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Investigating the "Complementarity Hypothesis" in Greek Agriculture: An Empirical Analysis

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ABSTRACT

This study investigates determinants of private capital formation in Greek agriculture and tests the "complementarity" against the "crowding out" hypothesis using multivariate cointegration techniques and ECVAR modeling in conjunction with variance decomposition and impulse response analysis. The results provide evidence of a significant positive causal effect of government spending on private capital formation, thus supporting the "complementarity" hypothesis for Greek agriculture.

Key Words: *agriculture, cointegration, complementarity hypothesis, Greece, innovation accounting, investment.*

One of the main policy questions in the international empirical literature concerns the determinants of private capital formation as well as the existence of a systematic relationship between fiscal spending and the demand for fixed private investment. Public investment is "complementary" to private investment if an initial increase in public investment leads to an increase in total investment in the economy. Public investment "crowds out" private investment if the latter decreases as a result of an increase in the former.

The relevant international literature can be classified as i) studies that test the impact of government expenditure on economic growth (Ram; Grossman; Bairam and Ward), ii) studies that discuss the provision of infrastructure (Buiter), and iii) studies that focus on the effects of public investment on output and productivity (Eberts; Aschauer 1989a and 1989b; Munnel). All of these studies provide evidence of a significant positive correlation between public and private investment.

Since the above context of empirical analysis is rather general, that is, the results refer mainly to the economy as a whole or to the industrial sector, it is obvious that an approach focusing on the agricultural sector would be at least of the same importance. This study examines private capital formation in Greek agriculture. We believe that the behavior of private investment in Greek agriculture is an important subject for investigation, since the primary sector in Greece still contributes a high percentage to total output. The figures presented in Table 1 show that the share of agriculture to total output, though declining, was on average 18.63 percent from 1950 through 1994. This is a rather high share con-

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Table 1. Characteristics of Greek Agriculture

	Years					
	50–60	60–70	70–80	80–90	90–94	50–94
Agricultural output/Total output (in percent)	27	21.4	15.1	13.4	12.7	18.63
Agricultural output (average percentage changes)	4.24	5.27	2.74	−1.58	3.56	2.75
Agricultural income/National income (in percent)	32.8	23	18.1	17.4	15.9	22.2
Employment in agriculture/Total employment (in percent)	51.3	46.9	34	26	22	32.05
Real gross private investment in agriculture (average percentage changes)	23.6	6	0.6	0.7	−4.8	2.66
Real gross public investment in agriculture (average percentage changes)	16.9	11.2	−2.1	0.1	7.5	6.6

Source: National Statistical Service of Greece.

sidering that real output had an average growth rate of only 2.2 percent. Moreover, the share of sectoral employment to total employment was also high, approaching an average of 32 percent. For comparison purposes, we present in Table 2 some characteristics of the agricultural sector in European Community (EC) Member States in 1989.

According to the figures in Table 1, it is obvious that all the agricultural indices, e.g. output growth, income, employment and private investment follow, especially in the '70s and '80s, a descending course. Similar characteristics are provided by figures for public investment in Greek agriculture. It should be noted that in this period the public sector has been strikingly absent from undertaking investment of the social overhead type (e.g., land reclamation projects, public irrigation facilities, etc.). In addition, there has been a lack of public investments necessary to create local markets, to improve the trading system, to improve the educational level, and to support research activities (Mergos). This fact, combined with the oil crisis and the stagflation of the Greek economy, resulted in a further discouragement of private investment in agriculture and placed the whole sector in decline. This general decline in agriculture occurs despite the increasing financial support from FEOGA (European Agricultural Guidness and Guarantee Fund). Specifically, over the period 1981–1991, there has been an inflow of about 2.3 trillion drachmas. Thus the investigation of the main determinants of capital formation in Greek agriculture could provide significant information regarding the conduct of economic policy of the Greek government.

Table 2. Some Characteristics of the Agricultural Sector in EC Member States in 1989

Country	Share of GNP (Percent)	Share of Employment (Percent)
Belgium	2.2	2.8
Denmark	3.8	6
Germany	1.6	3.9
Greece	16.4	26.6
France	3.2	6.4
Ireland	10.9	15.1
Italy	4.1	9.3
Luxembourg	2.3	3.4
Netherlands	4.2	4.7
Portugal	5.2	18.9
UK	1.8	2.2

Source: European Economy, No. 5, 1994, p. 235.

