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Demographic transition and economic growth: Empirical evidence from Greece

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Abstract. Over the past decades, due to a combination of declining fertility rates and rising life expectancies, most industrialized countries have experienced aging populations and low numbers of young populations that may pose economic problems in the future. This paper investigates the relationship first between fertility rate and infant mortality rate and second among demographic changes, real wages and real output in Greece over the period 1960–96. When we control for fluctuations in overall economic activity and the labor market on the bivariate relationship between fertility and mortality rates, the evidence suggests that Granger-causation must exist in at least one direction. The results show that in the long run a decrease in infant mortality rates, taking into consideration economic performance and the labor market, causes a reduction in fertility rates. Also, employing the vector error-correction models, the variance decomposition analysis and the impulse response functions, the empirical results support the endogeneity of fertility choice to infant mortality, the labor market and the growth process.

JEL classification: I12, J13, C22

Key words: Fertility, infant mortality, VECM

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1. Introduction

Most countries, industrialized or not, experience important demographic changes, one of the most important of which is the transition from a phase of rapid population growth to one in which population growth is low. Initially, a country experiences a mortality decline and fertility rises, both contributing to a rise in population growth. With some time lag, the reduction in mortality triggers a steady and continuous decline in fertility. This pattern is called the "demographic transition", as earlier formulated by Notestein (1945).

While the transition theory lies at the center of modern scientific demography, economists have made few attempts to understand the causal links that generate the demographic transition. Demographers such as Kirk (1996) and Van de Kaa (1996) have summarized the theories, seeking to give a causal explanation of the demographic transition. Independent of demography theory, the study of fertility has long been studied from the perspective of economics research. The debate between followers of Malthusian theory and neoclassical economists shows the crucial link between fertility, mortality and economic growth. However, the modern economic theory of population emphasizes the interdependence between infant mortality and fertility in the context of economic theories of behavior (Sah 1991; Cigno 1998). Recently, the study of changes in fertility has been recognized as an important correlate of economic growth and has received considerable attention.

Becker (1960, 1973) in his pioneer studies supports the notion that fertility is a variable endogenous to the economic system and develops a theoretical framework explaining that the relationship between fertility and economic growth depends on a number of socioeconomic factors such as the incentive for having children, the "quality of children", the efficiency of private capital markets and intergenerational transfers within the family. Recently many economists such as Becker (1988, 1992), Becker and Barro (1988), Barro and Becker (1989), Ehrlich (1990), Becker et al. (1990), Ehrlich and Lui (1991), and Wang et al. (1994), based on the microfoundations of economic theory, treat both population and income growth as endogenous variables in an effort to develop a coherent model of economic growth and explain the process of dynamic economic growth.

The major trend in the literature today is the development of theoretical dynamic models which treat population growth and development as simultaneously determined endogenous variables, rather than as the separate outcomes of different economic systems. Over the last two decades, most of the work on endogenous population and economic growth has been theoretical. Only a few empirical studies, Yamada (1985), Ehrlich and Lui (1991), Wang et al. (1994), have examined the effects of population growth and fertility on economic growth, mainly for the U.S.A. However, there is only limited empirical evidence for other industrialized countries of Western Europe and some developing countries (Yamada 1985; Winegarden and Wheeler 1992; Brander and Dowrick 1994; Barlow 1994).

It is thus of interest to examine whether the conclusions drawn on factors affecting demographic changes and economic growth could be applied to other medium-sized countries like Greece. Greece represents a reasonably large country, and its demographic developments closely resemble the general trend in most OECD countries, that is decreasing fertility and infant mortality rates (Fig. 1) and the conclusions drawn could be indicative of the situation in other medium-sized countries.

Finally, most of the previous studies suffer from methodological shortcomings. They do not explicitly count for all factors affecting demographic change; that is declining fertility and infant mortality rates matched with the performance of the labor market and overall economic activity. In addition, some studies have applied the standard Granger-Sims methodology, but have not studied the time-series properties of the data used in the analysis, or have not investigated for the presence of a long-run relationship among the variables (Yamada 1985; Simon 1989; Barlow 1994). Furthermore, the various views on the relationship between infant mortality, fertility and economic growth do not explicitly define whether these variables should be treated as endogenous or exogenous to their models. The utilization of the most recently developed technique of vector-error correction models (VECM) has several advantages over the other methods used in the past by various researchers, since this type of multivariate analysis can clearly identify multiple cointegrating relationships and hence error-correction terms and distinguish between exogenous and endogenous variables.

The purpose of this paper is first to examine empirically the validity of the "demographic transition" theory and to extend our understanding of the relationship between fertility choice, infant mortality and economic growth. Second, it tests empirically the economic forces that contribute to a country's demographic transition process and finally it investigates the dynamic interaction between demographic changes and economic growth, in order to explain systematically the process of economic development and associated demographic changes. The relevance of endogenous fertility choice is investigated and its dynamic response to structural shocks is estimated for the case of Greece. The paper utilizes the technique of the vector-error correction models and the application of variance decomposition and impulse response functions.

This is accomplished in four steps. First, the stationarity properties of the data and the order of integration are tested. Second, the Engle-Granger, Phillips-Hansen and unrestricted error-correction model are employed to search for cointegration in a fertility rate – mortality rate bivariate model. Third, the Johansen maximum likelihood technique is applied to search for cointegration among the demographic variables, the labor market and overall economic activity; that is between fertility choice, the infant mortality rate, the real wage and real per capita output. The use of the Johansen technique controls for endogeneity and the complicated short-run dynamics, while focusing on long-run relationships (cointegration) among non-stationary variables. Finally, the vector error-correction model, the generalized variance decomposition analysis and the generalized impulse response functions are used to investigate the response of fertility, the mortality rate, wages and output growth to fertility, mortality, employment and output shocks, with the aim being to test the proposition that fertility choice and the infant mortality rate should *not* be considered exogenous to labor market developments or to the growth process.

The paper proceeds as follows. Section 2 briefly describes recent demographic developments in Greece. Section 3 reviews the empirical findings of the demographic transition theory. Section 4 deals with methodological issues and the data used in the empirical analysis. Section 5 presents the empirical results. In Sect 6, the conclusions of the analysis are summarized.

