filtered series X^s and Y^s, one can perform tests of causation by regressing

$$X_t^s = a + \sum_{i=-n}^{m} b_i Y_{t+i}^s + u_t. \tag{2}$$

The F-test on the set of coefficients b_i for $i = +1, +2, \ldots m$ constitutes the test of feedback causation from X to Y. This is one of the tests used below. This Box-Jenkins method of filtering the initial series X and Y has been employed in test of causation among a number of monetary variables (see Pierce (1977)). However, it has been criticized, by e.g. Sims (1977), as containing a bias in favor of the null hypothesis of no causation (this is further discussed below).

A second filtering procedure applies a single, predetermined filter to both the X and Y series to whiten them. The filter $(1-0.75L)^2$ for lag operator L is used here as elsewhere. That filter is intended also to produce whitened series $X^{s'}$ and $Y^{s'}$ which can be used to estimate equation (2) yielding another test of the feedback causation from X to Y. By running equation (2) reversing the X and Y series, an analogous test of causation from Y to X can be made using either the Box-Jenkins-filtered series or the single-filtered series.

A third method of performing this test involves a somewhat different procedure, appealing in terms of its intuitive nature. One regresses the original series X on lagged values of itself and lagged values of Y and uses the F-test on the lagged Y as the direct test of causation from Y to X. That is, regress

$$X_t = \alpha + \sum_{i=1}^{n} \beta_i X_{t-i} + \sum_{i=1}^{m} \lambda_i Y_{t-i} + e_t \tag{3}$$

and use the partial F-test on the set of coefficients λ_i as the test of causation from Y to X.[2] A comparable regression interchanging X and Y can be used to test for causation from X to Y, using the set β'_i:

$$Y_t = \alpha' + \sum_{i=1}^{n} \beta'_i X_{t-i} + \sum_{i=1}^{m} \gamma'_i Y_{t-i} + \varepsilon_t. \tag{4}$$

The pair of equations (3) and (4) constitutes a simultaneous system in X and Y which can be estimated as "seemingly unrelated" equations. The important issue for the F-test is that each of the error terms be serially uncorrelated.

III. Findings

LF, F and D: 1950-1974. The following three annual time series for the post-war period are studied:

F: fertility: the annual number of births per 1000 women aged 14-44; $\mu = 108.0$, $\sigma = 12.0$

LF: labor force participation rate of women, defined for women with spouse present and with children under the age of six; $\mu = 20.1$, $\sigma = 6.2$

D: divorce rate: the annual number of divorces and annulments per 1000 married couples; $\mu = 11.5$, $\sigma = 3.1$

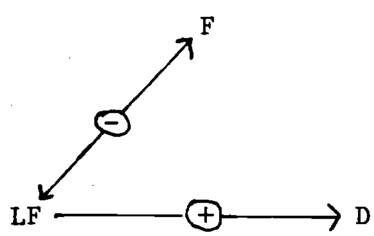
Using these three series, all six possible directions of causation are tested using each of the three filtering procedures just described: the Box-Jenkins or ARIMA filter, the single filter $(1-0.75L)^2$, and the simultaneous system approach. For the first two procedures a first-stage filtering is performed on each series and then equation (2) is estimated for all six permutations of the pairs of three variables and the partial F-test on the lead values of Y_{t+1}, Y_{t+2} and Y_{t+3} is used as the test of causation on X and Y. In the third filtering procedure equation (3) is estimated on the original X and Y series and the partial F-test on Y_{t-1}, Y_{t-2}, Y_{t-3} from the regression on X_t is used as the test of causation from Y to X.