This research addresses several issues. First, employing Johansen's multivariate cointegration techniques we test the "complementarity" against the "crowding out" hypothesis in Greek agriculture by evaluating the long-run relationship between private investment and public investment in this sector. Second, we use error-correction vector autoregressive (ECVAR) modeling to examine the short-run dynamics of the variables involved. Third, to test for the robustness of our results, we use variance decomposition and impulse-response analysis.

The rest of this study is organized as follows: Section 2 discusses theoretical and methodological issues. In Section 3 empirical results are reported and discussed. Concluding remarks are given in Section 4.

Theoretical and Methodological Issues

Cointegration

The long-run relationship between a number of series can be looked at from the viewpoint of cointegration (Engle and Granger). Cointegration is a time-series modelling technique developed to deal with non-stationary time series in a way that does not waste the valuable long-run information contained in the data. Moreover, the need to evaluate models which combine both short-run and long-run properties and which at the same time maintain stationarity in all of the variables has prompted a reconsideration of the problem of regression using variables measured in their levels. As Granger and Newbold and Phillips pointed out, given that many economic time series exhibit the characteristics of the integrated processes of order one, I(1), estimating traditional OLS or VAR models with I(1) processes can lead to nonsensical or spurious results. Note that, I(1) processes are those which need to be differenced to achieve stationarity.

Let x(t) be a vector of n-component time series each integrated of order one. Then x(t) is said to be cointegrated CI(1, 0), if there exists a vector ϕ such that

$$s(t) = \phi' x(t)$$

is I(0). Stationarity of s(t) implies that the n variables of x(t) do not drift away from one another over the long-run, obeying thus an equilibrium relationship. If ϕ exists, it will not be unique unless x(t) has only two elements. The Engle and Granger approach can deal with the possibility of only one linear combination of variables that is stationary. Recent advances in cointegration theory (Johansen and Juselius) have developed a maximum likelihood (ML) testing procedure on the number of cointegrating vectors which also allows inferences on parameter restrictions. The ML method uses a vector autoregressive (VAR) model

$$(1) \quad \Delta x(t) = \sum_{i=1}^{q-1} \Pi_i \Delta x(t-i) + \Pi_q x(t-q) + \mu + v(t)$$

where x(t) is a $n \times 1$ vector of variables, Π_q is a $n \times n$ matrix of rank $r \leq n$, μ is a $n \times 1$ vector of constant terms, v(t) is a $n \times 1$ vector of residuals and Δ is the first-difference operator. The testing procedure involves the hypothesis H_2: $\alpha\beta'$, where α and β are $n \times r$ matrices of loadings and eigenvectors respectively, and that there are r cointegrating vectors $\beta_1, \beta_2, \ldots, \beta_r$ which provide r stationary linear combinations $\beta' x(t-q)$. The likelihood ratio (LR) statistic for testing the above hypothesis

$$(2) \quad -2 \ln Q = -T \sum_{i=r+1}^{n} \ln(1 - \hat{\lambda}_i)$$

is a test that there are at most r cointegrating vectors versus the general alternative (trace), where λ_i corresponds to the $n - r$ smaller eigenvalues. The $n \times r$ matrix of cointegrating vectors β can be obtained as the r, n-element eigenvectors corresponding to λ_i.

The LR test statistic for testing r against r + 1 cointegrating vectors is given by

$$(3) \quad -2 \ln(Q: r | r+1) = -T \ln(1 - \hat{\lambda}_{r+1}).$$

The above tests (2) and (3) are used to determine the significant eigenvalues and the corresponding number of eigenvectors.

Innovation Accounting

Innovation accounting consists of impulse response analysis and variance decompositions. More specifically, according to the Wold decomposition theorem, any finite linearly regular covariance stationary process y(t), $m \times 1$, has a moving average representation

(4) $$y(t) = \sum_{s=0}^{\infty} \Phi(s)u(t - s)$$

with $Var[u(t)] = \Sigma$.

Although u(t) is serially uncorrelated by construction, the components of u(t) may be contemporaneously correlated. Therefore, an orthogonalizing transformation to u(t) is done so that (4) can be rewritten as[1]

$$y(t) = \sum_{s=0}^{\infty} \Phi(s)P^{-1}Pu(t - s)$$

$$= \sum_{s=0}^{\infty} \theta(s)w(t - s)$$

where $\theta(s) = \Phi(s)P^{-1}$, $w(t - s) = Pu(t - s)$ and $Var[w(t)] = Var[Pu(t)] = I$.