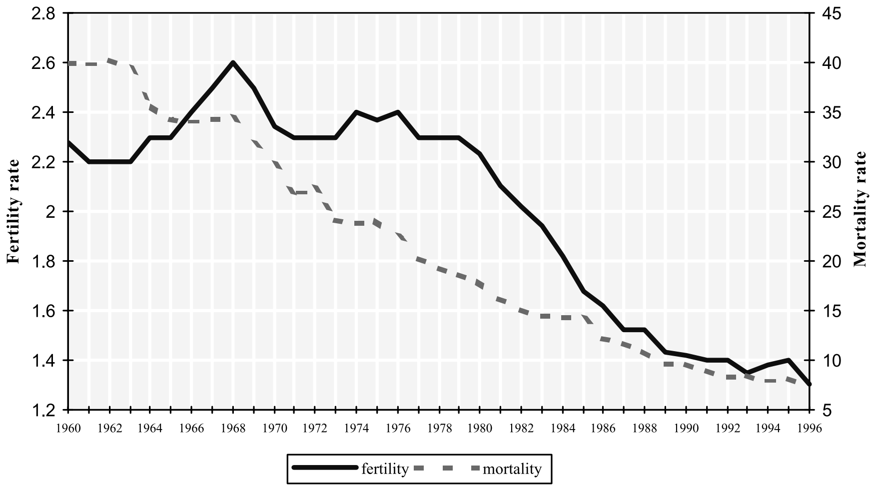

Fig. 1. Fertility and mortality under 1 year, Greece 1960–1996

2. Demographic developments in Greece

Fertility in Greece has declined, especially over the last decade, during which the economy has developed at a slow pace. In 1975 around 150,000 births were reported, while in 1990 only 85,000 children were born, almost half those born in 1975. Moreover, fertility rates, especially since 1985, have been lower than in most EU countries while the demographic scenarios assume, perhaps optimistically, that the fertility rate will increase to 2.1, the necessary level to maintain a stable population. According to OECD projections even if the fertility rate were to increase, in 2010 there will be 600,000 less children under the age of 20. On the other hand, the infant mortality rate has decreased and is expected to decrease further due to increased industrialization and urbanization, the diffusion of medical technology and an overall improvement in economic activity which has contributed to increased living standards. Figure 1 reports the total fertility rate in Greece over the period 1960–1996, defined as the number of children born to an average woman during her lifetime and the mortality rate for children under one year old.

Given these trends, the important demographic developments, such as the declining fertility and mortality rates, do not seem to have received the appropriate attention, especially in light of the major economic changes that Greece is currently undergoing. Limited empirical studies, such as Provopoulos (1987), recognize that adverse developments in demographic factors, such as low fertility rates and the aging of population, put further pressure on the economic performance in Greece through their unfavorable consequences mainly for the social security system.

Since the beginning of the 1990s, Greece has been pursuing a medium-term adjustment program, the Convergence Program 1993/4–99, aiming at achieving nominal convergence towards the other EU member states. The attainment of this objective is a precondition for Greece's participation in European and Monetary Union (EMU), expected by 2001. The success of the

European integration process also requires real convergence of the economies, that is a reduction in income inequalities between the EU member states. Real convergence of the Greek economy can only be attained in the medium and longer term and presupposes the achievement of GDP growth rates appreciably higher than the EU average.

Participation in EMU requires a high degree of price stability, the reduction of public deficit and debt-to-GDP ratios to the reference values laid down in the Maastricht Treaty, exchange rate stability and convergence of long-term interest rates.[1] These targets are outlined in the Greek convergence program.

An additional goal of the convergence program is the stabilization of the surpluses of social security funds, since their further growth is not anticipated in the short-run.[2] Furthermore, the widening of the primary deficit of the major social security and welfare funds underlines the chronic and structural nature of the problems faced by the Greek social security system and the efforts required for its consolidation. In the medium term, problems in the social security system will be aggravated given the transition of many large funds to a stage of maturity and the upward trend in health costs. Policy measures that will reverse the downward trend of fertility rates will facilitate the financing and resolve the chronic deficiencies of the Greek social security system and may improve substantially the economic performance of the Greek economy.

3. Empirical considerations

Over the past decades, the causal relationship between infant mortality and fertility has been a controversial one which has been examined by various researchers.[3] Rostow (1990) uses data from seventy-six countries and finds that birth and death rates are negatively correlated with per capita GNP. These results suggest that as a country develops, both fertility and mortality rates tend to go down.

Schultz (1985), using Swedish data from 1860 to 1910, has shown that a quarter of the decline in fertility over this period was due to a 50% reduction in child mortality. He also finds, by using changes in the world prices of agricultural commodities as an instrument to overcome the endogeneity of income and labor supply, that an increase in the relative wages of women played an important role in Sweden's fertility transition. Yamada (1985) has shown that infant mortality and fertility are jointly determined. He also found that a decline in infant mortality that is due to an increase in per capita real income causes a subsequent decline in fertility.

Other studies have dealt more directly with the causal relationship between population and per capita income. Coale and Hoover (1958) find that a high fertility rate increases the dependency burden and lowers private saving and investment rates. There is therefore a fall in the "per capita consumer equivalent" income.

Simon (1989) observed that the rate of population growth and the rate of growth of per capita income showed no significant correlation. Barlow (1994) using data from 86 countries and a three variable model demonstrated that per capita income growth is negatively related to current population growth and positively to lagged fertility. Wang et al. (1994) examined a growth model where fertility is affected by employment and output shocks and the historical decomposition of fertility indicates that shocks to employment and preferences are important in explaining movements in the fertility rate.

4. Methodological issues and data

In the empirical analysis we test first for the validity of "demographic transition" theory and second for the contribution of economic forces to the demographic transition process. In particular we employ the VECM model to investigate empirically the endogeneity of the demographic variables, the fertility rate and mortality rate, as well as of output and wages. In addition we examine the responses of fertility, mortality, wages and output to fertility choice, labor market and output disturbances, in order to capture the short-run dynamics of the variables. The four macroeconomic variables employed in the empirical analysis are fertility choice, the infant mortality rate, the real wage and real per capita output.[4]

Testing for the existence of statistical relationship among the variables is done in four steps. The first step is to verify the order of integration of the variables since the causality tests are valid only if the variables have the same order of integration. Standard tests for the presence of a unit root based on the work of Dickey and Fuller (1979, 1981), Perron (1988), Phillips (1987), and Phillips and Perron (1988)[5] and Kwiatkowski et al. (1992)[6] are used to investigate the degree of integration of the variables used in the empirical analysis.[7]

The second step involves testing for cointegration using the Engle-Granger (1987) error-correction method, the Phillips-Hansen (1990) method for the bivariate model and the Johansen maximum likelihood approach (Johansen 1988; Johansen and Juselius 1990, 1992) for the mutivariate model. The Engle-Granger (1987) method is a residual-based cointegration test which has been criticized by Kremers et al. (1992) for having reduced power because it imposes the "common factor restriction". For this reason an unrestricted error-correction model is employed to test directly for cointegration between two variables by checking the significance of the lagged level of the dependent variable, based on the critical *t*-values from Banerjee et al. (1998). Another method which overcomes the shortcomings of the Engle-Granger method is the Phillips-Hansen estimator (PH) which takes into account correlations among the residuals and their lagged values in a semi-parametric manner.