The Box-Jenkins first-stage estimation of each series' ARIMA structure is shown in Table 1. Panel A shows the autocorrelations while Panel B indicates the estimated structures and related diagnostics.[3] Table 2 col. (1) reports the relevant tests of causation among these ARIMA-filtered series. Only two of the six pair-wise relationships exhibit causation (at 90% level of confidence). Four of the tests do not reject the null hypothesis of no causation; we can say that the labor force series "causes" the divorce series, and that the fertility series "causes" the labor force series. Finding relatively few causal relationships is quantitatively not unlike Pierce's (1977) results for various monetary series. It is also not inconsistent with Granger's contention that, "The empirical fact [is] that weak relationships will often be found in economics when a sound method of analysis is applied" (Granger, 1977, p. 23). However, Sims' point about downward bias in these tests suggests that other filtering schemes besides the Box-Jenkins procedure should be investigated. The single-filter approach yielded even weaker results as shown in Table 2 col. (3) -- none of the pairs of variables exhibited a statistically significant relationship.[4]

The tests of causation from the simultaneous system of equations, shown in col. (5) of Table 2, yield a different picture: three of these estimated causal links are significant at conventional levels of confidence.[5] LF appears to cause both the divorce and fertility series (at

α = .05) and there is less statistically significant evidence (α = .10) of causation from fertility to labor force participation rates of women.

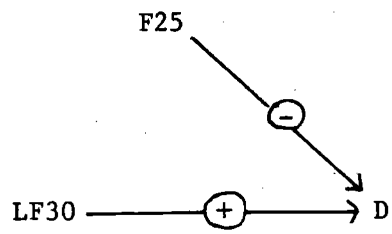
Using the estimated two-equation relationship between LF and D, a one-unit increase in LF_t raises divorce by, say, year t+3 by 0.24; a one-unit increase in LF_t lowers fertility by year t+3 by -1.41 while the causation from F to LF implies that a one-unit increase in F_t lowers LF by t+3 by only -0.09. If we convert these three-year duration effects into quasi-elasticities as $(\Delta X_{t+3}/\Delta Y_t)(\overline{Y}/\overline{X})$ for $\Delta Y_t = 1.0$, those elasticities are $\varepsilon_{D,LF} = 0.42$; $\varepsilon_{F,LF} = -0.26$, and $\varepsilon_{LF,F} = -0.50$. (Alternatively, the unitless measure $(\Delta X_{t+3}/\Delta Y_t)\ \sigma(Y)/\sigma(X) = \beta$ is $\beta_{D,LF} = 0.48$, $\beta_{F,LF} = -0.73$ and $\beta_{LF,F} = -0.18$.) In summary, the directions of causation are found to be:



Extensions: Age specific F and LF series, and a longer time period. Two additional relationships have been investigated to provide some further check on these results. One uses age-specific series for LF and F over the same twenty-five year time period (1950-1974), the other extends the estimation where possible to a fifty year period (1924-1974). The LFPR of married women aged 25-34, LF30, is available in the post-war period (note that this variable does not control for age of or presence of children). Also available (for a longer time-span) is age-specific fertility, F25, the number of children ever born to women age 25 (from Heuser

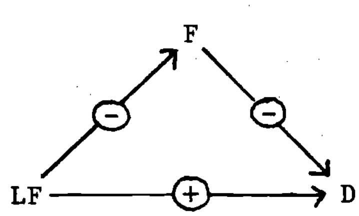
(1976)). The variable F25 is an age-specific stock-fertility measure while the variable used above, F, is a flow measure defined over all ages of women.[6] Given that F25 is a stock measure at age 25 while LF30 is a flow measure of labor force attachment of women 25-34 it seems reasonable to expect F25 $\rightarrow$ LF30 but rather unlikely that LF30 $\rightarrow$ F25 (of course, a scenario with anticipations of future labor force attachment affecting current fertility is possible). Regarding the divorce series, no age-specific series is available for the whole post-war period; a series has been constructed for 1960-1970 for women 25-29 and for that decade the age-specific series is highly correlated with the total divorce rate series D (correlation = 0.95). So the series D will be assumed to be an adequate proxy for a divorce rate for women in their late 20's, and thus D is investigated together with LF30 and F25.