When P is taken to be lower triangular matrix, the coefficients of $\theta(s)$ represent "responses to shocks or innovations" in particular variables. More precisely, the jk-th element of $\theta(s)$ is assumed to represent the effect on variable j of a unit innovation in the k-th variable that has occurred s periods ago. Furthermore, we can allocate the variance of each element in y to sources in elements of w, since w is serially and contemporaneously uncorrelated. The orthogonalization provides

$$\sum_{s=0}^{T} \theta(s)_{ij}^2$$

which is the components-of-error variance in the T + 1 step ahead forecast of y_i which is accounted for by innovations in y_j.

Empirical Analysis

The Model and Data

Based on conventional demand theory and following Ramirez, and Bairam and Ward, we hypothesize an expression of the general form below which incorporates the basic variables employed in the literature mentioned above:

$$PI(t) = a + bGI(t) + cY(t) + dR(t) + u(t)$$

where PI, GI and Y denote, respectively, real private investment in agriculture, real public investment in agriculture and real agricultural income proxied by the real gross domestic product in agriculture minus real total investment in agriculture. R is the real long-term lending rate for agricultural loans measured by the log of the respective nominal interest rate minus the inflation rate. The empirical analysis is carried out using annual data over the period 1948–94.[2] All variables, except the lending rate, are expressed in logarithms. Last, u denotes a white noise error term.

Cointegration Analysis and Short-Run Dynamics

As mentioned previously, many macroeconomic series are characterized by nonstationarities. In such cases, the classical t- and F-tests are inappropriate because the limiting distribution of the asymptotic variance of the parameter estimates is not finitely defined (Fuller). Thus, it is customary to test the hypothesis that the individual series are integrated of order one, denoted by I(1), that is, to test for the existence of a unit root employing the Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) test. It should be noted that statistical inference with nonstationary data may lead to invalid results. Moreover, cointegration requires nonstationary time series of the same order of integration. Thus, we first test for stationarity using the ADF test. The unit root results in both trended and non-trended cases are presented in Table 3 and suggest that all series are nonstationary in levels but stationary in first differences. One implication of these results is that first-differencing is required to induce stationarity.

Next, we proceed with the investigation of the joint integration properties of the series using the maximum likelihood method of multivariate cointegration technique proposed by Johansen (1988 and 1989). The first step is to postulate a VAR model to obtain a long-run

[1] This representation is obtained by decomposing Σ^{-1} as $\Sigma^{-1} = P'P$.

[2] Data are from the *Statistical Bulletin of Bank of Greece* (various issues). All empirical analysis employs MICROFIT 386 computer package.

Table 3. Augmented Dickey-Fuller (ADF) Unit Root Tests

Variables	PI	GI	Y	R
		Levels		
ADF Statistic with trend	−2.3873 (1)	−2.1538 (1)	−1.514 (1)	−2.7303 (1)
ADF Statistic without trend	−2.5442 (1)	−1.7172 (1)	−2.400 (1)	−2.6559 (1)
		First Differences		
ADF Statistic with trend	−6.3077 (1)	−4.7928 (1)	−5.297 (1)	−6.7564 (1)
ADF Statistic without trend	−5.4014 (1)	−4.9713 (1)	−4.844 (1)	−6.7768 (1)

Notes: The ADF statistics were calculated with one lag (indicated in the parentheses) to ensure that the residuals were "white noise." The critical values from Fuller, for the respective degrees of freedom and the 5 percent level of significance, are −3.51 and −2.93 for the trended and non-trended cases, respectively.

relationship.[3] The strategy adopted in specifying the number of lagged terms in equation (1) was based on Sims likelihood ratio (LR) tests. The LR values have been calculated for lag lengths varying from one to three years. The results indicate that a 2-lag VAR system is the optimal specification.[4] It should be noted that the chosen lag-structures were also checked for the presence of serial correlation associated with the truncation of the lag polynomial using the Ljung-Box test. The results were consistent with the absence of serial correlation.

The third step is to test for the existence of the number of cointegrating vectors based on the previously specified VAR model. The results, derived from the LR tests based on maximal eigenvalue and the trace of the stochastic matrix Π, are reported in Table 4. The tests suggest the existence of at most two cointegrating vectors at the 95-percent confidence level. Further examination of the graphs of the residuals of the two cointegrating vectors associated with DF unit root tests suggest the rejection of the second cointegrating vector. Thus, only residuals from the first cointegrating vector should be considered.