In the case of more than two variables, the Johansen maximum likelihood approach is used (Johansen 1988; Johansen and Juselius 1990, 1992). The Johansen-Juselius estimation method is based on the error-correction representation of the VAR model with Gaussian errors.[8]

Evidence of cointegration rules out the possibility of the estimated relationship being "spurious". So long as the four variables have a common trend, causality, in the Granger sense and not in the structural sense, must exist in at least one direction.[9] Although cointegration implies the presence of Granger-causality it does not necessarily identify the direction of causality between variables. This temporal Granger-causality can be captured through the vector error-correction model derived from the long-run cointegrating vectors (Granger 1986, 1988).

Thus, the third step involves utilization of the vector error-correction modeling and testing for exogeneity of variables. Engle and Granger (1987) show that in the presence of cointegration, there always exists a corresponding error-correction representation which implies that changes in the dependent variable are a function of the level of disequilibrium in the cointegrating relationship, captured by the error-correction term (ECT), as well as changes in other explanatory variables. Thus through ECT, the VECM modeling establishes an additional way to examine the Granger-causality ignored initially from the Granger-Sims tests.

The Wald-test applied to the joint significance of the sum of the lags of each explanatory variable and the *t*-test of the lagged error-correction term will imply statistically the Granger-exogeneity or endogeneity of the dependent variable. The non-significance of ECT is referred as long-run non-causality, which is equivalent to saying that the variable is weakly exogenous with respect to long-run parameters. The absence of short-run causality (Granger-causality in the strict sense) is established from the non-significance of the sums of the lags of each explanatory variable. Finally, the non-significance of all the explanatory variables including the ECT term in the VECM indicates the econometric strong-exogeneity of the dependent variable, that is the absence of Granger-causality.[10]

However, the above tests do not provide an indicator of the dynamic properties of the system and do not measure the relative strength of the Granger-causal chain or the degree of exogeneity among the variables beyond the sample period. Therefore, the fourth step of the empirical analysis investigates the properties of the system estimating the generalized variance decomposition and the generalized impulse response function. The purpose of the investigation is to find how each variable responds to shocks in the other variables of the system. The forecast-error of generalized variance decomposition analysis reveals information about the proportion of the movements in sequence due its "own" shocks versus shocks to other variables. If the shocks do not explain any of the forecast error variance of one macroeconomic variable Y_t in all forecast horizons, then Y_t is an exogenous variable. At the other extreme, if shocks can explain all the forecast error variance of Y_t at all forecast horizons then Y_t is an entirely endogenous variable. The generalized impulse responses provide an estimate of the response of a variable in the case of innovation in another variable. Plotting the generalized impulse response functions is a practical way to explore the response of a variable to a shock immediately or with various lags. Unlike the orthogonalized variance decomposition and impulse response functions obtained using the Cholesky factorization, the generalized variance decomposition and impulse response functions are unique and invariant to the ordering of the variables in the VAR (Koop et al. 1996; Pesaran and Shin 1997).

Pesaran and Shin (1996) have proposed the estimation of persistence profile to account for the ambiguities of the impulse response function and to estimate the speed with which the effect of system-wide shocks on cointegrating relationship disappears. In particular, the persistence profile at n periods after a shock can be viewed as the variance of the difference between the forecast for n periods if a shock had occurred and the forecast for n periods if no shock had occurred.

The empirical analysis has been carried out using annual data for the period 1960 to 1996 for Greece. The wage variable (RWAGE) is the minimum real daily wage based on national general collective agreements; the fertility choice variable (FERT) is the total fertility rate (i.e. the number of children which a woman would bear if she followed throughout her life the current age specific birthrates); the infant mortality rate is defined as the number of children aged under one year old who die per 1000; and the output variable (RCGDP) is the real per capita GDP at market prices. The data on RWAGE are obtained from the *Bulletin of Conjunctural Indicators* of the Bank of Greece. The data of fertility are obtained from the *OECD Health Data*. The data on mortality rates are obtained from various issues of the *Statistical Yearbook of Greece* published by the National Statistical Service of Greece (NSSG) on annual basis. Finally, the GDP data are obtained from various issues of the *Provisional National Accounts of Greece* published by the NSSG on annual basis. All variables are expressed in logarithmic form (LFERT, LMORT, LRWAGE, LRCGDP).

5. Empirical results

5.1. Unit root tests

Table 1 presents the ADF, PP and KPSS tests for the four variables, fertility rate, infant mortality rate, real per capita GDP and wages used in the analysis in levels and first differences. The ADF statistic suggests that all variables are integrated of order one, $I(1)$, whereas the first differences are integrated of order zero, $I(0)$. Therefore, the hypothesis that the time series contain an autoregressive unit root is accepted in all cases. Although, employing the Phillips-Perron test gives different lag profiles for the various time series and sometimes lowered the level of significance, the main conclusion is qualitatively the same as reported above by the Dickey-Fuller tests. In particular, the Phillips-Perron test based on the 5 and 1 per cent critical values supports the hypothesis that all series contain a unit root. Thus, both tests are in favor of the unit root hypothesis in all time series.

Finally, the KPSS statistics test for lag-truncation parameters one and four ($l = 1$ and $l = 4$)[11] since it is unknown how many lagged residuals should be used to construct a consistent estimator of the residual variance. The KPSS test rejects the null hypothesis of level and trend stationarity for both lag truncation parameters. The KPSS statistics does not reject the $I(0)$ hypothesis for the first differences of the series at various levels of significance. Therefore, the combined results from all the tests (ADF, PP, KPSS) suggest that all the series under consideration appear to be $I(1)$ processes.