Table 3, Panel A shows the results of the F-tests for pairs of these three series, LF30, F25, and D estimated from the two equation system. Again the labor force series appears to "cause" changes in the D series: the coefficients on this statistically significant relationship imply that a one-unit increase in $LF30_t$ raises D_{t+3} by +0.13. However, LF30 does not appear to cause changes in the F25 series; that is what we should expect, as indicated in the preceding paragraph. There is evidence of causation from the stock of fertility, F25, to the divorce rate, while no such causation was found using the flow measure of fertility, F. (Here a 0.1 increase in $F25_t$ lowers D_{t+3} by -0.14.) The most puzzling result in this set of tests is the lack of causation from F25 to LF30. It seems reasonable that changes in the stock of fertility to 25-year-old women might be causally linked to the subsequent changes in LFPR of women 25-34. The test does not provide support for that hypothesis. In summary:



The variables D, F and F25 are available as annual time series over the fifty year period 1924-1974. Panel B of Table 3 shows the comparable results for the two-equation systems estimated over this time span. (As the degrees of freedom are larger in these regressions I experimented with six-year lags on F and F25 as well as the usual three-year lags.) Flow fertility, F, and D appear to be causally linked with the statistically stronger relationship running from F to D (a one-unit increase in F_t lowers D_{t+3} by -0.11; while a one-unit increase in D_t is estimated to raise F_{t+3} by the tiny amount +0.35 (on a mean of 108.0)). Whereas the stock fertility measure F25 did show causality in the short time period (see Panel A), it did not do so in the fifty-year period with the three-year lag; only when the six-year lags were included did evidence of causation from F25 to D emerge.

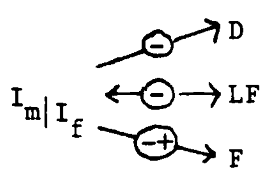
To recap, regarding the six hypothesized directions of causation suggested on page 2, at a 95 percent level of confidence we find evidence that LF $\xrightarrow{+}$ D, both using LF and LF30; LF $\xrightarrow{-}$ F but not so using the age-specific variables; and we find F $\xrightarrow{-}$ D when we use F25 and when we consider a fifty-year time span. Diagrammatically,

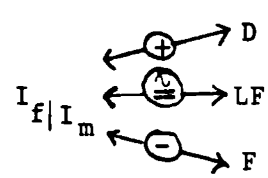


Only at a lower level of confidence (α = .10) do we observe any feedback effect of $F \xrightarrow{-} LF$ (and an anomalous weak positive effect of D on F in the fifty-year period).

IV. The Effect of Income

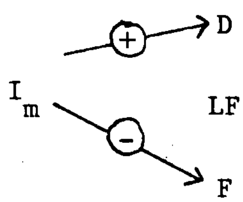
As an extension of the procedures employed above, income is added to the set of variables and causal links between income and each of the three socioeconomic variables D, LF, and F are investigated. At the risk of considerable over-simplification of the existing literature, the following diagram suggests the directions of effects typically hypothesized in the literature regarding men's income, I_m, holding women's income (or wage rates) fixed ($I_m | I_f$) and the hypothesized effects of women's income, holding men's income fixed ($I_f | I_m$)

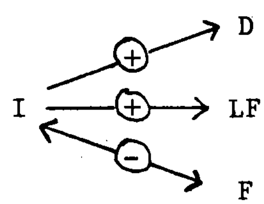




That is, men's income is expected to be negatively related to divorce rates as cross-sectional evidence suggests. The positive income elasticity of leisure accounts for the negative relationship between I_m and LFPR of women, and for various reasons (see either Willis (page 40) or Becker-Lewis (p. 83) in Schultz (1974)), the observed effect of I_m on F may be negative even though the "true" income elasticity for children is expected to be positive. The effects for I_f simply reflect the hypothesized effects for LF which were discussed above.

Two measures of annual income are used here: I_m is defined as median real income of men age 14 and over and I is defined as real per capita income.[7] While I_m is a reasonably adequate measure of men's income, I is not a measure of I_f. Instead changes in I reflect both changes in men's income and changes in I_f and additionally, I is inversely affected by changes in fertility. Moreover, while the relationships diagrammed in the previous paragraph are partial effects, the results to which we now turn do not "hold constant" the other source of income. Table 4 shows the tests of causation between each pair of variables using both I and I_m as a measure of income.[8] The findings are summarized as follows:





The results for I do in fact generally mirror the results reported above for LF in terms of the effects on D and F, although the reverse effect of F on I may be reflecting the definitional relationship between a decline in fertility and consequent rise in per capita income rather than any behavioral relationship from fewer children to increased labor market activity by women (the effect is small in any case). The comparison of results for I and I_m are interesting: although I_m exhibits a positive and significant effect on D, the effect is far smaller than that of I. If I_m were tested holding I_f or LF constant, one might expect that significant positive effect to disappear. In fact that is what is found: extending these tests of causation to test $I \overset{?}{\rightarrow} D|_{D,LF}$ $LF \overset{?}{\rightarrow} D|_{D,I}$ and similarly for I_m in place of I, none of the four F-tests is statistically significant. While LF and I have strong positive effects on D, and I_m has a much smaller, positive effect on D, none of the partial effects is significant.[9]

Summary

The causation tests performed here are neutral with respect to which series might have exhibited causally prior influence on the other series. The results suggest that income--measured as either real per capita disposable income, I, or real median income of adult men, I_m,--is an important causally prior force affecting the divorce rate and fertility behavior. Likewise the LFPR of married women (with spouse and young children present) is causally prior to the divorce rate and fertility, at a 95 percent level of confidence. There is not a discernible degree of feedback causation from divorce to either income or LFPR (of married women) nor from fertility to men's income. There is evidence at a 90 percent level of confidence of causation from fertility to married women's LFPR and to I, a measure of per capita income which includes the income of women. The relationship from fertility to LFPR was, surprisingly, not confirmed when a measure of stock fertility was used but stock fertility (total number of children born per woman aged 25) did appear to have a causal effect on divorce.

Regarding the relationship between LFPR and fertility, the results suggest that when aggregate flow measures are used, the causation from women's LFPR to fertility is strong and negative while the reverse causation is present, negative but quite weak. A similar conclusion was reached in a recent sociological study using young women's stated intentions about their completed-fertility and their planned labor force participation at a later age (age 35).[10] Regarding divorce and fertility no causal influence is seen in the post-war period when flow measures are used, but when a stock measure of fertility (to young women, age 25) is used instead, causation from fertility to divorce is found.

Although income and labor force participation rates of married women appear to be causally prior to fertility and divorce, neither has a statistically significant partial effect when the other is controlled for. It appears that the behavior of phenomena which are the more traditional areas of concern to economists--income and labor market changes--influence socioeconomic phenomena such as fertility and divorce more than vice versa, based on tests using a short-run lag in the post-World War II era. The investigation reported here does not, obviously, address the issue of much longer run feedback (as for example the effect of cohort size on wages).

Many limitations in the analysis performed here seem quite apparent. (1) The results appear to be sensitive to the filtering process employed, but the weak results using Box-Jenkins are not quantitatively different among this set of socioeconomic variables than is found in the mini-growth industry of estimating causal relationships among macro-economic time series. The results are also sensitive to the particular measure used of, say, income or fertility, but that is neither surprising nor intellectually troublesome. The results using the third estimation scheme seem to be consistent with what might be expected when one measure or another of, say, fertility is used. (2) Another issue is that the relationships estimated here are not structural in any sense. From the few checks which have been made the estimated equations do not exhibit a dampening effect over time of an initial shock from one series. However, the directions of effects are as expected: an increase in LFPR, for example, raises the divorce rate and lowers fertility; a rise in fertility lowers LFPR; a rise in income per capita (dominated by the rise in women's income) raises divorce while a rise in men's income (which is correlated with the rise in women's income) raises divorce but by much less.

(3) The tests of causation performed here involve essentially leads and lags. But there are differences among these time series phenomena in the inherent lags between a behavioral decision and its evidence in the measured variable. For example, if at the same moment in time an individual decided to enter the labor force, bear a child, and divorce (an unlikely event, but useful for illustration here), those events would not show up as contemporaneous events in the measured statistics: the decision at $t = 0$ would likely be observed in LF_0, F_1, and, depending upon the complications of the relevant divorce laws, in D_1 or D_2. So the natural leads and lags in the measured series confound the interpretations of causation.