Normalizing the cointegrating vector on PI yields the following cointegrating equation:

$$PI(t) = 0.5173 + 0.7771GI(t) + 0.1558Y(t) - 0.0445R(t).$$

All signs are consistent with economic theory. Furthermore, the positive coefficient of GI reveals a long-run complementary effect of public sector on private investment. The magnitude of the respective coefficient states that an increase of, say, 10 percent in public investment in agriculture should cause private investment to increase by 7.77 percent.

Having established that real private investment is cointegrated with real public investment, real gross domestic product and real lending rate, it is appropriate to examine short-run dynamics (i.e., Granger-causal effects) in the context of the associated error-correction mechanism. Thus, we estimate an equation of the following form

$$(5)\quad \Delta PI(t) = a\Delta PI(t-1) + b\Delta GI(t-1) + c\Delta Y(t-1) + d\Delta R(t-1) + eECT(t-1) + v(t)$$

where ECT is the residual from the cointegrating equation. The results[5] are reported in Table 5. The number of lags was limited to one.

The estimated equation satisfies all econometric criteria, namely absence of serial correlation, absence of functional misspecification, and homoscedasticity. CUSUM and CUSUMSQ tests,[6] based on recursive residuals, have also been applied and revealed stability in the parameter estimates.

The results referring to equation (5) and

[3] Tested VAR includes a constant term.

[4] The specification test results are available from the authors on request.

[5] Because of the difficulty in interpreting estimated reduced form VAR coefficients, the study does not report these coefficients.

[6] We do not report the plots due to space limitations.

Table 4. Johansen Maximum Likelihood Tests for Cointegration

Variables included in the cointegrating vector: PI, GI, R, Y, Intercept (Max lag in VAR = 2).

Cointegration LR Test Based on Maximal Eigenvalue of the Stochastic Matrix

Null	Alternative	Statistic	95 Percent Crit. Value	90 Percent Crit. Value
$r = 0$	$r = 1$	42.8492	28.1380	25.5590
$r \leq 1$	$r = 2$	19.6790	22.0020	19.7660
$r \leq 2$	$r = 3$	13.5592	15.6720	13.7520
$r \leq 3$	$r = 4$	3.9403	9.2430	7.5250

Cointegration LR Test Based on Trace of the Stochastic Matrix

Null	Alternative	Statistic	95 Percent Crit. Value	90 Percent Crit. Value
$r = 0$	$r \geq 1$	80.0278	53.1160	49.6480
$r \leq 1$	$r \geq 2$	37.1786	34.9100	32.0030
$r \leq 2$	$r \geq 3$	17.4996	19.9640	17.8520
$r \leq 3$	$r = 4$	3.9403	9.2430	7.5250

Estimated Cointegrated Vectors (Normalized)

	Vector 1	Vector 2
PI	−1.0000	−1.0000
GI	0.7771	0.8727
R	−0.0445	−0.0247
Y	0.1558	1.9607
Intercept	0.5173	−20.1076

concerning the detection of Granger-causal effects, based on standard F-tests, reject the null hypothesis that the coefficients on the lagged real public investment is zero while they do not reject the null hypotheses that the coefficients on the lagged real income and on the lagged real lending rate are zero. Moreover, there is evidence of a causal relationship in the long run, which emerges through the lagged ECT term derived by the respective t-test. The ECT term is significant at the 5-percent level, indicating that real private investment in agriculture adjusts to restore long-run equilibrium after a short-run disturbance.

In sum, the empirical findings support that in the short run public investment significantly influences private investment. Further tests regarding the statistical significance of the ECT term in conjunction with the estimated loading[7] factors obtained through cointegration analysis provide evidence that similar conclusions can be drawn for the long run, e.g., there have been detected long-run causal effects running from public investment towards private investment. However, we can not conclude similarly for real income and interest rates.

Variance Decompositions and Impulse Response Analysis

Since the data used in this study are characterized by low frequency and may be considered to produce ambiguous inferences, we present further evidence based on variance decomposition and responses of the system to shocks in the variables of interest.[8] Following Section 2, the moving average representation can be used to depict the responses of all var-

[7] Estimates of the loading factors and t-test values for the statistical significance are available from the authors on request.