5.2. Cointegration analysis and the error-correction model

Since both the fertility and infant mortality rates are integrated of the same order, it is appropriate to look for a relationship between the two variables. Table 2 summarizes the results of cointegration analysis using the Engle-Granger method. The results suggest that the hypothesis of no cointegration between the two variables, the fertility rate and the mortality rate, cannot be rejected.

However, since this test is not very powerful we test for cointegration between the two variables using the Phillips-Hansen method and the error-correction model. The use of the error-correction model directly tests for the significance of the coefficient of the lagged level of the dependent variable using the critical values from Banerjee et al. (1998). The results presented in Table 2 suggest that the hypothesis of no cointegration cannot be rejected Thus, the combined results from all tests employed do not provide support for the existence of a long-run relationship among the two variables.

Table 1. Tests of unit roots hypothesis

	Augmented Dickey-Fuller			Phillips-Perron			KPSS			
Variable	τ_μ	τ_τ	k	τ_μ	τ_τ	k	$l=1$		$l=4$	
							η_μ	η_τ	η_μ	η_τ
LFERT	0.62	−2.24	1	0.89	−1.54	1	1.612**	0.415**	0.697*	0.194*
LMORT	0.53	−2.67	1	1.02	−3.22	1	1.923**	0.321**	0.839**	0.183*
LRWAGE	−2.71	−1.29	0	−2.77	−1.07	1	1.508**	0.432**	0.683*	0.212*
LRCGDP	−1.53	−1.76	6	−5.06	−1.92	1	1.567**	0.461**	0.711*	0.214*
ΔLFERT	−3.67**	−4.25**	0	−3.75**	−4.41**	1	0.517*	0.114	0.338	0.091
ΔLRMORT	−7.26**	−7.25**	0	−6.97**	−7.10**	1	0.233	0.062	0.355	0.117
ΔLRWAGE	−5.27**	−6.09**	0	−5.31**	−6.18**	1	0.575*	0.031	0.531*	0.060
ΔLRCGDP	3.29*	−4.92**	0	−4.21**	−5.61**	1	1.139**	0.136	0.633*	0.134

Notes: The relevant tests are derived from the OLS estimation of the following autoregression for the variable involved:

$$\Delta x_t = \delta_0 + \delta_1 (Time)_t - \delta_2 x_{t-1} + \sum_{i=1}^{k} \phi_i \Delta x_{t-i} + u_t \quad (1)$$

τ_μ is the t-statistic for testing the significance of δ_2 when a time trend is not included in Eq. 1 and τ_τ is the t-statistic for testing the significance of δ_2 when a time trend is included in Eq. 1. The calculated statistics are those reported in Dickey-Fuller (1981).

The critical values at 5% and 1% for $N = 50$ are −2.93 and −3.58 for τ_μ and −3.5 and −4.15 for τ_τ respectively. The lag length structure of Φ_i of the dependent variable x_t is determined using a recursive procedure in the light of a Lagrange multiplier (LM) autocorrelation test (for orders up to two) which is asymptotically distributed as chi-squared distribution and the value of t-statistic of the coefficient associated with the last lag in the estimated autoregression. For the case of GDP an exogeneous break in 1973 is used to account for the structural shock in that year due to the oil crisis. In this case the calculated statistics are those reported in Perron (1989).

The critical values for the Phillips-Perron unit root tests are obtained from Dickey-Fuller (1981). η_μ and η_τ are the KPSS statistics for testing the null hypothesis that the series are $I(0)$ when the residuals are computed from a regression equation with only an intercept and intercept and time trend, respectively. The critical values for η_μ and η_τ at 5% are 0.463 and 0.146 and at 1% are 0.739 and 0.216, respectively (Kwiatkowski et al. 1992, Table 1).

**,* Indicate significance at the 1 and 5 percentage levels.

In order to account for influences on the fertility – mortality rate relationship of changes in medical technology, literacy, standard of living, overall economic performance and the labor market, real GDP per capita (RCGDP) and real wages (RWAGE) variables are added to the VAR model. Table 3 summarizes the results of cointegration analysis among the four variables using the Johansen maximum likelihood approach employing both the maximum eigenvalue and trace statistic. To determine the lag length of the VAR, three versions of the system were initially estimated: a four, a three and a two-lag version. Then, an Akaike Information criterion (AIC), a Schwarz Bayesian Criterion (SBC) and a likelihood ratio test (Sims' test) were used to test whether all three specifications are statistically equivalent. All tests reject the null hypothesis that all the specifications are equivalent. In particular, the tests suggest that VAR = 3 should be used in the cointegration estimation

Table 2. Bivariate cointegration tests

Method	Dependent Variable Fertility		Dependent Variable Mortality	
	k	t-test	k	t-test
Engle-Granger	0	−1.94	0	−2.20
Error-Correction Estimates	0	−1.69	1	0.04
Phillips-Hansen	0	−2.10	0	−2.58

Notes: The augmented Dickey-Fuller test is based on Eq. (1) (see Table 1) with a constant and without a trend, where x_t is the estimated residual from the long-run model $\text{LFERT}_t = \alpha_0 + \alpha_1 \text{LMORT}_t$. The lag length k is chosen so the estimated residuals of Eq. (1) will be without autocorrelation. The critical values for the rejection of null hypothesis of no co-integration between the two variables are selected from Engle and Yoo (1987, Tables 2 and 3, pp. 157–158). The single-equation error correction model is estimated for LFERT and LMORT.

$$\Delta Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 X_{t-1} + \sum_{i=1}^{k} \beta_i \Delta Y_{t-1} + \sum_{i=1}^{k} \gamma_i \Delta X_{t-1} + u_t$$

The reported values are the t-tests for the estimated coefficient α_1. The critical values for α_1 at 5% and 1% for $N = 50$ are −3.28 and 3.94, respectively (Banerjee et al. 1998, Table 1). The Phillips and Hansen estimates are based on the Parzen lag window. The results are for length lag window equal to two. The results are similar for length lag window equal to 3.