Finally, the set of four variables chosen for analysis here is surely no more than a very partial set of the variables one might want to include--marriage, remarriage, schooling and migration behavior and unemployment rates seem likely candidates to incorporate. The analysis to date may, however, serve to illustrate that the time series techniques used with increasing frequency in another area can be as fruitfully applied to time series in sociological economics as in traditional macroeconomics.

Table 1: Estimated ARIMA structures for four socioeconomic time series; post-war period

Panel A: Autocorrelations; lags 1 through 5 years

Variable	Autocorrelation					Partial Autocorrelation					Range
	1	2	3	4	5	1	2	3	4	5	
Divorce Rate	0.84*	0.68*	0.52*	0.37	0.23	0.84*	-0.09	-0.07	-0.07	-0.11	1950-74
Fertility	0.86*	0.71*	0.60*	0.50*	0.42*	0.86*	-0.11	0.06	-0.02	-0.02	1945-74
LFPR	0.87*	0.75*	0.65*	0.56*	0.44*	0.87*	-0.04	0.02	-0.01	-0.15	1948-74
Income	0.86*	0.73*	0.63*	0.52*	0.38	0.86*	-0.02	0.03	-0.07	-0.19	1950-74

*Implies correlation greater than two times its estimated standard error.

Panel B: ARIMA structures

Variable	ARIMA Structure	α	ϕ	θ	R^2	F	σ_i^2	χ^2
Divorce Rate	211	0.008 (0.56)	0.543 0.508 (2.07) (1.89)	0.327 (1.06)	0.67	13.3*	0.13	12.1†
Fertility	011	-0.459 (-0.35)		-0.631 (-4.49)	0.30	11.7*	19.2	5.4†
LFPR	011	0.895 (8.83)		0.414 (2.01)	0.08	2.11	0.72	7.9†
Income	100	0.088 (2.22)	0.966 (65.2)		0.96	498.0*	0.008	8.7†

*Implies the relationship is statistically significant at $\alpha = 0.05$.
†The null hypothesis (no serial correlation) is accepted at $\alpha = 0.05$.
The general form of the relationship is:

$$\Delta^d X_t = \alpha + \phi_1 \Delta^d X_{t-1} + \cdots + \phi_p \Delta^d X_{t-p} - \theta_1 u_{t-1} - \cdots - \theta_q u_{t-q} + u_t$$

where the ARIMA structure (pdq) defines the values of the indices (e.g., 011 has no ϕ's, a first-order difference and one θ_1: $(X_t - X_{t-1}) = \alpha - \theta_1(u_{t-1}) + u_t$).

Table 2: Tests of causation (F-tests) on pairs of variables, by three filtering schemes.

Test of Causation	ARIMA Filter F	ARIMA Filter (dep. var.; range)	Single Filter F	Single Filter (dep. var.; range)	Simultaneou System (Range = 1951 F
	(1)	(2)	(3)	(4)	(5)
LF → D	4.70**	(LF; 54-71)	0.35	(LF; 53-71)	6.02***
F → D	0.61	(F; 54-71)	1.95	(F; 50-71)	2.03
D → LF	0.31	(D; 52-71)	1.08	(D; 53-71)	0.89
F → LF	2.65*	(F; 52-71)	2.33	(F; 53-71)	2.70*
D → F	1.38	(D; 51-71)	2.42	(D; 50-71)	0.52
LF → F	0.28	(LF; 52-71)	0.14	(LF; 53-71)	4.30**

*, **, *** F-test significant at α = .10, .05, and .01.

Table 3: Additional tests of causation using age-specific series and using a fifty-year time span

Test of Causation	F-test
Panel A: Age-specific series: F25, LF30, and D, for 1951-1974	
LF30 → D	6.73***
F25 → D	7.79***
D → LF30	2.02
F25 → LF30	1.26
D → F25	1.48
LF30 → F25	0.66
Panel B: Fifty-year time span; annual series from 1924-1974 for F, F25, and D	
3-year lags	
F → D	10.30***
F25 → D	0.21
D → F	2.75*
D → F25	1.25
6-year lags	
F → D	5.72***
F25 → D	2.58**

*, **, *** implies F-test significant at α=.10, .05, or .01.