[8] Since the variables exhibit cointegration properties, variance decomposition and impulses use variables in levels (Lutkepohl).

Table 5. Granger-Causality Tests and Diagnostics

Dependent variable: ΔPI		
Lagged ΔGI do not Granger-cause ΔPI:	$F(1, 36) = 5.624$	(p-value = 0.024)
Lagged ΔY do not Granger-cause ΔPI:	$F(1, 36) = 0.108$	(p-value = 0.744)
Lagged ΔR do not Granger-cause ΔPI:	$F(1, 36) = 0.716$	(p-value = 0.403)
ECT term:	t-Stat = −2.068	(p-value = 0.046)
Diagnostic Tests (LM Version)		
Serial Correlation:	$\chi^2(1) = 0.119$	(p-value = 0.729)
Functional Form:	$\chi^2(1) = 0.551$	(p-value = 0.458)
Heteroscedasticity:	$\chi^2(1) = 0.098$	(p-value = 0.754)

iables to shocks (i.e. innovations) in the residuals. Given the unrestricted VAR system, typical random shocks are positive residuals of one standard deviation unit in each equation.

The variance decomposition of the private investment variable is reported in Table 6. More specifically, Table 6 reports the percentage of the variance of the k-year ahead forecast error of the variables that is attributable to each of the shocks for k = 1, 2, 5 and 10. We consider a one-year-ahead time horizon as short run, a two-year-ahead time horizon as medium run and a five-year-ahead horizon as long run. According to the results, private investment is explained basically by the path of public investment in agriculture. In particular, public capital formation explains the 11.42 percent variation of the private capital formation in the short run, while in the medium-run time horizon this percentage increases up to 27.5 percent and exceeds the 40 percent in the long-run. Real income contributes with rather insignificant percentages for all periods examined as well as interest rate.

Next, impulse response analysis is applied to detect the out-of-sample response of the variables involved in our model to exogenous shocks of one standard deviation in the residuals. Figure 1 displays the change over 10 years in the log-level of private investment to typical first-period shocks to each of the equations forming the employed VAR system. The figure shows that there is a positive significant response of private investment to public investment innovations, which attains its peak during the second year and declines after the third year. The responses to real income and interest rate shocks are relatively too small[9] to consider their impact on private investment over the whole forecasted horizon.

We further use the results from the impulse response analysis to trace out a scenario, illustrating the out-of-sample response of each

[9] The statistical significance of all responses has been estimated considering the standard errors of the estimated responses.

Table 6. Variance Decomposition of PI

Forecast Horizon	Percentage of Variation of PI Due to Shocks in: PI	GI	Y	R
1	88.58	11.42	0.01	0.01
2	70.61	27.49	0.11	1.78
5	55.03	40.86	1.21	2.88
10	49.18	41.14	4.93	4.75

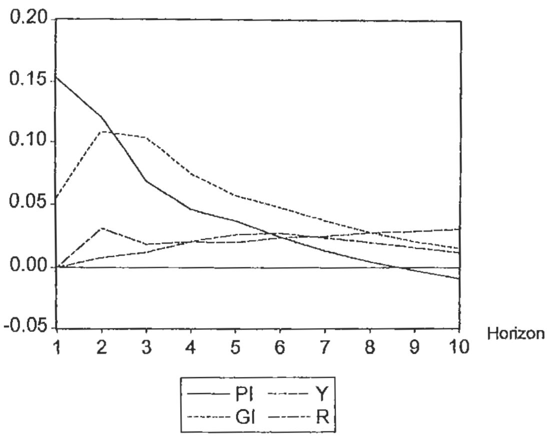

Figure 1. Response of PI to shocks

Table 7. Impulse Responses

Forecast Horizon	Effect of a One Standard Deviation Shock in GI on: PI	GI	Y	R
1	0.002	0.159	0.011	0.288
	(0.003)	(0.017)	(0.009)	(0.469)
2	0.054	0.138	0.005	0.923
	(0.021)	(0.026)	(0.008)	(0.478)
5	0.021	0.038	0.007	−0.501
	(0.023)	(0.031)	(0.003)	(0.297)
10	0.001	0.012	0.012	−0.148
	(0.013)	(0.019)	(0.005)	(0.213)

Note: Numbers in parentheses indicate the estimated standard errors.

variable involved in the VAR system to an exogenous increase in public investment. The outcomes, reported in Table 7, present the impact of a typical first-period shock in public investment on the log-level of each variable in the VAR. Regarding the impact on private investment, which clearly predominates, it has already been plotted and discussed in the context of Figure 1. Next, considering the change in the remaining variables, we should mention the following: the response of public investment does not return to zero, which is consistent with the notion of long-run equilibrium being shocked. The response of real income is positive and rather steadily increasing after the second year but becomes statistically significant only after the fifth year of the forecasted horizon. Finally, the interest rate responds positively and significantly in the short- and medium-run horizon, while in the long run it turns negative. This seems theoretically consistent since, as mentioned above, an increase in public capital formation should increase the demand for private investment and hence the demand for credits.