Table 3. Johansen and Juselius cointegration test fertility choice, mortality, real wages and real per capita output: sample 1960–1996

VAR = 3, Variables: LFERT, LMORT, LRWAGE, LRCGDP

Maximum Eigenvalues

Null	Alternative	Eigenvalue	Critical values	
			95%	90%
$r = 0$	$r = 1$	38.15**	27.42	24.99
$r <= 1$	$r = 2$	14.37	21.12	19.02

Trace statistic

Null	Alternative	Trace	Critical values	
			95%	90%
$r = 0$	$r >= 1$	60.47**	48.88	45.70
$r <= 1$	$r >= 2$	22.31	39.33	28.78

$Z = \text{LFERT} - 0.71\text{LMORT} + 1.15\text{LRWAGE} - 2.01\text{LRCGDP}$

Note: r indicates the number of cointegrating relationships. Maximum eigenvalue and trace test statistics are compared with the critical values from Johansen and Juselius (1990).

**,* Indicate rejection of the null hypothesis at 95 and 90% critical value, respectively.

Table 4. Long-run Test for the hypothesis that each variable does not enter any cointegrating vector

Variables	LR Test of restrictions
LFERT	3.99**
LMORT	4.96**
LRWAGE	13.70***
LRCGDP	22.74***

Notes: The reported statistics are distributed as chi-square distribution with degrees of freedom the number of cointegrating vectors.
***, ** Indicate rejection of the null hypothesis at 1 and 5% level of significance.

procedure to avoid over-parameterization of the estimated models. Finally, a log-likelihood ratio test is used for testing the deletion of two dummy variables from the VAR model. The two dummy variables account for the sharp decline in fertility rate in 1969 and after 1980. The first dummy accounts for the sharp change in fertility trend between 1969 and 1979.[12] The second dummy accounts for changes in fertility and in the social security system between the years 1980 and 1996.[13,14] All tests reject the null hypothesis of the deletion of the two dummy variables from the VAR model.

The estimation procedure assumes unrestricted intercepts and no trends in the VAR estimation. The two test statistics give similar results. Both tests provide evidence to reject the null of zero cointegrating vectors in favor of one cointegrating vector at 5% level.[15] On the basis of the results, the long-run relationship between demographic variables, real wages and real per capita output finds statistical support in Greece over the period under examination.

Subsequently, we investigate whether all the variables, real wage, real per capita output and the two demographic variables enter into the cointegrating vector in a statistically significant way. Table 4 reports the likelihood ratio tests as described in Johansen (1992) and Johansen and Juselius (1992). The results suggest that all the variables, demographic and economic, enter in a statistically significant way into the cointegrating vector. The estimated cointegration relationship is presented in Table 3.

This equation can be rewritten as:

$$\mathrm{LFERT} = 0.71\mathrm{MORT} - 1.15\mathrm{LRWAGE} + 2.01\mathrm{LRGDP} + Z$$

From the above estimated equation three main points can be concluded. First, a downward shock to infant mortality, due for example to medical advances, leads to lower fertility. This result is consistent with the theoretical explanations provided by Sah (1991) and Cigno (1998). Sah (1991) showed that when the probability that a child survives to adulthood decreases, the parents may wish to replace them in their fecund period. Thus, when child survival is more likely fertility will not be higher. However, a cost may be incurred by a birth, regardless of whether or not the child survives. In such a case, when the probability that a child survives increases the effective price of a surviving birth decreases and therefore higher fertility is encouraged. When the parents are risk averse or have a target fertility level, the first effect, the "hoarding effect", dominates the second effect, the "cost effect", so better survival chances for children tend to reduce fertility. In addition, Cigno (1998) argues that when the level of child mortality is already low, as is the case in Greece (Fig. 1), then a further reduction in it is possible to decrease both fertility and survival-enhancing expenditures on children. Second, an upward shock in real wages, due for example to technological change, leads to lower fertility. This implies that the opportunity cost of time devoted to childcare has increased and consequently fertility has declined. Finally, an upward shock in real GDP per capita, due for example to an improvement in the terms of trade, leads to higher fertility. This implies a positive income effect on the demand for children. Overall, the estimated cointegrating vector suggests that the "demographic transition", a decrease in fertility and infant mortality rates, is affected by changes in real wage and real per capita output in the long-run.

Having verified that the variables are cointegrated, vector error-correction models can be applied. The lagged residuals from the cointegrating regression with the appropriate number of lags are included in the Granger-causality test structure. The lag length structure depends on the restricted error-correction models. The restricted error-correction models pass a series of diagnostic tests including serial correlation based on the inspection of the autocorrelation functions of the residuals as well as the reported Lagrange multiplier.

Table 5 reports the findings for the endogeneity of demographic and economic variables, based on the error-correction equations. The error-correction term measures the proportion by which the long-term imbalance in the dependent variable is corrected in each short-run period. The size and the statistical significance of the error-correction term measures the extent to which each dependent variable has the tendency to return to its long-run equilibrium.

Estimates of the parameters show that the error-correction term measuring the long-run disequilibrium is significant for the fertility and real output equations. This implies that the fertility and output variables have a tendency to restore equilibrium and take the brunt of any shock to the system. The *t*-tests for the error-correction terms indicate, at the 1% level of significance, that fertility and output are not weakly exogenous variables. In addition, the *t*-tests of the error correction term for the infant mortality rate and the real wage are not statistically significant. The results imply at different levels of significance that the real wage and infant mortality rate are weakly exogenous variables. In the short-run dynamics (Granger-causality in the strict sense), the Wald-tests indicate that there is a relationship between the real output and fertility choice equations. In particular, the results suggest that, in the short-term, fertility and the real wage are affected by the output variable while real output is affected by the mortality and the real wage variable.

Finally, the significance levels associated with the Wald-tests of joint significance of the sum of the lags of the explanatory variable and the error-correction term, provide more information on the impact of demographic variables on economic variables and vice versa, as a further channel of Granger-causality is explored. For the fertility and the real output variables, the results imply the Granger-endogeneity of the variables. Finally, the empirical results reject the hypothesis of strong exogeneity of fertility choice and real per capita output variables supporting the proposition that there is a relationship between demographic changes and economic development in Greece.