Table 4: Causation tests using two alternative definitions of income; implied effects; simultaneous two-equation systems; 1951-1974

	F-test		Implied effect of $\Delta Y_t \rightarrow X_{t+3}$	
Causation test	I	I_m	$\Delta I=0.1$	$\Delta I_m=0.1$
Income → D	4.07**	3.78**	+0.21	+0.08
Income → LF	3.33**	1.92	+0.75	---
Income → F	3.62**	5.37**	-1.43	-0.56
D → Income	1.22	1.33	---	---
LF → Income	1.81	1.12	---	---
			$\Delta F=1.0$	
F → Income	2.70*	0.76	-0.01	---

*, ** implies F-test significant at α = .10, or .05.

Footnotes

1. For example, see Bane (1976), Bronfenbrenner (1974), Easterlin, Wachter and Wachter (1977), Kobrin (1976), Ross, Sawhill (1975), Ryder (1974), et. al. The generally positive relationship between women's labor force participation rate and the divorce rate is explained in terms of the greater independence provided women by improved labor market opportunities, an independence which lowers the attractiveness of marriage and thus encourages divorce. Alternatively, the growing acceptance of divorce increases its likelihood which induces women to secure for themselves market careers that lower their dependence on their spouses.

   Likewise, the negative relationship between fertility and labor force participation rates of women is explained in terms of the higher value of women's time caused by improved labor market opportunities for women. This higher value of time in the labor market has induced women to substitute more of their time toward market activities and away from child rearing.

2. Equation (1) can be written for X_t, Y_{t-1}, Y_{t-2}, and Y_{t-3} with intercepts k_x and k_y and slope coefficients ϕ_i^x and ϕ_i^y, for n=3 in all cases. Then writing equation (2) with the summation over the periods t-3, t-2, an t-1 for testing causation from $\underline{Y}$ to X, we can substitute into equation (2) for the terms X_t^S, Y_{t-1}^S, Y_{t-2}^S, Y_{t-3}^S from equation (1) yielding the form of equation (3) with

   $\alpha = a + k_x - k_y(b_1 + b_2 + b_3)$; $\beta_i = \phi_i^x$; $\gamma_1 = b_1$; $\gamma_2 = b_2 - b_1\phi_1^y$;

   $\gamma_3 = (b_3 - b_2\phi_1^y - b_1\phi_2^y)$; $\gamma_4 = -(b_1\phi_3^y + b_2\phi_2^y + b_3\phi_1^y)$;

   $\gamma_5 = -(b_2\phi_3^y + b_3\phi_2^y)$; $\gamma_6 = -b_3\phi_3^y$. Here Sims' point about the downward bias imposed by the Box-Jenkins filtering is clear--that filtering estimates the ϕ's first and then in a second stage, estimates the b's, yielding generally biased estimates of the b's (see Sims (1977), p. 24).

3. For convenience Table 1 includes the Box-Jenkins analysis of the income series described and used in the following section.

   Regarding the interpretation of Table 1, the fertility series for example is characterized as a first-difference, first-order moving average process, $(F_t - F_{t-1}) = -0.459 + 0.631u_{t-1} + u_t$ with the residual series as white noise when judged by the Box and Pierce χ^2 test. Each of the residual series from Table 1 can be considered serially uncorrelated through at least a lag of 12 years.

   As the implementation of this empirical technique is seemingly as much art as science, I am not certain that the ARIMA structure used here is precisely that which another practitioner would adopt. However, some comparisons of the resulting residual series have convinced me that the use of another, similar ARIMA structure would not have appreciably affected the results--for example, for the divorce rate series, the simple correlations of the whitened series from an ARIMA (111) or ARIMA (212) with the series used here are 0.93 and 0.99 respectively and they are intercorrelated at the level of 0.96.

4. After filtering the series, serial correlation coefficients r for lags of 1, 2 and 3 were computed and the Box-Pierce Chi-squared test of significance,

$$N \sum_{t=1}^{3} r_t^2 = \chi^2$$

with N = number of observations, e.g. years, and degree of freedom k-p (=3 lags minus 2 parameters = 1) was calculated. The χ^2 value for divorce, fertility, and labor force respectively were 2.87, 0.73, and 9.58 with $\chi_1^2(\alpha = 0.05) = 3.84$; so the labor force series showed significant serial correlation remaining in the first three lags.