The sensitivity of the reported results is further tested by changing the ordering of the variables. The findings, not reported in the paper due to space limitation, indicate no substantial differences before and after changing the ordering, thus supporting the robustness of our empirical results.

Results

After all, the evidence obtained from the cointegration analysis, the variance decompositions, and the impulse response analysis clearly support the complementarity hypothesis in Greek agriculture and suggest that public investment in agriculture is the most influential factor of the private capital formation. Therefore, serious attention has to be given to this matter by the policy makers in Greece. In particular, considering the empirical findings and having in mind the figures reported in Table 1, we can reach the conclusions below.

It is a common belief that the contraction of Greek agriculture observed over the period 1970–1980 is the result of the industrialization policy. During the ’80s and in the context of CAP (Common Agricultural Policy), a serious effort aiming at modernizing the sectoral performance had been undertaken. In fact, a number of regulations concerning the financing of investment plans provided the necessary conditions for further improvement. The resultant positive impacts were primarily reflected by the level of mechanization of the sector, the increase of the irrigated and arable areas, and the installation of an accounting information network system. At the same time, major infrastructure projects, undertaken by the government and cofinanced by the Agricultural Bank of Greece, created the prerequisites for attracting more private investment.

However, the overall improvement in Greek agriculture, on an ex post consideration, is rather inadequate for the convergence with the other EC members. It is believed that the major reason for this is a number of structural constraints and deficiencies which restrained the achievement of rapid growth rates. In particular, the small farm size as well as the low level of general and professional education of the sectoral labor force and hence the serious delay in adopting new technology strongly reduce the effectiveness of the development plans. Under this situation, it is obvious that new private investment, when undertaken, is of low profitability and high risk. This fact further stresses the need for more public intervention which should be directed towards the elimination of the above major structural problems. In particular, the government's intervention through public investment should be directed towards:

- The unification of smallholders in agriculture to the greatest extent possible.
- The replacement of the old technology mechanical equipment used in agriculture with new modern technology.
- The enforcement of appropriate training programs for the people involved in agricultural production.

This sort of intervention will moderate the major handicap of the small and fragmented farms and will make it possible to obtain the maximum utility resulting from any further expansion of the level of mechanization of Greek agriculture. Also it will facilitate the adoption of technological innovation so as to increase sectoral output and improve quality standards.

Moreover, special attention has to be paid to:

- Developing efficiency in the manufacturing and trading of agricultural products by increasing the subsidization of these activities so as to attract new firms to the agricultural sector and strengthen the activities of the existing ones.
- Completing the large public infrastructure projects and research activities to make private investment less risky and more profitable. Consequently, agriculture will become more efficient and will become more in balance with the other sectors of the Greek economy.
- Better utilizating the EC funds flowing into Greece in policies aimed at re-encouraging private investment in the agriculture sector through the increase in public capital. This is justified by the fact that, over the last two decades about 90 percent of the EC inflows was spent on supporting the agricultural income and on improving the standard of living of people involved in Greek agriculture. On the other hand, only 10 percent was spent on increasing and modernizing the fixed capital assets of the sector.

Concluding Remarks

This study has investigated the determinants of the private capital formation in Greek agriculture and has tested the "complementarity" against the "crowding out" hypothesis using multivariate cointegration techniques and ECVAR modeling in conjunction with variance decomposition and impulse-response analysis. The analysis has been carried out over the period 1948–1994, using annual data for real private and real public investment, real income and the real long-term lending rate. All data concern the agricultural sector. The results provide evidence of a significant positive causal effect of public investment on private capital formation, thus supporting the "complementarity" hypothesis for Greek agriculture. Moreover, the results stress the importance of government spending on this matter as an effective policy instrument in the long run, aiming at enforcing the formation of private capital in the agricultural sector and thus improving the sector's performance.

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