Table 5. Summary of tests for weak and strong exogeneity of variables based on vector error-correction models

Equations	Test of restrictions									
	Short-run dynamics non-causality				Weak exogeneity, (ECT coefficient)	Tests for granger non-causality, (Joint short-run dynamics and ECT)				Tests for strong exogeneity
	ΔFERT	ΔMORT	ΔRWAGE	ΔRCGDP	$Z=0$	ΔLFERT and ECT	ΔLMORT and ECT	ΔLRWAGE and ECT	ΔLRCGDP and ECT	
ΔFERT		0.49	1.81	4.90*	−0.21***		17.76***	18.85***	17.82***	22.49***
ΔMORT	1.70		0.62	3.89	−0.02	2.41		0.82	4.11	8.39
ΔRWAGE	1.51	1.41		7.92**	−0.06	2.24	1.84		7.95**	10.32
ΔRCGDP	0.60	13.50***	8.40**		0.22***	20.35***	28.64***	18.51***		29.40***

Note: The lagged ECT is derived by normalizing the cointegrating vector on fertility. The statistics reported are distributed as chi-square distribution with degrees of freedom the number of restrictions. In the short-run dynamics asterisks indicate rejection of the H_o that there is short-run non-causal relationship between the two variables. The coefficients of the lagged ECTs are negative. Asterisks indicate rejection of the null hypothesis that the estimated coefficient is equal to zero (weak exogeneity). Finally, in the tests for Granger-non causality and strong exogeneity, asterisks denote rejection of the null hypothesis of Granger-non causality and strong exogeneity respectively.

***, **, * Indicate significance at the 1, 5 and 10% levels.

5.3. Generalized variance decomposition analysis and generalized impulse response functions

Having verified the long-run relationship, the exogeneity and endogeneity, as well as the direction of causality among the four variables, the generalized variance decomposition analysis and the estimation of the generalized impulse response functions are used to investigate the dynamic properties of the system.

The generalized variance decomposition results for the four variables provide an indication of the relative strength of the Granger-causal relationship as well as a quantitative measure of the dynamic interactions between the variables. The results are presented in Table 6. The reported numbers indicate the percentage of the forecast error in each variable that can be attributed to innovations in other variables at five different time horizons: one year ahead (the short-run period), two or four years ahead (the medium-run period), eight

Table 6. Generalized forecast error variance decomposition

Generalized variance decomposition of fertility

Period	Fertility shock	Mortality shock	Wage shock	Output shock
1	0.94	0.16	0.12	0.04
2	0.86	0.21	0.19	0.06
4	0.65	0.19	0.31	0.17
8	0.58	0.15	0.35	0.23
12	0.58	0.14	0.35	0.23

Generalized variance decomposition of mortality

Period	Fertility shock	Mortality shock	Wage shock	Output shock
1	0.18	0.93	0.00	0.07
2	0.16	0.93	0.01	0.08
4	0.17	0.95	0.02	0.05
8	0.20	0.93	0.05	0.03
12	0.21	0.93	0.04	0.02

Generalized variance decomposition of real wages

Period	Fertility shock	Mortality shock	Wage shock	Output shock
1	0.08	0.04	0.95	0.02
2	0.08	0.04	0.90	0.06
4	0.09	0.03	0.90	0.05
8	0.09	0.03	0.91	0.05
12	0.09	0.03	0.93	0.04

Generalized variance decomposition of real per capita output

Period	Fertility shock	Mortality shock	Wage shock	Output shock
1	0.13	0.04	0.00	0.89
2	0.14	0.10	0.00	0.79
4	0.11	0.12	0.10	0.68
8	0.08	0.15	0.24	0.51
12	0.07	0.15	0.26	0.49

or twelve years ahead (the long-run period). The results of generalized variance decomposition analysis and generalized impulse response function provide the same conclusions regardless of the order of decomposition since their estimation is independent on the ordering.

The analysis of variance decomposition tends to suggest that, mainly fertility choice and economic performance can be explained by the disturbances in the other variables. Specifically, our results suggest that a significant percentage of the variability of fertility choice, more so in the long run, can be attributed to innovations in technology, the labor market and infant mortality. In addition, these empirical results suggest that a significant percentage of the variability in economic performance could be attributed to innovations in the labor market, fertility choice and mortality.

An alternative way to obtain the information regarding the relationships among the three variables included in the variance decomposition analysis is through the generalized impulse response functions. The generalized impulse response functions show how the four variables respond over a twelve-year horizon, to each one-standard deviation shock. Figures 2, 3, 4 and 5 present the generalized impulse response functions to a one standard error shock in real per capita output, the real wage, mortality and fertility respectively.

The graphical analysis (Fig. 2) suggests that a positive shock to technology increases fertility substantially mainly in the medium-run period. This implies a positive income effect on the demand for children. In addition this improvement in technology reduces substantially infant mortality. This is expected since an improvement in technology will result in medical advances which will further reduce child mortality. A positive shock to real wages (Fig. 3) decreases fertility in all periods since the opportunity cost of time devoted to childcare is higher and therefore time is reallocated toward labor. A negative shock to infant mortality (decrease in the infant mortality rate, Fig. 4) due to medical advances decreases the fertility rate. In addition, this result supports Cigno's proposition that when the level of child mortality is already low then a further reduction in it is likely to decrease fertility.[16] It appears that this finding is relevant to Greece, a country that is experiencing low mortality rates (Fig. 1). Furthermore, an increase in fertility (Fig. 5) increases output mainly

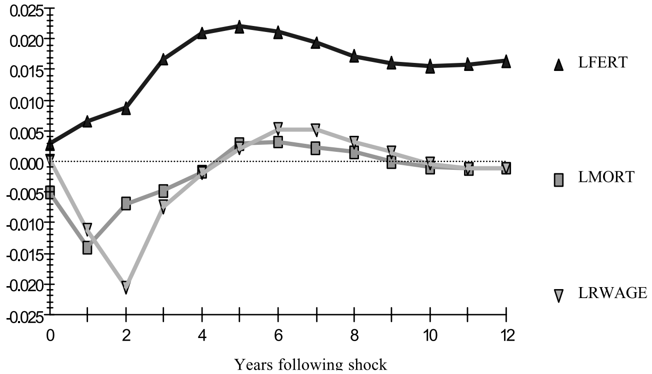

Fig. 2. Generalized impulse responses to one S.E. shock to the equation for real per capita output

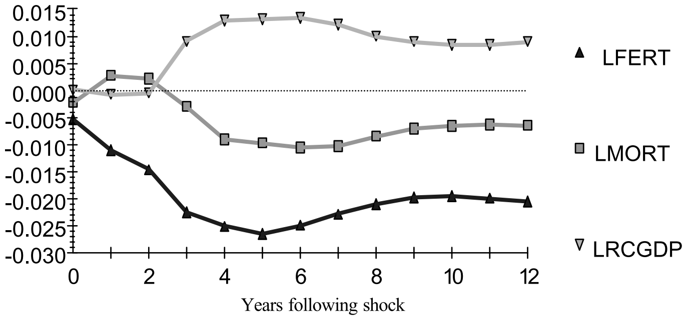

Fig. 3. Generalized impulse responses to one S.E. shock to the equation for real wages