5. In order to estimate equation (3), one must remove the correlation between X_{t-1} and e_t which exists if there is autocorrelation in the residuals. This is done by the use of instrumental variables. A four-equation scheme is employed. First, instruments for each of the three variables D, LF, and F were obtained by regression of each separately on a set of auxiliary variables: marriage duration, unemployment, a measure of women's education level and a proxy for the available contraceptive technology. These regressions, run on annual data from 1947 or 1948 to 1974 had $\bar{R}^2$'s of around .90 and yielded instruments for each year for $\hat{D}$, $\hat{LF}$, and $\hat{F}$.

Second, the regression of interest is estimated employing the instruments in place of the stochastic LHS-lagged regressors, e.g., $D_t = f(\hat{D}_{t-1}, \hat{D}_{t-2}, \hat{D}_{t-3}, F_{t-1}, F_{t-2}, F_{t-3}) + e_t$. Third, the residuals e_t were used to estimate the first-order autocorrelation by regressing $e_t = a + b\,e_{t-1} + u_t$ where $b = \hat{\rho}$. Then a modified first difference equation was estimated, $(D_t - \hat{\rho}D_{t-1}) = f(D_{t-1} - \hat{\rho}D_{t-2}), \cdots, (F_{t-1} - \hat{\rho}F_{t-2}), \cdots + \varepsilon_t$.

6. The simple correlation between F and F25 for the period 1924-1974 is .615. The age-specific annual time series for 1950-1974 are:

F25: children ever born to women age 25; $\mu = 1.44$, $\sigma = 0.20$.

LF30: LFPR of women age 25-34; $\mu = 39.8$, $\sigma = 5.9$.

The annual time series for 1924-1974 include:

D: $\mu = 10.3$, $\sigma = 3.1$

F: $\mu = 96.5$, $\sigma = 16.0$

F25: $\mu = 1.21$, $\sigma = 0.26$

7. The simple correlation in the post-war period between I and I_m is 0.98. The mean and standard deviation of I and I_m are respectively: $\mu = 2.57$, $\sigma = 0.43$; and $\mu = 4.89$, $\sigma = 0.77$.

8. The Box-Jenkins and single-filter procedures were also applied to I, although these results are not shown in Table 4. Neither procedure showed causation from I to any of the three socioeconomic variables. The only significant F-test was the test on feedback from fertility to income: the Box-Jenkins filter yielded an F-statistic of 3.30, significant at $\alpha = .10$. This same weak effect is exhibited in Table 4 using the other procedure.

9. In these tests equation (3) is estimated in an expanded form where D is regressed on D, LF and I (or on D, LF and I_m), all lagged three years; the partial F-tests for LF and I are then computed. The results were as follows:

Test	F-test
$LF \overset{?}{\rightarrow} D\|_{D,I}$	1.75
$I \overset{?}{\rightarrow} D\|_{D,LF}$	0.68
$LF \overset{?}{\rightarrow} D\|_{D,I_m}$	1.38
$I_m \overset{?}{\rightarrow} D\|_{D,LF}$	0.22

The critical value of F at $\alpha = .10$ is 2.52 so none of these partial effects is statistically significant. Thus while we can say that I, I_m, or LF "causes" D, the interpretation of that finding is in doubt. It appears that the causally prior variable represents some causally prior force but either I, I_m or LF reflects that force as well as the other. So we have not identified in the laymen's sense what "causes" divorce, we have only identified three separate series which are independently causally prior.

10. Waite and Stolzenberg (1976) use the young women's National Longitudinal Survey data to estimate a simultaneous equations model and found planned LFPR a relatively strong influence on planned fertility (plans to be in the labor force lowered planned fertility by 0.8 children (on a mean of 2.4 children)) while the reverse relationship was statistically significant but quite small (plans for one more child lowered the implicit probability of planned LFPR by only 3.2 percentage points (on a mean of 48. percent).

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