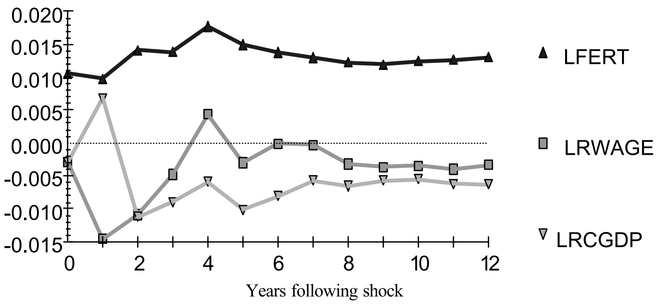

Fig. 4. Generalized impulse responses to one S.E. shock to the equation for infant mortality

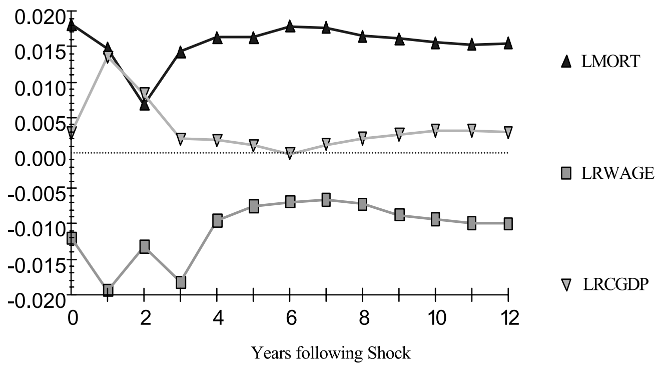

Fig. 5. Generalized impulse responses to one S.E. shock to the equation for fertility

in the medium run after which output returns to its original level and stabilizes since this type of disturbance affects labor effort and capital accumulation.

In short, it is expected that if fertility is exogenous it should not respond to output or wages or infant mortality disturbances. However, as mentioned before the results show that fertility does respond to output, real wages and

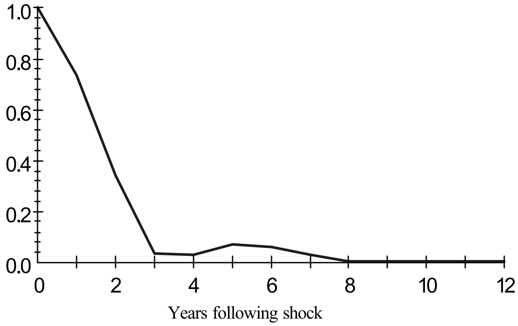

Fig. 6. Persistence profile of the effect of a system-wide shock to cointegrating vector Z

infant mortality shocks and the clear endogeneity of fertility is revealed. The combined results of Table 5 and Figs. 2, 3, and 4 show that the short-run response of fertility to infant mortality and real wages shocks is rather weak on impact, but is found to be quite significant at all horizons. The results show that output does not only significantly influence fertility changes in the long-term as a component of the lagged error-correction term, but also significantly influences fertility change through the short-run channel. Finally, these combined results suggest that shocks to infant mortality rate and real wage mainly operate through the error-correction to the long-term relationship.

Finally, turning to the persistence profile, Fig. 6, presents the persistence profile for the long-run relationship Z. It is important to notice that the relationship has the tendency to converge relatively fast (three years after the shock) to equilibria. This suggests that the cointegrating relationship tends to respond quickly to changes in the fertility rate, the infant mortality rate, the real wage and economic changes.

From the empirical analysis four conclusions can be drawn. First, a downward shock to infant mortality leads to lower fertility supporting the theoretical propositions by Sah (1991) and Cigno (1998). The results support Sah's theoretical proposition that when parents are risk averse or have a target fertility rate the "hoarding effect" dominates the "cost effect" resulting in lower fertility rate when the probability of child survival increases. These results also support Cigno's proposition that when child mortality is already low a further reduction in it will decrease fertility. Second, fertility choice should not be considered exogenous to the infant mortality rate, the labor market or the growth process. Third, positive employment shocks (higher real wages) are responsible for the deterioration of fertility, since time is reallocated from childbearing toward labor supply in response to the higher opportunity cost of time. Finally, an upward shock in real GDP per capita leads to higher fertility. This implies a positive income effect on the demand for children. These results are similar to the results of Yamada (1985), Shapiro and Watson (1988), Simon (1992, Ch. 2), and Wang et al. (1994) for the U.S.A.

6. Conclusions

This paper provides an empirical model that explains the economic forces which affect the demographic transition process. The statistical relationship among fertility choice, the infant mortality rate, the real wage and real per capita output is estimated for Greece during the 1960–1996 period, thus adding to the theory of "demographic transition" and to current concepts of economic growth.

The demographic changes and the economic developments are explained in a temporal Granger-causal framework. This is accomplished by examining the dynamic relationship between fertility and mortality rates initially and then between demographic changes and economic conditions in a multivariate system. The empirical results indicate that there is not long-run relationship between fertility and mortality. However, when we control for the potential influences of technology and the labor market on the bivariate relationship between fertility and mortality, the empirical evidence of cointegration, within this multivariate cointegrated system, rules out the possibility that the estimated relationship is "spurious" and implies that Granger-causality must exist in at least one direction. In turn, this leads to the conclusion that these variables, although subject occasionally to short-term or transitory deviations from their long-run equilibrium, eventually are driven together by forces within the system.

The results of the empirical model using the error-correction model estimation, the generalized variance decomposition analysis and the generalized impulse response function, suggest that fertility changes should be considered as endogenous to infant mortality, the labor market and the growth process. In particular, infant mortality, labor market and economic performance shocks are responsible for the variations in fertility rate. A negative shock to the infant mortality rate decreases fertility suggesting that when the probability of child survival increases fertility increases since the "hoarding effect" is higher than the "cost effect". In addition the empirical results confirm the proposition that a positive relation between mortality and fertility is more likely to be observed in a country where infant mortality is already low. Finally, a negative labor market shock causes a reallocation of time from labor effort to childbearing, thus increasing fertility, while at the same time an upward shock in real GDP per capita leads to higher fertility implying a positive income effect.

The empirical results have important implications for Greece, where the infant mortality is low and there are declining fertility rates. The empirical results suggest that the decreasing infant mortality rate will further decrease fertility, resulting in a decline in the population of Greece during the coming decades. Finally, an increase in real GDP per capita due to productivity improvements will lead to higher fertility.

Endnotes

[1] For a further discussion on these issues, see *Bank of Greece* (1997, Ch. 2).

[2] This reflects the existing constraints, given that the positive effects of increases in social security contribution rates have faded out and revenue from the investment of assets from social security funds' surpluses has declined as a result of the drop in interest rates.

[3] Ehrlich and Lui (1997) and Kirk (1996), among others, have summarized the theories and developments that have sought to give a causal explanation of the demographic transition.

[4] Some other variables, such as social security payments, number of marriages, interest rates and cohabitation trends could play a significant role in the VECM specification. However, the addition of these variables will increase the size of the VECM causing serious estimation problems. These problems are mainly due to the fact that the number of unknown coefficients can quickly approach the available sample size. For more details see Johnston and Dinardo (1997).

[5] This version of the test is an extension of the Dickey-Fuller test which makes a semi-parametric correction for autocorrelation and is more robust in the case of weakly autocorrelated and heteroskedastic regression residuals. According to Choi (1992), the Phillips-Perron tests (PP) extension appear to be more powerful than the ADF tests, for aggregate data. For more details see Perron (1990).

[6] The KPSS procedure assumes the univariate series can be decomposed into the sum of a deterministic trend, random walk and stationary $I(0)$ disturbance and is based on a Lagrange Multiplier score testing principle. This test reverses the null and the alternative hypothesis. A finding favorable to a unit root in this case requires strong evidence against the null hypothesis of stationarity. The KPSS test statistic is defined as:

$$\eta = T^2 \Sigma S_t^2 / s^2(k),$$

where

$$S_t = \sum_{i=1}^{t} e_i \quad (i = 1, 2, \ldots, t)$$

and e_i is the partial sum of the residuals from regressing the series on an intercept and possibly a time trend. $s^2(k)$ is a consistent non-parametric estimate of the disturbance variance and T is the sample size.

[7] The combined use of the three tests employed to investigate the degree of integration of the series may result in four possible outcomes. First, rejection by the ADF and PP statistics and non-rejection by the KPSS test gives strong evidence of stationarity. Second, non-rejection by both ADF and PP and rejection by the KPSS is a strong indication of $I(1)$. Third, non-rejection by all tests suggests that the data is not sufficiently informative on the long-run characteristics of the series. Fourth, rejection by all tests indicates that the series is neither an $I(1)$ nor an $I(0)$ process. The gain from testing both stationarity and non-stationarity employing the three tests and comparing their outcomes is that the inference is not uncertain. Specifically, the inference is either stationarity, non-stationarity or we do not know, which is preferable to being uncertain.

[8] This approach has several advantages over the Engle and Granger (1987) technique employed in empirical studies. First, the Johansen and Juselius method tests for the number of cointegrating vectors between the variables. These tests are based on the trace statistic test and the maximum eigenvalue test. Second, it treats all variables as endogenous thus avoiding an arbitrary choice of dependent variable. Third, it provides a unified framework for estimating and testing cointegrating relations within the framework of a vector error-correction model.

[9] As discussed by Granger (1988) causality in mean is the one that has empirical relevance because of its forecasting content, that is "if Y_t causes X_t, then X_{t+1} is better forecast if the information in Y_t is used than if it is not used, where better means a smaller variance of forecast error or the matrix equivalence of variance. The simple Granger-causality tests can be formulated using $I(1)$ variables. According to the Granger representation theorem, the error-correction model in the case of two variables X_t, and Y_t, derived from the long-run cointegrating relationship among the variables is of the following form

$$\Delta LX_t = \alpha_0 + \sum_{i=1}^{m} \beta_i \Delta LX_{t-i} + \sum_{i=1}^{n} \gamma_i \Delta LY_{t-i} + \delta\, \mathrm{ECT}_{t-1} + u_t \qquad \text{(i)}$$

$$\Delta LY_t = a_0 + \sum_{i=1}^{m} b_i \Delta LY_{t-i} + \sum_{i=1}^{r} c_i \Delta LX_{t-i} + d\, \mathrm{ECT}_{t-1} + e_t \qquad \text{(ii)}$$

where ECT is the error-correction term derived from the long-run relationship, ΔLX_t and ΔLY_t are the first differences of the variables LX_t and LY_t and u_t and e_t are the error terms. The Granger causality implies testing the significance of the joint hypothesis $H_o : \gamma = 0, \delta = 0$ and $H_o : c = 0, d = 0$ using equation (i) and (ii) respectively, with the appropriate number of lags to eliminate autocorrelation in the estimated regression equations.

[10] For another application of this technique in a different discipline see Masih and Masih (1999) and Hondroyiannis and Papapetrou (2000).

[11] The KPSS statistics are known to be sensitive to the choice of truncation parameter l and tend to decline monotonically as l increases.

[12] During the period 1969 to 1979 fertility rate started to decline and in the end of the period the fertility rate was marginally above the fertility rate compatible with stable population. During that period major structural reforms in manufacturing resulted in higher female employment. This development contributed to the increase of average female working time from 31.94 hours in the beginning of the period to 36.74 at the end of the period. For more details see Velengas (1992).

[13] During the period 1980–1996 due to the low fertility rates the government through reforms in the social security and tax systems provided incentives such as maternity leave, financial contribution to pregnancy expenses, financial assistant to single mothers and tax deductions to families with more than two children.

[14] The results are invariant to the inclusion or exclusion of the dummy variables. When the dummy variables are not included in the empirical analysis there is still one cointegrating vector and the empirical results are very similar. The results are available from the authors upon request.

[15] It is known that the Johansen cointegration procedure is biased towards the rejection of the null hypothesis in a small sample (Cheung and Lai 1993). Therefore, in the estimation procedure we used the critical values obtained from Johansen and Juselious (1990) and the critical values from Osterwald-Lenum (1992, Table 1). However, Table 3 reports only the Johansen and Juselious (1990). Both critical values reject the null of zero cointegrating vectors in favor of one cointegrating vector at 5% level.

[16] In Fig. 4, a positive shock with the exact adverse effects is presented.

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